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GUIDEBOOK 09-13

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Considering Life Cycle Costs in Airport Asset Procurement

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OF THE NATIONAL ACADEMIES

Project No. ACRP 09-13

CONSIDERING LIFE CYCLE COSTS IN AIRPORT ASSET PROCUREMENT

FINAL GUIDEBOOK

Prepared for
Airport Cooperative Research Program
Transportation Research Board
of
The National Academies of Sciences, Engineering, and Medicine

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November 2016

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CHAPTER 1

Introduction

Project Background

The US aviation industry experienced unprecedented growth in the 1970s, 1980s, and early 1990s. Faced with expanding operations and an increasing number of passengers to serve, airport managers rallied to address the demands of capacity expansion as best they could. When combined with the community pride associated with landmark airports, this exponential growth spurred airport managers to focus on building iconic facilities that were intended to meet the needs of the traveling public, serve as an economic growth engine for their region, and represent the community's desired image.

On the heels of this prosperity and growth, the industry experienced a sudden economic downturn in the late 1990s, which was immediately followed by the watershed events of September 11, 2001. These events would drastically—and permanently—redefine the airport operational environment. According to *Fiscal Times* (Jasen 2011), passenger carriers posted a cumulative loss of $63 billion in the decade between 2000 and 2010. As would be expected, these losses directly affected airport budgets, but it also reduced the bonding capacity necessary to fund the capital programs at many airports. This situation was exacerbated by a passenger facility charge cap that had not been raised for 20 years and lagged behind inflation. Economic woes, reduced customer-base, constrained funding, and obsolete charges combined to present a significant change for the industry; previously, airports enjoyed budgets commensurate with their responsibility to their traveling public's expectation for service. Suddenly, this was no longer the case.

In short, the changes wrought by deregulation and politico-economic shifts over the last 20 years have significantly shifted business demands under which airports must operate. Rather than focusing on growth-fueled improvements, airport staff is faced with the challenge of stretching budgets by preserving assets and identifying long-term operating efficiencies. The challenge becomes more complex when one considers the increasing number of new and aging assets in airports, managed over multiple departments that use many different standards and tools that are also quickly approaching the end of their useful life. Airports currently procure new assets using a linear and siloed approach, starting with planning, progressing to designing, building, operating, maintaining, rehabilitating, and finally decommissioning. Because of this linear approach, the total cost of owning an asset throughout its entire life cycle is often not considered in ongoing procurement decisions. As a result, many US airports are forced to either 1) retrofit their facilities under high capital replacement costs; or 2) or operate under the burden of the highest possible level of ongoing operating costs. Neither represent an optimal situation.

A better alternative is to shift toward actively managing the total cost of ownership (TCO) to improve procurement decision-making and use both capital and operating funds. Fortunately, TCO is not a theoretical construct, but a proven process that is used successfully in manufacturing, transportation, and utilities. It renders quantifiable results and it is immediately available for use by airport management, enabling them to make informed decisions based on lifecycle costs.

The airport industry is well-positioned to take advantage of industry experience in the best practices of asset management, TCO technology, and operational efficiency. Current research, as presented in this

guide, suggests establishing a "systematic view" of asset procurement and ownership. Upfront planning and design-level decisions set the tone for proper asset management planning and a full understanding of total ownership costs.

Guidebook Content and Organization

A research team of industry and asset management experts developed and organized this guidebook on behalf of the airport management industry, based on the knowledge, expertise, opinions, and recommendations of actual airport personnel and other aviation professionals. This guidebook provides a comprehensive collection of case studies, best practices, and a TCO Tool to facilitate the implementation of a robust and reliable TCO program. The program has been designed to be easily integrated within the airports' existing and planned asset management programs.

This guidebook is intended to be a resource for airport personnel, to support the implementation of their TCO program. It has been organized to allow readers to find and focus on particular areas of information or interest within the guidebook, as needed.

Chapter One provides the reader with a general overview about the Airport Cooperative Research Program (ACRP) 09-13 research project along with the content and organization of this guidebook.

Chapter Two introduces the reader to the new industry asset management standards (ISO55000), with an emphasis on life cycle cost. It also discusses how to consider life cycle cost within an enterprise asset management system.

Chapter Three introduces the reader to procurement strategy and best practices from different industries. It discusses both the benefits and limitations of TCO, the status of TCO at airports, its impact on procurement, and how to encourage its implementation. Additionally, it discusses the impact of TCO on capital and maintenance projects.

Chapter Four discusses the incorporation of sustainability into the airport procurement's life cycle. It discusses how sustainability is central to airport procurement decisions, and its impact on operations and maintenance. Additionally, the reader is informed about supply chain sustainability and airport utility budget management. As part of this chapter, each topic includes a case study to inform the discussion.

Chapter Five introduces the reader to Building Information Modeling (BIM) and how BIM is a valuable concept in assisting airports in the procurement process and in the asset and life cycle management of the assets. This chapter details what an airport needs to consider when implementing BIM and how to successfully implement it. Additionally, it shows examples of airports using BIM.

Chapter Six is about O&M Ready. O&M Ready is a concept of filling the gaps between the different phases of the asset life cycle. By implementing O&M Ready, the communication increases between the different business units and allows for a seamless commissioning process of the asset. In this chapter, the reader learns about O&M Ready and how O&M Ready will benefit airports' operations and maintenance activities.

Chapter Seven provides a case study of a utility that implemented an asset commissioning and turnover process.

Chapter Eight presents the reader with four case studies, three airports and one non-airport, describing the journey and current status of these organizations in the areas of asset management, CMMS, TCO, and procurement. These case studies demonstrate examples of airports (Toronto, Phoenix, and Atlanta) that have been successful and one that is seeking to implement TCO and the challenges that they are facing.

Chapter Nine includes information and description about the TCO Tool in terms of its architecture, elements, features, input, and outputs. It informs the reader about the life cycle calculation methodologies and analysis that the tool can conduct.

Chapter Ten provides the reader with a road map on how to successfully implement these procurement best practices, on how to successfully launch and navigate through the execution of strategies such as the TCO procurement strategy within an organization, using the DELTA FORCE method.

Chapter Eleven provides some insight into the future of asset management at airports, to identify what the airports might be facing in managing their assets especially as airports participate in the Internet of Things (IoT) to become “smart small cities.”

CHAPTER 2

Asset Management Systems Implementation – A Catalyst for Life Cycle Cost

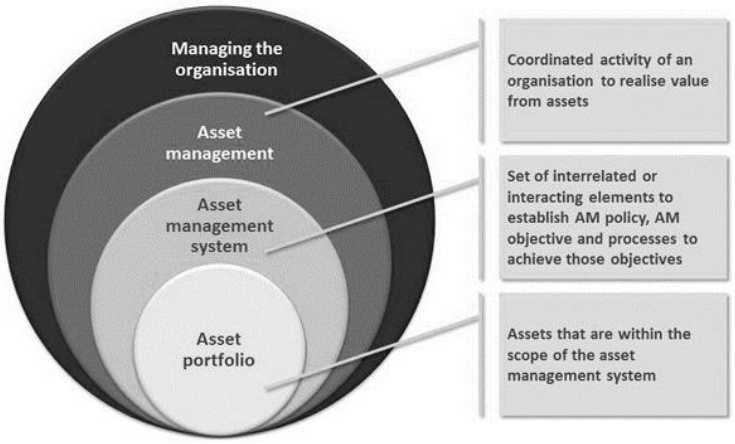
Asset management is a set of practices focused on making informed decisions that sustain assets throughout their whole life cycle—from ongoing procurement, performance tracking, maintenance, and decommissioning. Taken as a whole, these practices result should result in controlled operational expenditures, optimized reliability, and reduced risk. This chapter describes asset management as the overarching framework within which many of the subsequent tools and methodologies described in this guidebook have a role.

Asset Management Defined: ISO 55000

The International Organization for Standardization (ISO) developed and produced an international management system standard for asset management. The standard is known as ISO 55000. The main goal of ISO 55000 is to enable organizations to achieve their operational objectives through an effective and efficient management of their assets. This implementation assures that these objectives are achieved consistently and are sustained over time.

An asset management system "*is the set of interrelated and interacting elements of an organization, whose function is to establish the asset management policy and asset management objectives, and the processes needed to achieve those objectives."*

An asset management system consists of the set of tools, policies, plans, business processes, and information systems collectively working together to achieve and deliver the asset management activities. Figure 2-1 shows the relationship between the different asset management terms.



Source: ISO 55000

Figure 2-1. Relationship between asset management terms

Benefits of Asset Management The implementation of asset management has many benefits to the organization (ISO 55000 2014). They include:

- Improved financial performance – There is more informed allocation of capital and operation funds within the organization, optimal O&M of assets to preserve their value, and increased return on investment (ROI).
- Informed asset investment decisions – Better data collection, management, analysis and reporting improves the decision making, reduces risks and improves performance.
- Managed risk – Internal risk is reduced by avoiding financial losses, improved health and safety, and regulatory compliance. This results in fewer liabilities, which would reduce insurance premiums and fines. External risk is also managed through environmental stewardship, and improved relationships with local community stakeholders.
- Improved services and outputs – Improved asset performance leads to improved services and products.
- Demonstrated social responsibility –Demonstrated social responsible and ethical business practices allow for investments in the local community to have a positive impact on the community-at-large.
- Demonstrated compliance – It is easier to ensure transparent compliance with legal and regulatory requirements as well to adhere to asset management standards, policies and processes.
- Enhanced reputation – Improved customer satisfaction and relationship with stakeholders builds confidence with the organization's ability to serve.
- Improved organizational sustainability – The organization is able to more effectively manage the short- and long-term effects, expenditures and performance of its activities.
- Improved efficiency and effectiveness – The organization is able to better implement, review and improve its processes, procedures, and asset performance to improve efficiency and effectiveness.

Organizational Impacts

Implementing asset management practices provides the organization with a robust and structured approach to managing the asset life cycle, relative to risk and organizational goals. Similar to the implementation of any comprehensive business approach, asset management requires the commitment of resources and patience to achieve positive gains at both the functional and the organization levels.

Asset management can help an organization to manage complex and voluminous data garnered from various sources and in different formats and quality. There are methods for collecting, storing, assuring quality, organizing, analyzing and producing reports. Having these data management processes in place allows the organization to better understand the inputs and outputs from the system, which positively impacts the quality of the asset decisions made.

The implementation process of an asset management system can be a catalyst to the organization in terms of bringing new perspectives and value added improvements. These improvements would inspire and positively impact other functions such as finance, human resources, information technology (IT), and procurement.

The effectiveness of an asset management system relies upon cross-functional, organization-wide implementation to ensure its focus is on functional integration and life cycle planning. Enterprise-wide application of asset management allows staff to develop a TCO for assets and identify and present the real cost and value of this asset to the organization.

As part of the research informing this guidebook, airport personnel were asked to rate the success of their asset management implementation at their airport. The rating was on a scale of 1 to 10, where 1 is not very successful and 10 is very successful. The majority of the responses indicated that the airports' asset management programs are at a good to a satisfactory stage. The responses and their distribution per airport classification are presented in Figure 2-2.

Asset management also presents an advantage for the financial functions within the organization. Linking the asset information with the financial one provides a better outlook and assessment of the funding requirements of the assets.

One of the main objectives of any organization is to manage and reduce risk. Asset management practices provide the needed information to manage assets based on their performance, potential for failure, and consequences resulting from that failure. The organization is able to continually prioritize investments and deliver service in a way that considers various types of risks, allowing the organization to take a long-term and sustainable approach to decision-making.

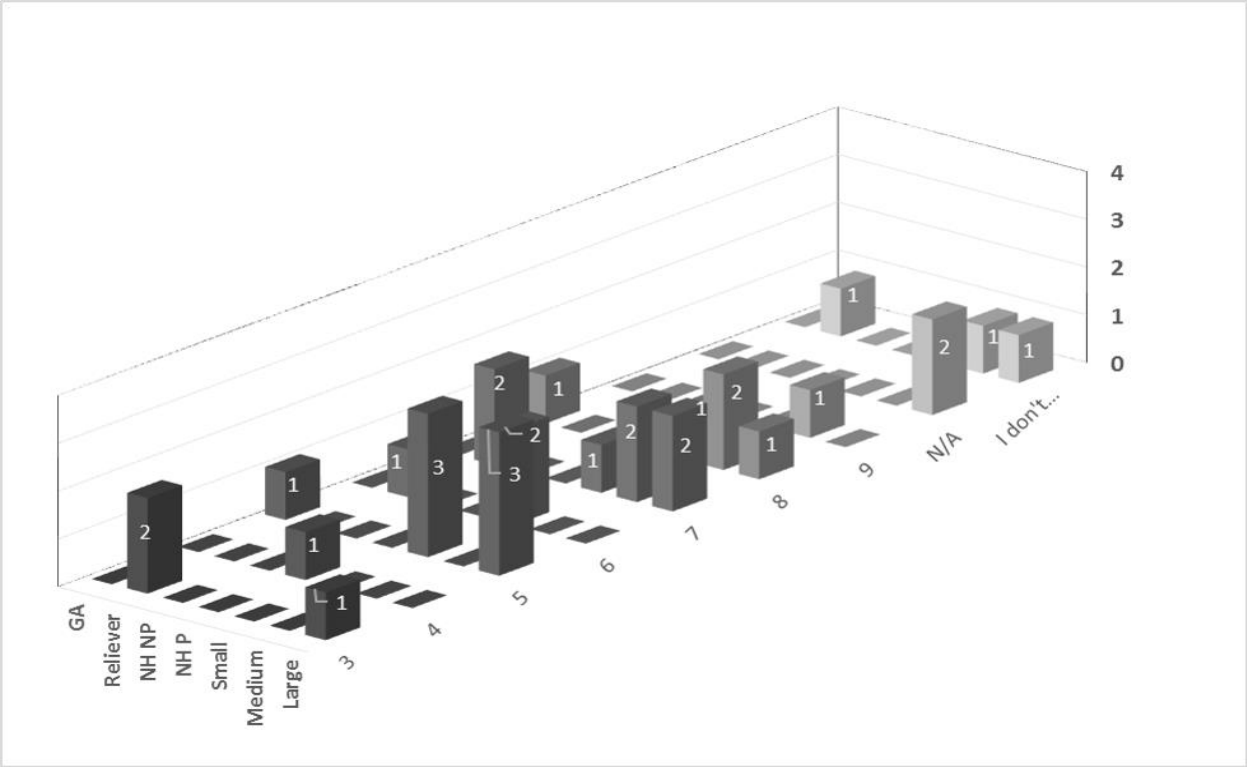


Figure 2-2. Successful asset management implementation distribution per airport classification

Enterprise Asset Management Systems

Enterprise Asset Management (EAM) is the optimal life cycle management of the physical assets across an entire organization. It deals with every phase of the asset from design, construction, commissioning, operations, maintenance, and decommissioning. EAM uses various software tools as enablers to manage asset data and good decision-making. ISO 55002 (Asset Management Guidelines for ISO 55001) outlines the information management technology part (EAM) as support to the asset management system implementation. The implementation of EAM and support systems provides many benefits (Reliabilityweb.com 2011), including:

- Informed asset life cycle and replacement forecasting
- Increased system reliability
- Improved maintenance records and history
- Reduced maintenance work and its related cost
- Reduced equipment downtime
- Reduced reactive maintenance work
- Effective and efficient preventive maintenance program
- Improved relationship between operations and maintenance
- Enhanced MRO and purchasing control

- Improved health and safety
- Improved stewardship
- Regulatory compliance
- Improved reliability
- Reduced emergencies and improved relationship with stakeholders
- Cost savings
- Life cycle approach to better manage capital expenses

EAM Data Management Systems

There are many organization asset management systems in the market that can be utilized. These systems range from a simple spreadsheet to a complex system that includes maintenance planning and scheduling, assets' analytics, and geospatial and real time information. Some of the most familiar systems are: CGI, Mainsaver, Ventyx, SAP, IFS, ORACLE (Work and AM), Infor, Schneider (Invensys), and IBM (Maximo).

IBM's Maximo system, is used in this guidebook as an example of an EAM system. Maximo has been integrated into many organizations worldwide. It has a core solution and many add-on modules. The core solution is *Maximo Asset Management*. The add-ons modules include: *Spatial, Scheduler, Linear Asset Manager, Health Safety And Environment (HSE),* and *Calibration*.

Maximo affects the organizations' asset management and customer service business areas in many ways. From an asset management perspective, Maximo helps with:

- Asset inventory
- Condition assessment
- Priority and risk analysis
- Preventive maintenance
- Capacity planning
- Infrastructure life cycle planning
- Predictive maintenance

From a customer service perspective, Maximo helps with:

- Call center operations
- Service management
- Construction management
- Contractor management
- Fleet management
- Regulatory compliance

Maximo systems adds many business values to the industries through:

- Risk and compliance management
  - Regulatory
  - HSE
- Operations Excellence
  - Implementing best practices
  - Reliability
- Business agility
  - Standardization
  - Ability to adapt
- Business alignment
  - Supporting strategic goals
  - CAPEX and OPEX
- System consolidation
  - One data source
  - Cost and complexity

Table 2-1 provides some examples where EAM systems have provided measurable efficiency gains to for a variety of business functions in numerous industries and applications (IBM 2015).

Table 2-1. Business values through implementing an asset management system

Business Scenarios	ROI Points	Customer Examples
Labor Utilization	Up 8-20%	Electric Distribution Utility achieves 14% productivity improvement while reducing the workforce 7% through attrition. Tracked increased work historical accomplishment .
Asset Utilization	Up 2-5%	A large Original Equipment Manufacturer (OEM) reduced overhauls from 56 days to 21 days
Equipment Purchases	Down 3-5%	A fleet management company saved US $9.5M by meeting 100% availability with fewer vehicles
Warranty Recoveries	Up 8-50%	A consumer products company with a medium size fleet increased warranty recovery 50%
Plant Downtime	Down 3-18%	Power generation utility 5% reduction in planned overhauls and eliminated 5% of forced outages saving US $4.6M annually
Inventory Needs	Down 12-30%	A large passenger railroad was able to identify US $18M in excess or obsolete inventory
Inventory Costs	Down 8-30%	A power company reduced inventory by 26% and an electric and water utility achieved 25% inventory reduction and US $33M in savings
Material Costs	Down 7-30%	A rail maintenance service company reduced cost 20% by optimizing material purchases
Purchasing Labor	Down 6-20%	A fleet management company reduced purchasing staff by 20%

Source: IBM

Implementing Maximo, or any asset management system, should increase functional integration, ensure reliable operations, increase resiliency, reduce redundancy, and effectively allow the organization to

manage their assets in a way that is aligned with their financial and service goals. The following are some of the functional areas where an EAM systems can benefit the organization.

- Process improvement
  - Work management
  - Asset management program development
  - Supply chain management improvements
- Information management
  - Integration with geographic information system (GIS, finance, and other databases
  - Integration with supervisory control and data acquisition and data historian for asset condition monitoring
- Modeling, model integration, and visualization
  - Leverage tools for simulation
  - Visualize the condition of the assets
- Standards
  - Configure data based on national and international standards
  - Compliance with regulatory reporting standards

Informing Life Cycle Cost through EAM

EAM data systems house and provide access to information that supports both daily operations and wise capital investments. In this way, EAM systems impact the various operational and managerial levels within any organization.

Having key performance indicators (KPIs) for an EAM system allow the organization (front-line and decision makers) to identify the areas of concern within the system, reveal ways to optimize the processes, and track cost and the ROI. The most common measures for EAM systems are (Crain 2003):

- Planned versus reactive maintenance (cost and number of hours)
- Ratio of preventive maintenance of planned (cost and number of hours)
- Ratio of predictive maintenance of planned (cost and number of hours)
- Schedule backlog (cost and no. of hours)
- Inventory turns
- Cost by equipment class
- Maintenance cost as a percent of equipment replacement cost
- Percent equipment availability
- Loss of revenue

These measures are integral for any organization to track costs and resources. Tracking these costs and resources through EAM allows the organization become more lean, robust and sustainable. Organizations that implement EAM have claimed a three to five time return on the initial investment within the first 3 years (Maintenance Maven, accessed 2016). The average savings on maintenance expenditures ranges between 10 and 40 percent (Maintenance Maven, accessed 2016). A further breakdown of these benefits is in the following list (Berger 2010; O'Brien 2010).

- 15 to 20 percent increase in productivity

- 15 to 25 percent reduction in equipment failure
- 20 to 40 percent reduction in overtime
- 15 to 35 percent reduction in spare parts cost
- Up to 35 percent reduction in spare parts inventory
- Up to 50 percent increase in equipment's residual value and its life cycle

Successfully utilizing and implementing EAM systems at airports is fundamental to tracking and managing the life cycle of assets and reducing the TCO. Once an EAM system is incorporated, it will provide the organization information that will allow it to make better operational and capital decisions.

CHAPTER 3

Procurement Best Practices and TCO Implementation at Airports

In asset management, procurement lies at the "beginning" of the asset lifecycle. As part of an effective asset management program, procuring an asset requires knowing and considering the total lifecycle cost (TCO) rather than simply its purchase price. This chapter discusses elements of devising a procurement strategy that incorporates TCO as a way of ensuring new assets support the overall asset management program objectives.

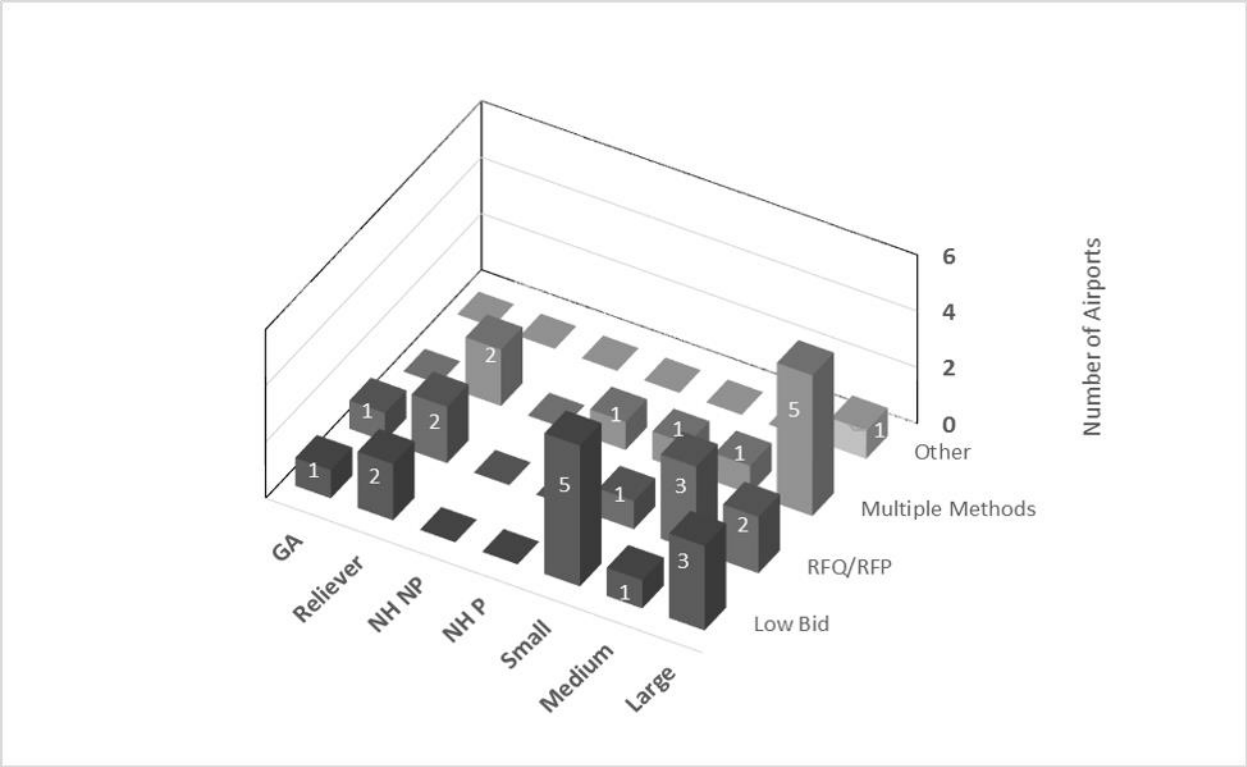
Introduction

Procurement is an important and strategic driver in the overall process of managing costs and delivering expected levels of service by an organization. Organizations that implement strong and reliable procurement practices are able to reduce costs (capital expenditures [CAPEX]) and operational expenditures [OPEX]) and get twice as much measurable reduction as typical ones. This cost reduction comes from gaining a competitive advantage through implementing risk management practices and supplier-driven innovation (Blascovich et al. 2014). Procurement innovations lead to better supplier management, timely procurement of assets, and organization integration and alignment towards a common strategy.

Over the years, procurement has progressed from "I need a purchase order for this," to an integral alignment between business units and functional strategies, combined with analysis of market dynamics. As part of the research informing this guidebook, airport personnel were asked about the procurement methods used at their airports (Figure 3-1). The results showed that airports utilize multiple procurement methods (low bid, RFP/RFQ, on call services, etc.), however, the one that is used the most is low bid.

Implementing procurement best practices realizes many benefits for organizations. These practices can be achieved through having proper planning, processes, policies, guidance, and resources in place (Local Government Victoria, 2013). Procurement best practices allow an organization to:

- Get the best value for the money invested
- Provide stakeholders with reliable services
- Effectively and efficiently distribute available resources
- Comply with federal and regulatory requirements
- Reduce and manage risk



Airport classification key: General Aviation (GA); Non-Hub Non-Primary (NH NP); Non-Hub Primary (NH P)

Figure 3-1. Procurement methods at airports

A study on excellence in procurement concluded that the procurement departments of the most successful organizations had medium to high involvement in the organization's strategic plan (Blascovich et al. 2014). In these organizations, procurement helps to shape the business strategy and make sure that it is fully aligned with other business processes. A description of the value a procurement organization contributes to the business, as it moves from a transactional to a class-leading one was detailed by Clearview Procurement Business Services (web content accessed 2016). This description of the procurement value is illustrated in Figure 3-2.

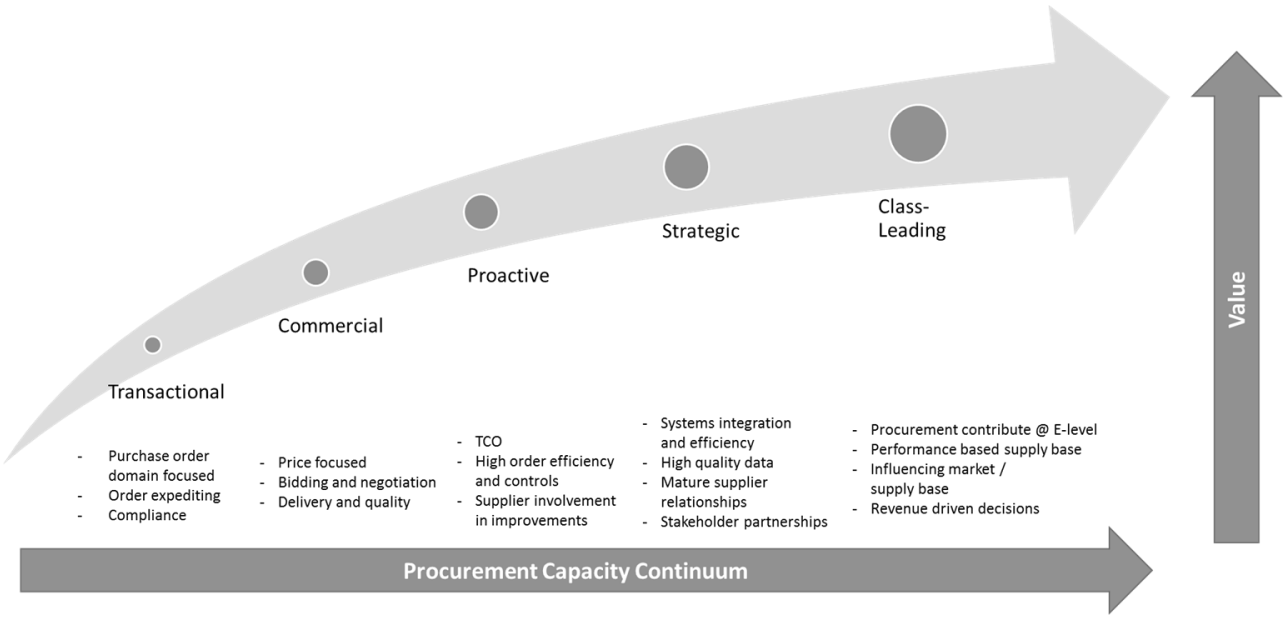


Figure 3-2. Strategic procurement: value contribution curve

Procurement Strategy

Having a procurement strategy in place can guide the organization through short- and long-term plans and help facilitate the transition of procurement practices from their current state on the spectrum to class-leading practices. The essential elements and characteristics of such a strategy are (Local Government Victoria 2013, Blascovich et al. 2014):

- Leadership buy-in, support, and commitment towards implementing procurement best practices
- Policies and procedures in place to support implementing procurement best practices and incorporating TCO into procurement policy
- Alignment of business units under a common strategy when dealing with procurement and management of assets. As part of the research informing this guidebook, airport personnel were asked if other divisions provided input into the procurement process or if it was conducted in a silo. The majority of the airports indicated that other divisions provided input during the procurement process (Figure 3-3).
- Collaboration between business units to encourage communication and cooperative working environments
- Communication plan to increase awareness of the various business units and the activities and services they provide, as well as about procurement processes
- Increased involvement of Procurement throughout the phases of a project
- Increased capability of procurement personnel in:

  − Policy and procedure development
  − Risk management
  − Negotiations
  − Bid evaluation

– Project management

- Accurate and consistent data collection, analysis, and reporting processes to assist in decision making
  - Key performance indicators (KPIs) in place to measure outcomes and benchmark progress
  - Available information and data about vendors and their capabilities
- Optimized procurement processes to reflect market conditions

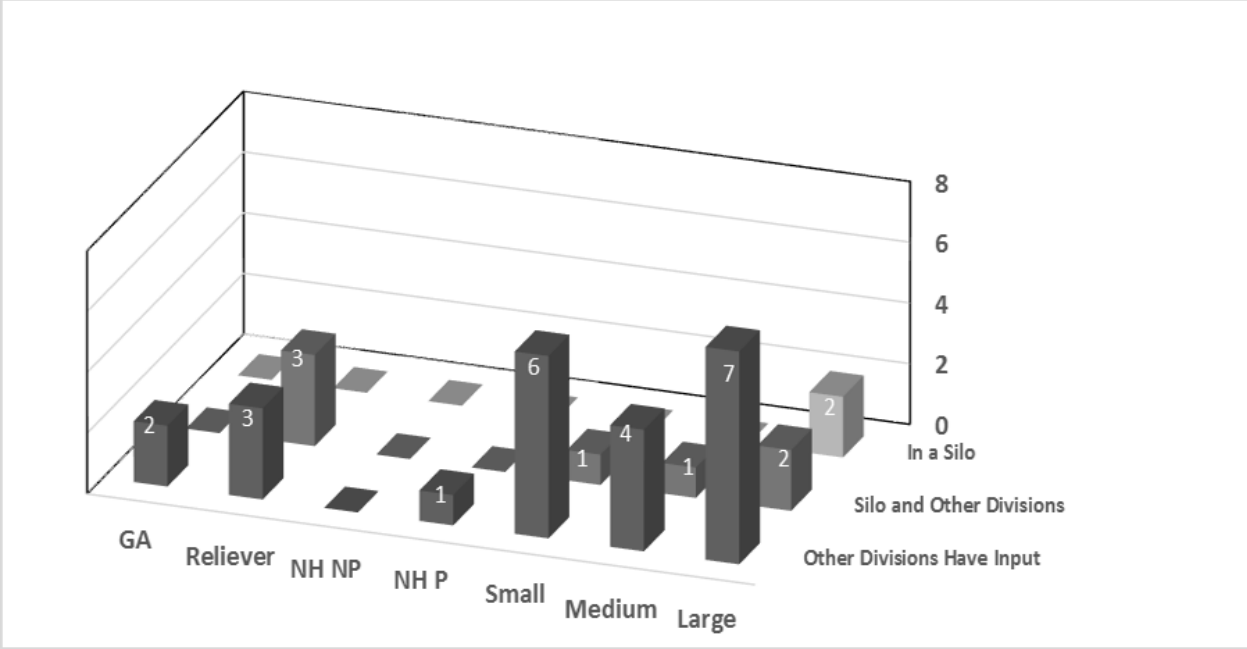


Figure 3-3. Asset procurement process at airports

Additionally, as part of the research informing this guidebook, airport personnel were asked to rate the procurement process implemented at their airports. The majority of the airports gave it a satisfactory rating as presented in Figure 3-4. The rating was on a scale of 1 to 10, where 1 is not very successful and 10 is very successful.

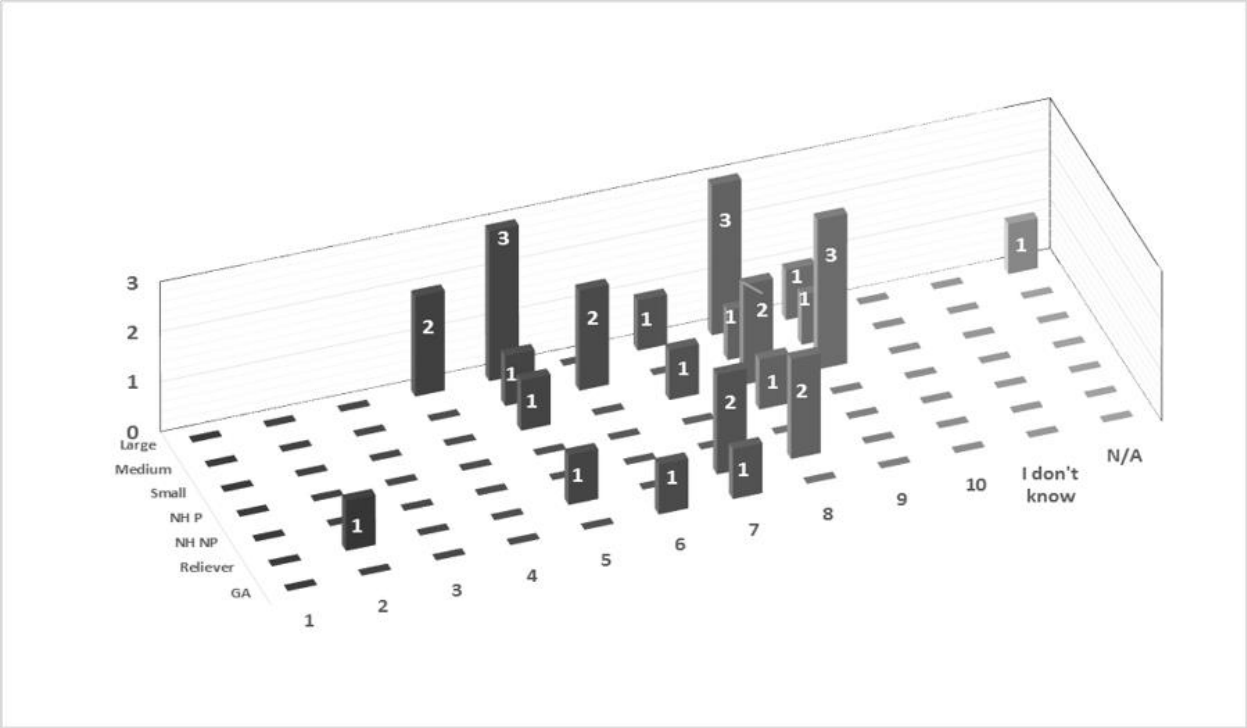


Figure 3-4. Asset procurement process rating at airports

Procurement Best Practices

For an organization to adopt leading procurement practices, it first must know what they are, then work to customize and ingrain those that fit their culture and business objectives. Not all best practices make sense for every organization and every circumstance. This section lists general procurement best practices gathered from across different industries, and then lists those specifically those from the power generation utility industry because of the depth of procurement experience that exists there.

General

- Establish procurement policies and procedures that together serve as a roadmap for the organization. This guidance would provide the answers and clarifications to the business units on procurement, including responsibilities, outcomes, and processes.
- Equip procurement professionals with the needed skills to effectively and efficiently conduct their work and master their roles. These professionals should have an understanding about the organization and the implemented systems and processes in order to align the procurement with the different business unit strategies. Additionally, procurement professional should have a strong understanding of the market and the vendors to collaborate with them on changes and process improvements.
- Incorporate TCO in the procurement evaluation process. Provide vendors with the details about TCO, how these values are analyzed, and how the vendor will be chosen based on TCO and not based on lowest initial cost. As part of the research informing this guidebook, airport personnel were asked to rate the success of implementing TCO as part of their procurement process if they learned that

considering and implementing life cycle costs in airport asset procurement would improve asset management, increase system reliability, reduce downtime, extends asset life, and reduce costs. The majority of the airports gave a score of seven or higher (on a scale of 1 to 10, where 1 is not very successful and 10 is very successful). The results are presented in Figure 3-5.

- Develop a list of pre-qualified vendors (quality of work, on-time delivery, communication, cost). This list should allow the buyers to communicate directly with these vendors, since they have been screened and evaluated by the organization. Prequalified vendors reduce risk and aid in building collaborative working relationships.
- Utilize available data to become more efficient and save time and money. The available data about the vendors and the assets should help the buyer in procuring assets (or parts) without the need to conduct additional market research.
- Have clear and thorough bid specifications that define the expectations from a bid. This should ensure accountability and reduce risk for the organization.

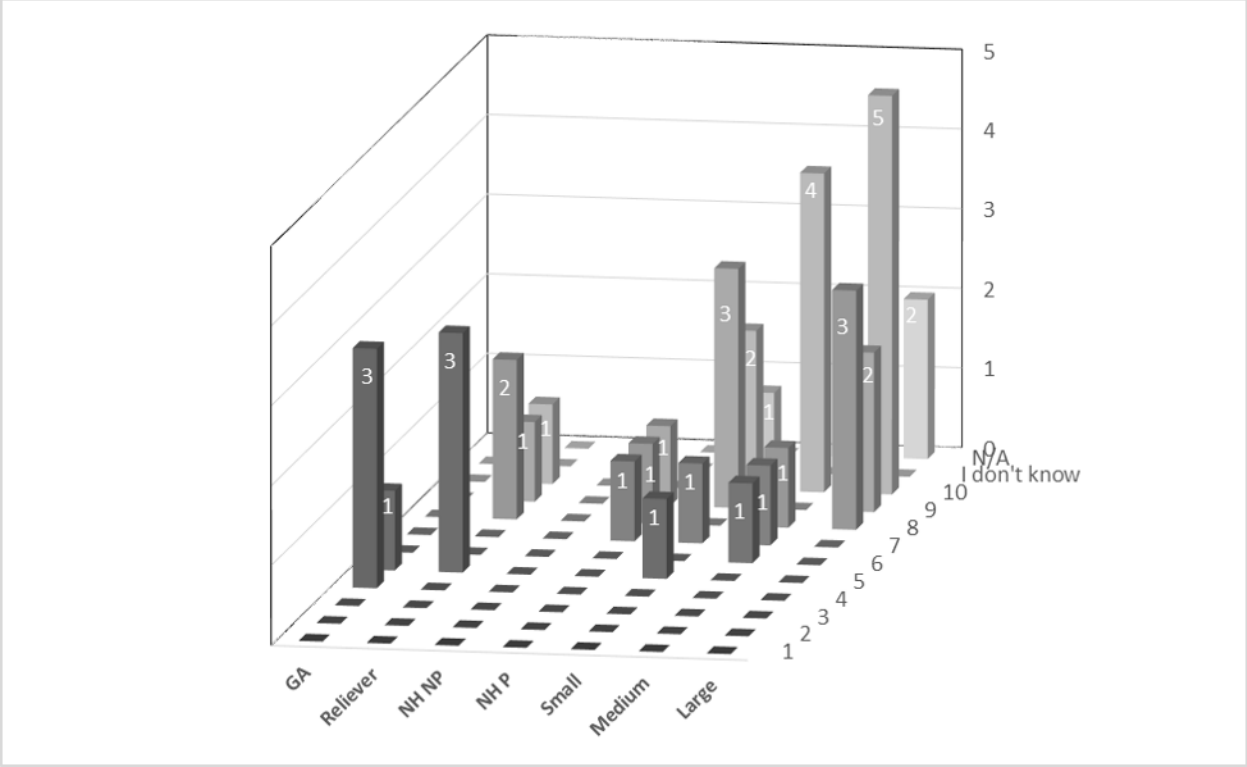


Figure 3-5. Potential success of considering the implementation of TCO as part of procurement process at airports

Utilities – Power Generation

Utilities, especially power generation, have extensive experiences in procurement and have many best practices (Frost & Sullivan 2014) . Table 2-1 summarizes these best practices. Many power utilities have benefited from implementing procurement best practices. For example, before the 1990s, power utilities saw procurement as a standalone business function. Recently, however, utilities have worked to integrate these activities across the enterprise and align them with the business strategy. This integration and alignment has increased the efficiency and effectiveness of procurement.

Table 3-1. Utilities procurement best practices

Facet	Best Practices
Central Procurement Team	- Clear procurement policies and guidelines - Single-point vendor management
Procurement Automation	- Implement e-procurement services (registration, bidding, procurement) - Implement maintenance, repair, and operation (MRO) program to manage spare parts
Vendor Relationship Management	- Produce list of reliable vendors - Document vendor capabilities
Business Integration	- Procurement team is integrated within the organization's internal teams - Data analysis is available to procurement team - Coordination between different supply chain teams through a procurement leader
Strategic Sourcing and Capacity Management	- Value-based rather than cost-based procurement - Other parameters in addition to cost should include quality, warranties, lead time, and technology - Procurement to be a long-term plan
Global Sourcing	- Identify multiple sources to procure from

The Case for Using TCO in Procurement

As stated earlier, the airport industry is shifting toward active management of TCO in an attempt to improve procurement decision-making and the use of both capital and operating funds. TCO is a leading methodology that looks beyond the procurement value/cost of the asset and attempts to take into consideration the actual "true" cost of that asset throughout its life cycle (i.e., planning and design, commissioning, operations and maintenance (O&M), decommissioning, and replacement). There have been advancements in the aviation industry, especially in the US, towards a greater understanding of TCO that have paved the way for the new operating realities demonstrated by recent ACRP projects including:

- Theory, practice, and technology for Asset and Infrastructure Management established in ACRP report 69 and project 09-05
- Sustainable O&M guidance establish with ACRP report 110
- Critical milestones for maintenance input on infrastructure projects established in ACRP project 09-07

The Chartered Institute of Procurement and Supply (CIPS) published a document in 2013 titled *Whole Life Costing – The CIPS position, and what the buyer needs to know*. In this document, CIPS listed views

in support of using TCO as a best practice for evaluating procurement alternatives. The highlights of these views are listed below:

- All procurement and supply management professionals should be knowledgeable about TCO.
- Procurement professionals should be the ones taking the lead in implementing and involving other business units in using TCO.
- Procurement professionals should involve vendors in TCO implementation.
- Procurement and supply management professionals are obligated towards making sure that high value/high risk decisions are not based on price alone.
- TCO can be implemented on low value purchases as well.

Through TCO, airports will be able to make better financial decisions when it comes to procuring assets and the financial allocation requirements to these assets over their life cycle. It would be a true/close representation of the actual cost of that asset. Additionally, through TCO financial forecasting, risks can be managed and significantly reduced.

Benefits and Limitations of TCO

According to research and industry publications (CIPS 2013; FHWA 2010), implementing TCO has many benefits for organizations of all types. Some of those include:

- Better communication internally and externally
- Ability to clearly evaluate competing alternatives
- Awareness of total cost and holistic asset management
- Better budgeting and prioritization of funds
- Capability to complete financial analysis such as trade-offs, budget forecasting, and cost allocation
- Ability to provide stakeholders with sound decision justification
- Better services provided by vendors
- Robust and better asset specifications detailed in the project bidding documents
- Reduce risk of provided services' quality

There are also limitations to TCO, which include (CIPS 2013):

- Future costs have uncertainty in them since they were projected values
- Manpower is necessary to attain information for completing the analysis
- It is dependent on the quality of historical data as an input into the analysis
- Maintenance and operational costs are not readily available
- State procurement policies that might deter from using other methods than low bid
- Lack of resources to support and maintain TCO

TCO Impact on Procurement

TCO is a comprehensive and inclusive process that extends across the organization. This process garners input from various sources within the organization to determine the life cycle cost of the asset. To identify the requirements that would most impact the cost of an asset, the research team asked a sample of airport personnel to score typical organizational/strategic requirements, based on the impact they would have on TCO. The results are presented in Figure 3-6. The top three parameters that those interviewed believed would most impact procurement are:

- Design/Engineering decisions
- Improve quality
- Service level agreements

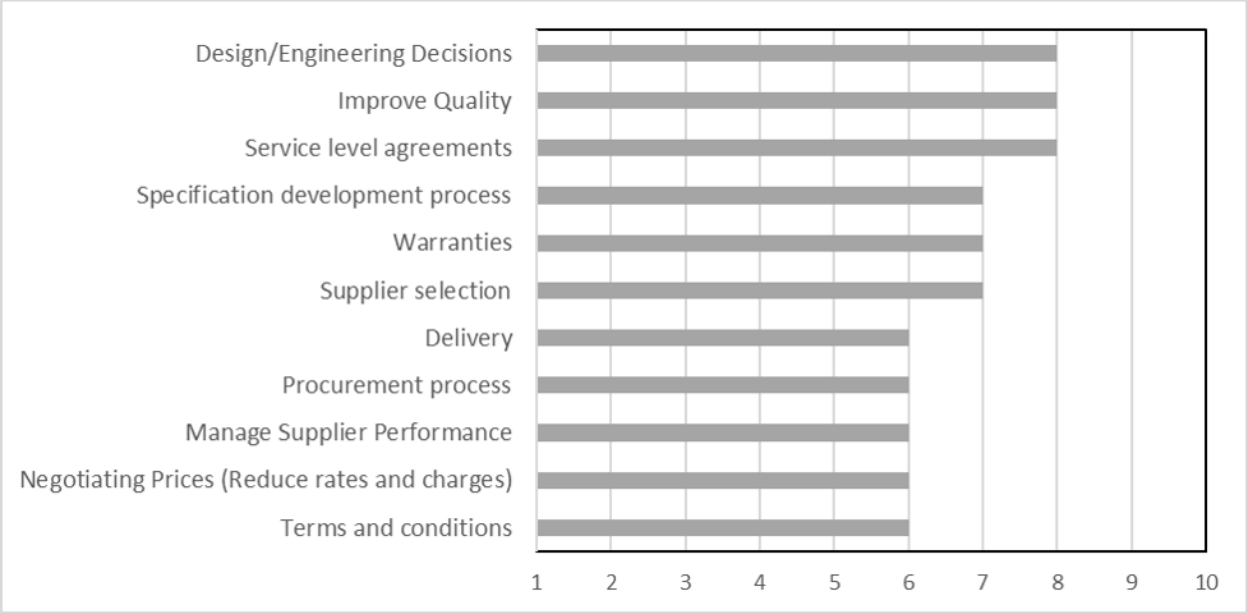


Figure 3-6. Impacts on TCO (average scores)

As a follow-up question to the scoring of these parameters, the participants were asked "How would implementing TCO impact the procurement process?" The summary of the responses is presented in Table 3-2.

Implementing TCO at airports would have a positive impact on the quality of the services provided by the airport to the stakeholders, which is due to procuring better material and services from vendors. Additionally, capital and operational budgets will be better managed and allocated strategically towards growth and better services.

Table 3-2. TCO implementation impact on procurement parameters

Parameter	TCO Impact
Design/Engineering decisions	Longer schedule and changes to procedures
Specification development process	Minimal to no impact
Negotiating Prices (Reduce rates and charges)	Leverage product pricing
Supplier selection	List of reliable suppliers
Procurement process	More cost upfront for better deliverables that would be minimal over the assets' life cycle
Improve quality	Longer life cycle, reliability, and lower O&M costs
Terms and conditions	Minimal to no impact
Warranties	Better products with longer warranties
Delivery	Consistent delivery of services from different locations
Service level agreements	Better agreements with vendors due to better products and services over the life cycle
Manage Supplier Performance	Minimal to no impact

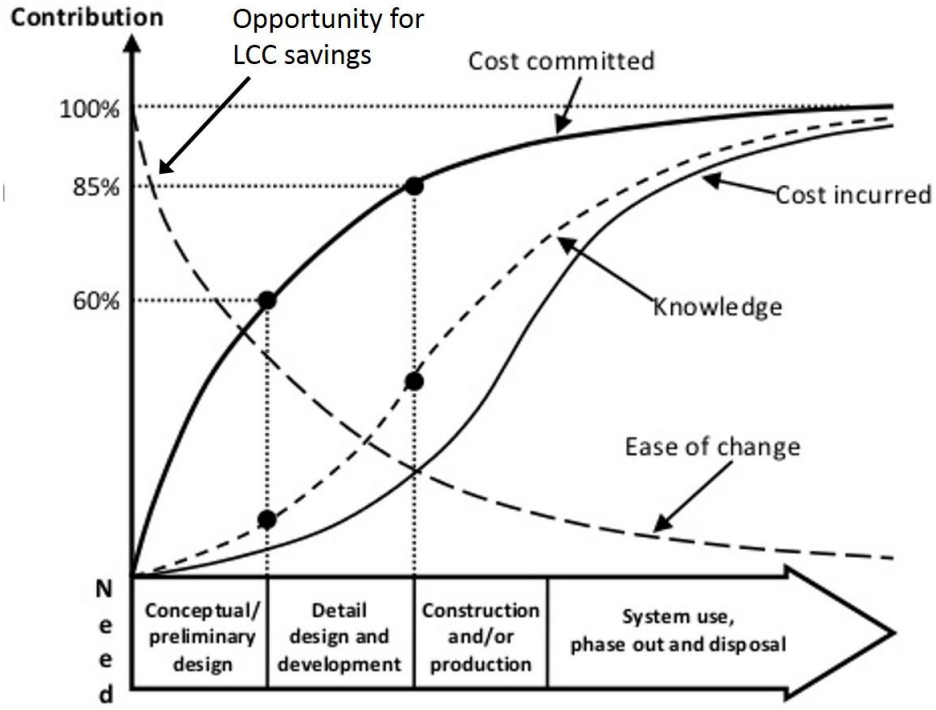
TCO Impact on Maintenance and Capital Improvement Projects

Implementing TCO at airports should, in effect, create a reliable and effective asset life cycle maintenance plan and budget. For example, incorporating the manufacturer's maintenance requirements should be incorporated into computerized maintenance management system (CMMS) at startup so that there are preventive maintenance plans in place to ensure higher equipment availability and longer life leading to an optimized TCO.

In addition, having a TCO in place will allow an airport to understand its short-/long-term budget forecast needs, which can also be helpful in prioritizing capital improvement projects. TCO analysis and documentation will provide a more robust, clear and defensible process for OPEX and CAPEX budget development. Project managers can also use this information in the business case process and as part of their project submittal for approval. Based on more comprehensive TCO data, decision makers can then see how a capital project will affect the long-term budget to help in prioritizing investments.

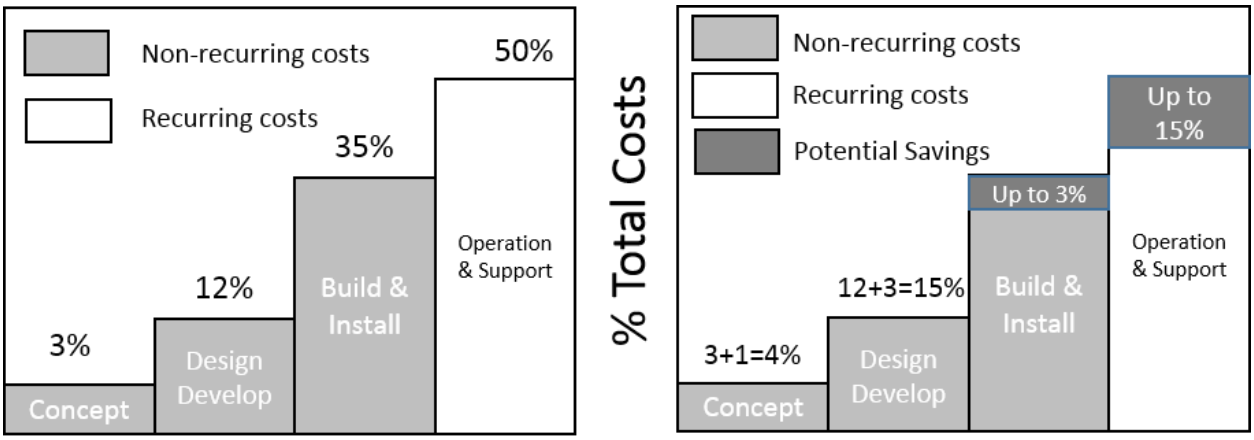
A study conducted by Swift and Brown (2003) showed that through implementing TCO for capital projects at the conceptual and planning phases of the project has a higher chance of creating savings over the project's life cycle. Once the project goes into the next phases of design, implementation, commissioning, and operation, these TCO savings would diminish. Figure 3-7 illustrates these savings.

Furthermore, the Society of Automotive Engineers conducted a study that compared the life cycle costs using traditional versus new asset management approaches. The study compared two similar projects, where one did not use TCO and the other did. The results have shown that although additional resources were expended during the conceptual and design phases of TCO, the overall cost savings through the asset's life cycle were greater than when not using TCO. The savings for this project were around 14 percent over its life cycle. Figure 3-8 shows this comparison.



Source: Swift and Brown 2003

Figure 3-7. Opportunities for cost savings throughout the project's life cycle



Source: Reliabilityweb.com (2015)

Figure 3-8. Cost savings comparison for a similar project if TCO is not utilized (left) and if TCO is utilized (right)

Implementing TCO

To conclude, TCO presents many benefits to the different business units at the airport in terms of managing and reporting the condition of existing and future assets. Additionally, it will assist the airport leadership in their decision-making on capital and operational investments.

TCO will have the most significant impact on the development of specifications and procurement processes. In order to successfully implement TCO, airport leadership will need to play a key role by getting on board early in the process and providing the business units with the needed support. Additionally, business units' management should develop the business case and communicate the TCO message to its employees. The adoption and implementation will take time and resources to obtain buy-in at all levels (Fortin 2016) in order to support a top-level vision with bottom-up operationalization.

The following techniques can be considered to encourage the incorporation of TCO:

- Develop a procurement strategy
- Have policies in place to encourage TCO implementation
- Include representatives from different business units in pre-bid meetings and communications
- Compare an asset's true cost over its life, rather than with a similar asset without considering TCO, by identifying the cost savings, productivity gains, and risk mitigation

CHAPTER 4

Incorporating Sustainability into Life Cycle Costs in Airport Procurement

Sustainability is material to airport procurement decisions because it helps integrate infrastructure decisions with the broader business objectives of the airport, including its role and reputation with the community. This chapter continues the discussion about procurement processes, this time showing how the financial, social, and environmental impacts of the airport on the community can be taken into consideration as part of asset planning and procurement decisions in order to ensure an airport's asset management program incorporates the costs and risks of resiliency and resource management concerns.

Sustainability Defined

Sustainable actions—reducing environmental impacts, maintaining high, stable levels of economic growth, and supporting "social progress"—represent a broad set of activities that together ensure organizational goals are achieved in a way that is consistent with the needs, and values of the local community (Figure 4-1).

Source: FAA, 2016

Figure 4-1. Sustainable airport parameters

Airport Sustainability Programs

The Federal Aviation Administration (FAA) Voluntary Airport Low Emissions (VALE) Program helps airports achieve its sustainability goals. Airport sustainability plans take these efforts a step further by fully integrating sustainability into airport planning. FAA further supports airport sustainability planning by providing eligible airports across the US with Airport Improvement Program grant funds to develop comprehensive sustainability planning documents. These documents include initiatives for reducing environmental impacts, achieving economic benefits, and increasing integration with local communities. To date, FAA has provided grants to 44 airports (FAA, www.faa.gov).

Sustainability is material to airport procurement decisions because it helps develop and integrate infrastructure around the broader vision of what airports can be, capturing public support. Evaluating TCO is about closing gaps in the asset procurement process by informing capital asset planning and procurement decisions. Traditionally, the systems boundaries are the physical boundaries of the airport or sub-asset being repaired or replaced. However, the financial, social, and environmental impacts of the airport on the community it serves must be taken into consideration as part of asset planning and procurement decisions. Why? Because issues like climate change, globalization, and growing population pressure is creating economic challenges as it comes to energy, water, and waste along with driving political and social action as it pertains to equity, investments, and action on pollution.

All three areas that historically drive change--economics, government regulations, and social demands—point to increasing complexity when it comes to planning, developing, and operating airports. Closing procurement gaps by incorporating sustainability into the asset procurement process benefits current airport stakeholders as well as future generations.

This section highlights several areas where additional process, governance, and tools may be considered by airports to be tailored and adopted in respect to each airport's unique situation. The objective is for multipliers and variables included in TCO decisions to be recalibrated as correctly as possible to best inform decision makers by including not just financial, but also environmental and social impacts. As such, airport managers are able to incorporate sustainability principles into TCO Tools that inform decisions and drive investments.

To do this, several "sustainability" areas that may influence TCO decisions are described in greater detail including:

- Resource conservation
- Critical systems modeling
- Impact on O&M
- Supply chain sustainability
- Airport utility budget management

Systematic Approach to Resource Conservation

Airport systems consume vast amounts of energy, water, and materials and output heat, emissions, wastewater, noise, and waste materials to name just a few broad examples. Traditional procurement practices focus on the cost and quality of the resources along with the most cost-effective means to dispose of waste. This traditional practice fails to capture additional financial, social, and environmental impacts on the broader airport community. TCO in airports must evolve to include these variables to account for the "true cost" even when that cost may be shifted to other entities.

For resources, a systematic approach to measure, monitor, and manage usage is essential to both running efficient operations and informing TCO decision makers for procurement decisions. Resource conservation is a management system that requires roles and responsibilities, procedures, governance, information management systems senior management buy-in, strategy, and goals. By developing a resource management program for energy, water, materials, and waste, airports will be able to systematically identify projects that are more sustainable for recommendations to a capital review process that funds planning and procurement activities.

A systematic Resource Management Program (RMP) is operated by a central manager that assists operational departments to develop baseline and behavior over time metrics on, for example, energy, water, and waste, resources to provide visibility and the opportunity to nominate RCMs to reduce or conserve resources. RCMs may consist of capital projects, maintenance, procedure, set points, and behavior changes that result in resource savings. Across airports, operations, departments and other business units may produce multiple RCMs and over time, a portfolio of RCMs is available for budget review and informing more sustainable procurement decisions. In addition, an RMP provides baseline data to evaluate the performance of procured assets vs. the prior status quo.

A systematic RMP operates when two organizational factors are in place. First, the airport has a Sustainability Strategy Plan in place with senior leadership responsibility and visible goals for improvement over time. Second, a public relations or marketing Sustainability Plan, that reports annually on the environmental, social, and economic impacts of the airport. This serves several purposes by educating and informing stakeholders while recognizing and celebrating employees, carriers, and suppliers who make sustainable progress possible.

Example: Seattle-Tacoma Five-Year Environmental Strategy Plan 2008-2014

The Seattle-Tacoma Environmental Strategy Plan served as a roadmap for achieving Sea-Tac's environmental vision. It provided a framework for annual planning, budgeting and accountability by identifying the measurable environmental outcomes targeted in 2014. The plan was organized around three themes: moving people and goods efficiently, managing natural resources wisely, and promoting sustainable communities. Within each focus area, the plan:

- Identified key environmental indicators
- Summarized ongoing environmental improvement efforts
- Established aspirational goals for continued environmental improvement
- Identified performance metrics for each environmental indicator area

The initial environmental strategy plan and summary reports from 2011 to 2014 are on the Port of Seattle's website (www.portseattle.org).

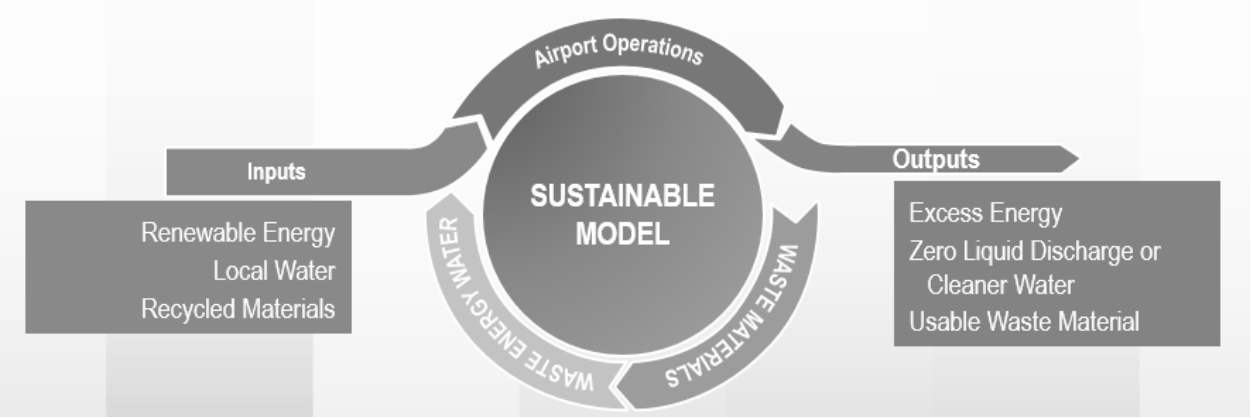
Critical Systems Modeling to Effectively Estimate Impact on Systems

Resources flow through assets and traditionally this flow is not optimized; for example the US Environmental Protection Agency (EPA) has reported organizations waste 30 percent of the energy they consume (EPA 2010). Wasted energy used to heat, cool and light, buildings but also to condition and move fresh water and wastewater or the energy embodied in waste materials shipped to landfills. Airports are overspending as well as having a negative impact on the natural and social environment by wasting resources.

In a traditional model (Figure 4-2), where the source of inputs and outputs are not viewed as a system, leads to waste. In contrast, the sustainable model (Figure 4-3) reduces the output flow stream by reclaiming materials energy (as heat), water, and other resources.

Source: CH2M

Figure 4-2. Traditional model



Source: CH2M

Figure 4-3. Sustainable model

Systems modeling assists in informing choices in procurement decisions. The system methodology captures and balances competing values that include: environment, water use, energy use, materials, emissions, financial, and social impacts to inform procurement decisions. Sometimes these values are complementary and sometimes they compete.

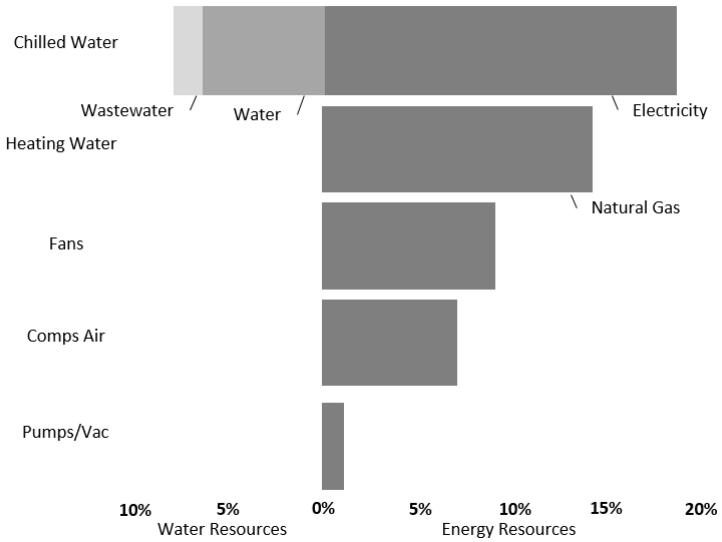
A common main point of discussion is energy savings of a given project. There are many possibilities for energy conservation at airport facilities. They each have their own magnitude of benefits versus difficulty to implement. By choosing one, how can the benefits be analyzed? For example, look at exhaust systems. Basic analysis would show savings in fan energy with reduced exhaust load. But, when systems are interrelated, as in a modern facility, reductions in one area affect others. Here, a reduction in exhaust load will reduce makeup air requirements, which would reduce the load on the chiller and boiler plant, pumps, cooling towers, etc. There are savings beyond simple fan energy. A simulation tool and a methodology are needed to properly calculate savings associated with energy conservation measures applied to integrated systems and these calculations are crucial to inform life cycle costs calculations.

Example: Critical System Modeling Tool

Airports often consume large amounts of electricity, natural gas, and water for heating, ventilation, and air conditioning (HVAC) duties and, thus, energy and resource conservation measures can provide significant benefits if they are properly designed, configured, analyzed, and implemented. A Visual Energy & Resource Optimization (VERO) modeling platform is one option to be considered to quantify and optimize the value of RCMs. This includes:

- Chiller-less cooling during cool climate periods. Chilled water plants typically comprise the majority of energy consumed by mission critical facilities such as airports. This RCM essentially eliminates this heavy energy consumer for a large portion of a typical year in many climates, but involves integrated system modeling to properly characterize and optimize its value.
- Heat source alternatives to boilers such as solar hot water heating, airside heat recovery, or chillers configured with heat-recovery features. Performance of these kinds of RCMs are difficult to quantify using traditional hand calculations, really requiring an integrated modeling solution.
- A modeling platform aims to quantify energy and water consumption of a site holistically by capturing annual operation of integrated systems. This approach allows stakeholders, architects and engineering disciplines to get quantified feedback on decisions made at every point in the design process on through to post-occupancy operation.

Figure 4-4 illustrates the balance of resources across an integrated view of critical systems.



Source: CH2M

Figure 4-4. Balance of resources across an integrated view

Impact on Operations and Maintenance

The benefits of incorporating sustainability in projects may be negated by an unintended increase in costs and resource consumption of energy, water, waste, and materials during operations. O&M departments maintain systems, equipment, procedures as part of their daily tasks. Therefore, this operating expense must be considered when evaluating life cycle costs during design and procurement decisions. These cost

increases may be in the simplest form of increased work orders, poorly integrated systems, incorrect set points, or misunderstanding and compounding efforts during day-to-day operational activity. For this reason, O&M representatives should be part of evaluating capital and maintenance projects during the review and approval process.

O&M managers must participate in the life cycle analysis process prior to procurement decisions. This provides input on changes to functions and activities to keep airport assets operating efficiently and in good condition. In practice, when the operational knowledge of O&M personnel is included in design and purchasing decisions, the overall decision is more sustainable. This arises from the ability to consider re-purposing or recycling owned assets or making changes to existing processes and procedures instead of starting over or purchasing new equipment. O&M managers are adept in their ability to solve challenges with the resources and budget available and this creativity translates well into better planning and design and ultimately bears out in more sustainable results in the total costs during life cycle analysis.

Example: ACRP Report 110: Evaluating Impacts of Sustainability Practices on Airport Operations and Maintenance

An evaluation process and tool was developed to help airport management consider the O&M impacts of implementing sustainability practices. ACRP Report 110: Evaluating Impacts of Sustainability Practices on Airport Operations and Maintenance provides an evaluation process and cost–benefit tool to evaluate life cycle costs of sustainability practices being considered by airport operators. The User's Guide discusses the evaluation process and how to navigate the cost-benefit tool. It also provides information from the case studies that were conducted in the development of the evaluation process and cost-benefit tool. The evaluation process and cost-benefit analysis tool is designed to evaluate sustainability practices in water conservation, energy conservation, waste management, consumables and materials, and alternative fuels. However, the tool can also be used to evaluate any two practices, sustainable or otherwise. An instructional video that demonstrates how to use the evaluation process and cost–benefit tool using data from an example project (also provided with the tool) is on the Transportation Research Board website (www.trb.org/main/blurbs/170580.aspx).

Supply Chain Sustainability

TCO requires looking upstream from airport operations into the services and life cycle characteristics of products of suppliers and vendors. For airports, which successfully embrace sustainability, the largest opportunities for improving sustainability performance such as reducing carbon emissions, water use, material waste, toxic chemicals and addressing social concerns lie within their supply chain. As a result, airports should consider increasingly promoting sustainability principles across their supply chain as this also may help mitigate risks in procurement decisions. Supply chain risks such as regulatory non-compliance, increasing cost of material inputs, energy, transportation, or human rights, labor and ethical violations, inherited from suppliers and vendors can result in disruption, financial losses, reputation damages, or stakeholder dissatisfaction for airports.

By managing and seeking to improve environmental, social and economic performance and good governance throughout supply chains, airports may uncover opportunities related to resources conservation, process optimization, innovation, cost savings, labor productivity, and promoting sustainability values. To be effective airport management should develop and communicate a vision and guidelines for sustainability with suppliers and vendors along with designating meaningful KPIs, implementing monitoring and audits, and, in some cases, supporting organizational learning, culture change, and continuous performance improvement. This effort with suppliers helps address and mitigate the upstream risk in procurement

decisions not just based on the cost and quality, but also the embodied elements in procured goods and services.

Example: Pilot Supply Chain Audits for a Global Manufacturing Company

A major US-based manufacturing company conducted a series of supply chain audits based on procurement guideline that included a code of conduct for suppliers. The audits were performed according to the supply chain code of conduct and included health and safety, labor and human rights, environment, compliance/ethics, and management systems. Auditors leveraged technical knowledge in the areas covered by the supply chain code of conduct along with industry expertise in order to identify potential risks and opportunities in the supply chain with suppliers. The overall objective was to encourage and improve the sustainability of approved suppliers over time to also decrease supply chain risk in TCO in procurement decisions.

Airport Utility Budget Management

By managing utility budgets differently, airports may conserve resources, which has an environmental and social impact, but more directly, managers may apply those savings to effect the TCO by using utility savings to pay for more efficient infrastructure (assets). This section discusses how this can be implemented and accomplished.

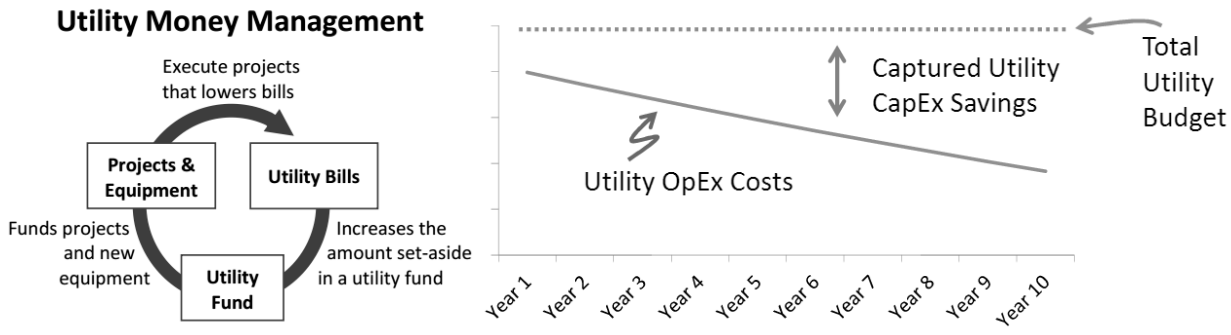
Generally, operating budgets are set annually and during the budgeting review process. Budgets for utilities are set for the upcoming year based on the prior year spend adjusted for anticipated operational changes in the upcoming year that may require more or less electricity or water, for example. After which, utility bills are paid and reported under a general ledger code commonly named something like "utilities and other." In short, utility budget is managed like a fixed amount, when in fact it is variable. Meanwhile, during the year several factors impact the actual utility spend vs. the budgeted amount including

- Efficiency efforts that leads to cost savings
- Warmer or colder weather that influences energy spending
- O&M managers being incentivized to come in under budget

Year-on-year, operations teams work hard to stay under budget by being more efficient while dealing with the realities of changing weather, economies, and operational demand. In addition, year-on-year, the delta between the actual amount spent on utilities versus the budgeted amount, which is usually a savings, is stripped from the budget.

Organizations, such as the University of Washington and Distributed Energy Management (Jia 2016), are approaching utility spend differently to drive more resource conservation and pay for capital upgrades through utility cost avoidance. To capture the cost avoidance, a utility revolving fund is set up either directly with a bank or virtually in an accounting system. The monthly utility budget is paid into the fund from which the monthly utility bills are paid.

In some cases, a "markup" of the monthly utility operating budget is put in place to help save for future capital projects. The funds not spent on utility costs are then earmarked to offset or pay for more efficient retrofits or new equipment, which, in-turn, pays for new projects with their savings. Figure 4-5 highlights the process.



Source: Distribution Energy Management

Figure 4-5. Utility money management

Example: University of Washington "Green Revolving Fund"

The University of Washington Facility Services supports a 643-acre campus with 243 buildings (13 million gross square feet), Central Steam & Chiller Plant, 13.8-kilovolt Power Distribution System, and 7 miles of utility tunnels to support a daily population of 60,000 consisting of 42,000 students. Average annual utility spend is $38 million. Through a coordinated effort, from 2005 to 2015, metering, audits, revolving fund, and project execution resulted in $21.5 million in projects with $9.1 million in rebates and $1 million in cost avoidance (Angelosante 2015).

CHAPTER 5

Building Information Modeling in the Asset Management Life Cycle

Up-to-date and complete information is the lifeblood of asset management. The more information the organization can have about any particular individual asset, as well as its criticality and relationship to the overall system, the better decisions the organization can make in terms of procurement, maintenance, decommissioning and more. This chapter discusses Building Information Modelling (BIM) and how this methodology can assist the organization in making good decisions throughout an asset's lifecycle. BIM complements the TCO program implementation but not necessary to maintain a TCO program.

BIM Defined

Building Information Modeling (BIM) has been used within the design phase of construction for well over a decade. Some countries have developed countrywide standards on the use of BIM for construction projects, each using its own interpretation of those standards. The application of BIM focused initially on the construction of vertical buildings and has since widened its scope to include infrastructure. The US definition of BIM (National Institute of Building Sciences 2015) is:

> *…a digital representation of physical and functional characteristics of a facility. As such, it serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its life cycle from inception onward.*

In the UK, the BIM Task Group defines BIM as:

> *value creating collaboration through the entire life cycle of an asset, underpinned by the creation, collation and exchange of shared 3D models and intelligent, structured data attached to them.*

The use of BIM to a locally-defined Level 2 standard has been mandated by all government departments starting in April 2016 on construction projects over $1.4 million. The Level 2 standard for BIM for the UK is defined as having a central repository for documents with a defined check, review, approve process and federated models linked to data and documents.

In both the US and UK, BIM centers on creating digital representation and structured data connected to it. "Structured data" are data that are in alignment to a data standard (e.g., ISO 15926 life cycle data for process plant) and thus produces a consistent output from modelled applications. The term "Information Model" will be used in this document to represent a graphical model with associated structured data that can be used throughout the entire life cycle of an asset.

The production of an Information Model, when taken in its broadest life cycle sense, starts from a conceptual model that outlines the requirements of a new asset or infrastructure and then progressively

builds upon acquired information from various disciplines, which are then federated to form a more complete visual representation. Figure 5-1 depicts the federation of a graphical model to form a visual representation of the Information Model. This is only part of the model, as non-graphical portions of the model as well as documentation also forms the Information Model. Through the process of applying structured information, the documentation and the non-graphical (data) portions of the model can also be attached to the model.

Figure 5-2 shows the linkage of a graphical model to (from top, clockwise) drawings, documentation, data and asset management applications. Thus, the potential of BIM is to harness an Information Model for further use downstream from design. This leads to potential BIM uses for construction, commissioning, operations, and maintenance.

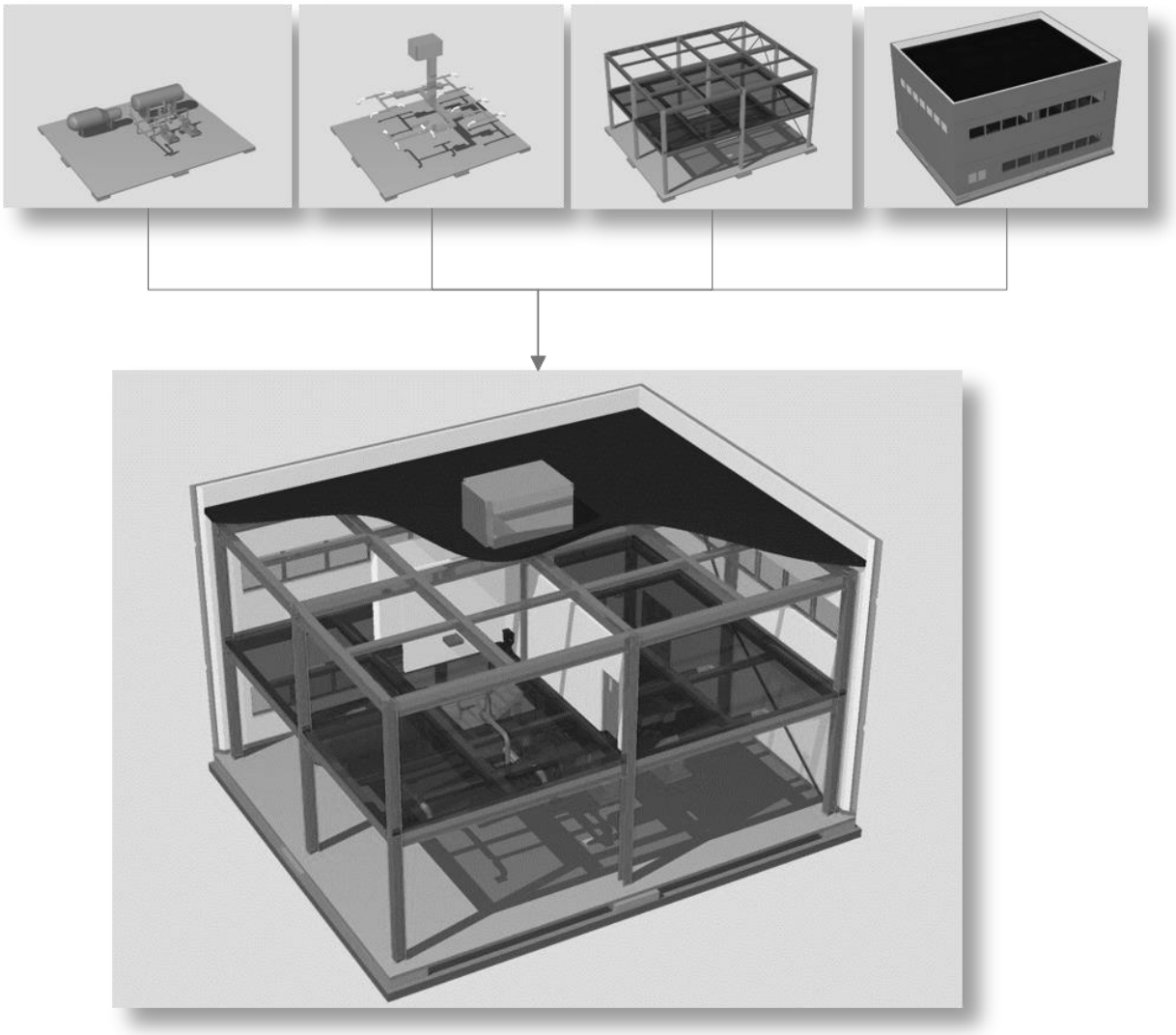


Figure 5-1. Federated model produced by combining discipline-specific intelligent models

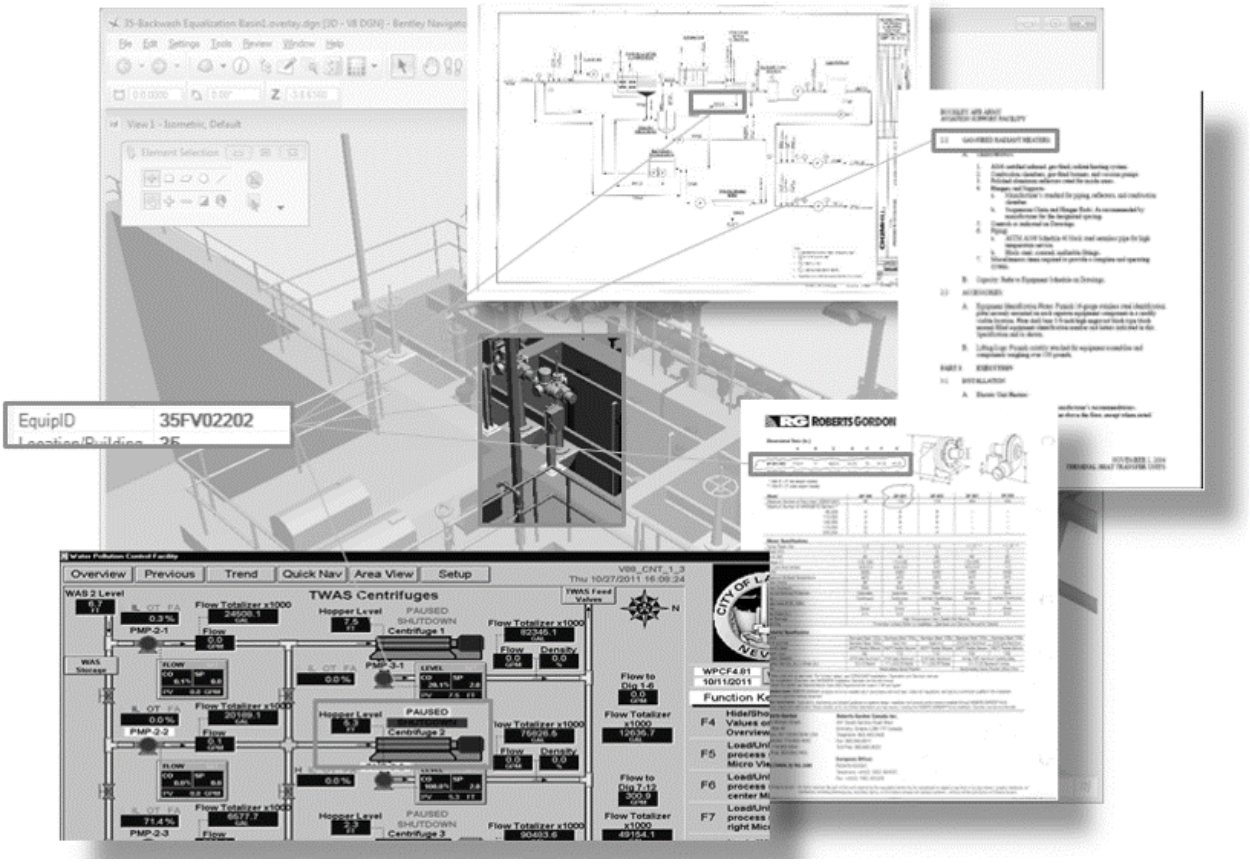


Figure 5-2. Linkage of the graphical model to structured data and documentation

Whole Life Cycle BIM

In order to maximize the use of an Information Model, consideration must be given to the required end users' needs. Figure 5-2 shows the potential for deriving data from an Information Model and linking the information to asset management systems. In order to facilitate this integrative process, the creators of the Information Model must understand the final uses to which the model will be placed such that appropriate data fields, metadata, and formats are chosen at the start.

An intelligent client will be at an advantage, if it can articulate its requirements for information holistically across the life of an asset. It is this whole life view of information that the UK government set out to realize in its strategy for BIM Level 2 by outlining the client organization's (employers) information needs from the supplier. This ability to define and request information in formats that align with client needs creates a framework that can be used for various functions such as planning applications, operations review, and update of asset inventories/systems.

An asset will go through many stages in its life cycle and some understanding of the typical stages is required so the impact that BIM can be optimized. A typical life of an asset may start with a need identified from a system owner, as a result of inspection, maintenance or new needs identified. This may generate initial or outline ideas and a procurement process derived for a new asset. This leads to design, construction,

commissioning, O&M through to end of life whereby the final step is decommissioning or demolition. This is illustrated in Figure 5-3.

Figure 5-3. Life cycle of an asset

At the end of each stage or gateway, there is usually a decision point that may decide if the development of a solution will continue to the proceeding stage or can be discarded. The decision making process will require the evaluation of data in various forms and from different perspectives such as cost, time, program, quality, environmental impact.

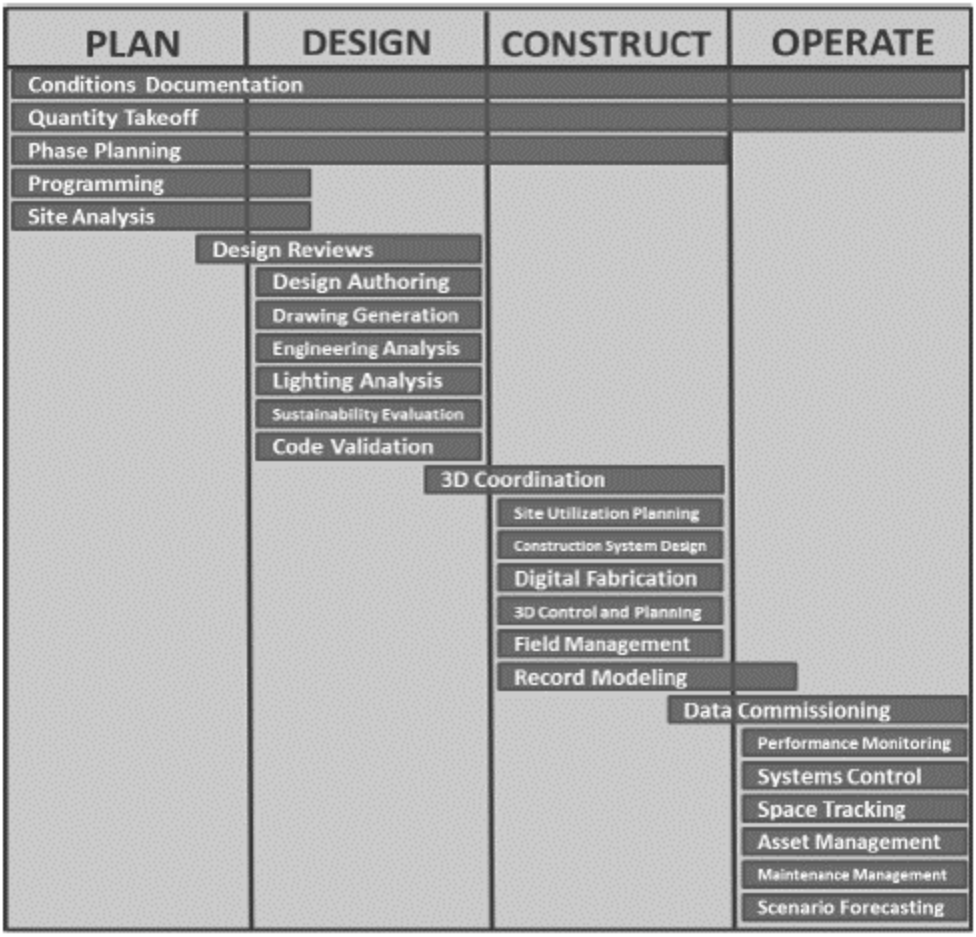
With the superimposition of BIM on the decision-making process, a client can specify their information requirements for given gateway. This information, if structured, can lead to a better decision-making process as the information is:

- Derived from validated sources of data (graphical and non-graphical)
- Structured in the same manner regardless of source (e.g., aligned to a standard such as ISO)
- Automated in production (derived from an intelligent model)
- Consistent in evaluation across projects and suppliers

Additional benefits derived from the BIM process are in the use of information across stages. If different suppliers are used at each stage, using a structured Information Model means the model can be enriched from the previous stage rather than starting from the beginning, leading to further improvements in the efficiency of the process. The Information Model can also be used for various functions such as:

- Visualizations, animations
- Quantity takeoffs
- Land use planning
- Logistics planning (construction, operations, maintenance, and decommissioning)
- Cost estimating
- Performance monitoring
- Systems control

In 2013, the Computer Integrated Construction Research Program at Penn State University published BIM planning guide for facility owners that identifies 26 uses of BIM throughout the life cycle of a facility (Figure 5-4) from planning through to operations.



Source: Computer Integrated Construction Research Program

Figure 5-4. List of BIM uses

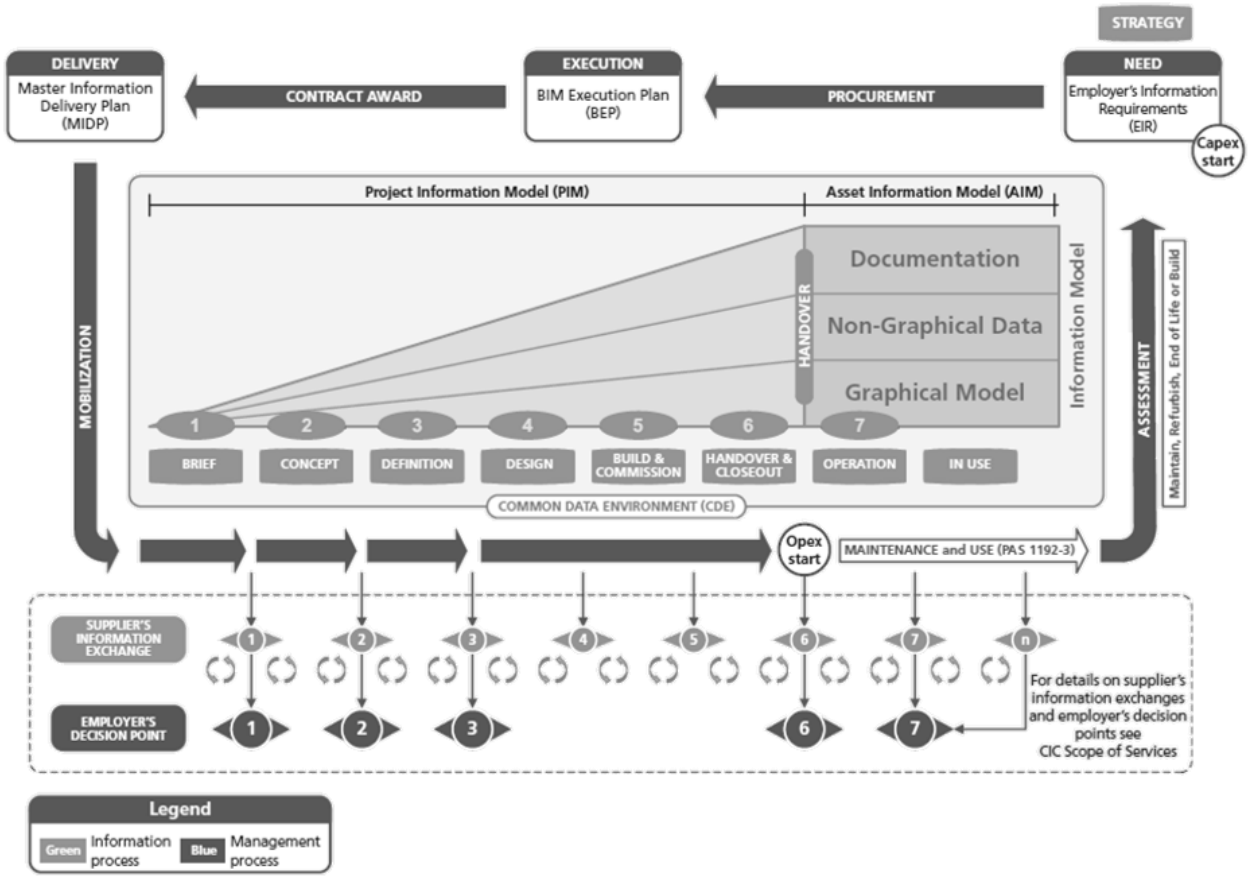
Case Study of BIM on the Procurement Process

An example of the BIM process that outlines the principles outlined in this section is taken from the Environment Agency's implementation of UK's BIM Level 2 standard. The Environment Agency has an annual procurement value in excess of $420 million and 16,000 assets to manage across the country.

Digital Plan of Work

The overarching structure of the procurement process is defined in a Publically Available Specification (PAS 1192-2: 2013), which outlines the life cycle of an asset, upon which it superimposes the information requirements that are derived from the BIM process. The creation of a new asset often starts within the OPEX phase and an identified need as a result of assessment (OPEX start in Figure 5-5). This results in the need to engage the supply chain for services. This is shown graphically as "CAPEX start" in Figure 5-5, the point where the employer defines the information requirements for each of the stages labelled 1 to 7.

The supply chain then mobilizes and undertakes the required phase for which the project was procured. The value of the Employers Information Requirement is the standardization of information from any supply chain organization for any of the asset phases.



Source: PAS 1192-2 2013

Figure 5-5. Life cycle management of an asset with BIM processes overlaid

For the Environment Agency, the Employers Information Requirements are split into three parts: overall information standards, information delivery plan, and asset specific information requirements.

Information Standards

The Information Standards document outlines the standards to be applied in the following areas:

- Software platforms
- Data exchange formats
- Coordinates
- Level of definition
- Training

- Standards
- Roles and responsibilities
- Work planning and data segregation
- Security
- Coordination and clash avoidance
- Collaboration process
- Health and safety
- Construction design management
- Systems performance
- Compliance plan
- Delivery strategy for asset information
- Information exchanges and project deliverables
- Client's strategic purposes

This sets the requirements for BIM for every project and every phase and calls upon British and international standards in the procurement of information.

Information Delivery Plan

The Information Delivery Plan sets out the specific information that the Environment Agency requires for a project and defines each deliverable, who will produce it, when, and the name of each deliverable. This means each document delivered is defined and classified in the receiving organization's naming structure, and is retrievable immediately upon handover. Figure 5-6 is an example of an Information Delivery Plan where a project number is identified (1) and a deliverable Stage (2). For each stage, a set of deliverables is defined (3) and for each intersection of deliverable against a stage, the resulting organization and level of definition (4) can be stated.

This results in a structured document naming system and automation that is used to request delivered materials, formatted with a defined document mask. An example output of this also shown in Figure 5-7.

Name	CreatedBy	CreatedOn	File
A001-EA0 Area of Study	hinesh.mistry@ch2m.com	2016-03-06T17-35-19	12345-EA-?-?-?-?-?-?-?-A001-EA0-LOD1-Area of Study.ext
A001-EA1 Area of Study	hinesh.mistry@ch2m.com	2016-03-06T17-35-19	12345-EA-?-?-?-?-?-?-?-A001-EA1-LOD1-Area of Study.ext
A001-EA2 Area of Study	hinesh.mistry@ch2m.com	2016-03-06T17-35-19	12345-EA-?-?-?-?-?-?-?-A001-EA2-LOD2-Area of Study.ext
A001-EA3 Area of Study	hinesh.mistry@ch2m.com	2016-03-06T17-35-19	12345-CONS-?-?-?-?-?-?-?-A001-EA3-LOD3-Area of Study.ext
A001-EA4 Area of Study	hinesh.mistry@ch2m.com	2016-03-06T17-35-19	12345-CONS-?-?-?-?-?-?-?-A001-EA4-LOD3-Area of Study.ext
A002-EA3 Site Boundaries	hinesh.mistry@ch2m.com	2016-03-06T17-35-19	12345-CONS-?-?-?-?-?-?-?-A002-EA3-LOD3-Site Boundaries.ext
A002-EA4 Site Boundaries	hinesh.mistry@ch2m.com	2016-03-06T17-35-19	12345-CONS-?-?-?-?-?-?-?-A002-EA4-LOD4-Site Boundaries.ext
A002-EA5 Site Boundaries	hinesh.mistry@ch2m.com	2016-03-06T17-35-19	12345-CONT-?-?-?-?-?-?-?-A002-EA5-LOD5-Site Boundaries.ext
A002-EA6 Site Boundaries	hinesh.mistry@ch2m.com	2016-03-06T17-35-19	12345-CONT-?-?-?-?-?-?-?-A002-EA6-LOD5-Site Boundaries.ext
A003-EA0 Topographic Survey(s)	hinesh.mistry@ch2m.com	2016-03-06T17-35-19	12345-EA-?-?-?-?-?-?-?-A003-EA0-LOD7-Topographic Survey(s).ext
A003-EA1 Topographic Survey(s)	hinesh.mistry@ch2m.com	2016-03-06T17-35-19	12345-EA-?-?-?-?-?-?-?-A003-EA1-LOD7-Topographic Survey(s).ext
A003-EA2 Topographic Survey(s)	hinesh.mistry@ch2m.com	2016-03-06T17-35-19	12345-EA-?-?-?-?-?-?-?-A003-EA2-LOD7-Topographic Survey(s).ext
A003-EA3 Topographic Survey(s)	hinesh.mistry@ch2m.com	2016-03-06T17-35-19	12345-CONS-?-?-?-?-?-?-?-A003-EA3-LOD4-Topographic Survey(s).ext
A003-EA4 Topographic Survey(s)	hinesh.mistry@ch2m.com	2016-03-06T17-35-19	12345-CONS-?-?-?-?-?-?-?-A003-EA4-LOD4-Topographic Survey(s).ext
A003-EA5 Topographic Survey(s)	hinesh.mistry@ch2m.com	2016-03-06T17-35-19	12345-CONT-?-?-?-?-?-?-?-A003-EA5-LOD6-Topographic Survey(s).ext
A003-EA6 Topographic Survey(s)	hinesh.mistry@ch2m.com	2016-03-06T17-35-19	12345-CONT-?-?-?-?-?-?-?-A003-EA6-LOD6-Topographic Survey(s).ext

Figure 5-6. Automated delivery of information delivery plan in standardized data structure

This means that the system owner defines information deliverables identified to answer business questions for a gateway before the procurement process. It also means the supply chain activities are aligned to the owner's vision of deliverables and are thus empowered to deliver the right information at the right time to the right team. The formation of document masks, as shown in Figure 5-5, means that all deliverables are allocated with logical names and can be filed and thus retrieved effectively with little rework.

Asset Specific Information Requirements

To facilitate the full life cycle generation of modeled content and derived data, it is necessary to articulate the data needs of the final organization and create the required level of attribution in the Information Model. The data that are generated and then stored in the model need to be transmitted in a form that can be read by the receiving organization. Within the UK, a subset of the Building Smart Industry Foundation Classes (IFC) schema has been selected as the medium by which structured data is transmitted. The subset selected is called COBie and was developed by the US Army Corps of Engineers as a method by which data can be stored about a facility such that handover of data is reliable.

IFC data model is intended to describe building and construction industry data. The IFC model specification is open and available. It is registered by ISO and is an official International Standard ISO 16739:2013. It is a platform neutral, open file format specification that is not controlled by a single vendor or group of vendors. It is an object-based file format with a data model developed by building smart. A subset of the data view of an IFC model is the COBie data schema as illustrated in Figure 5-8.

As the COBie schema is a data model used to describe an asset from an asset management perspective, the Environment Agency have placed all the asset attribution requirements within the data model and can thus deliver, in a structured data format, their requirements for leveraging asset level information for any asset and project phase. In its simplest form, the COBie data model is represented as a series of tabs in a spreadsheet format and is thus accessible to any organization.

Information Delivery Plan

Plan Status:
Employers Information Delivery Plan

[View] Hinesh Mistry Logout

Find: Clear Project: 12345: Sample IDP New Project CIR XML 3DMF Mask BlankX

Stage: All Stages 2 Role: All Roles LOD: All LOD

Ref: 1
12345
IDP Manager:
Graeme Tappenden

Project:
Sample IDP
Facility:
Sample IDP

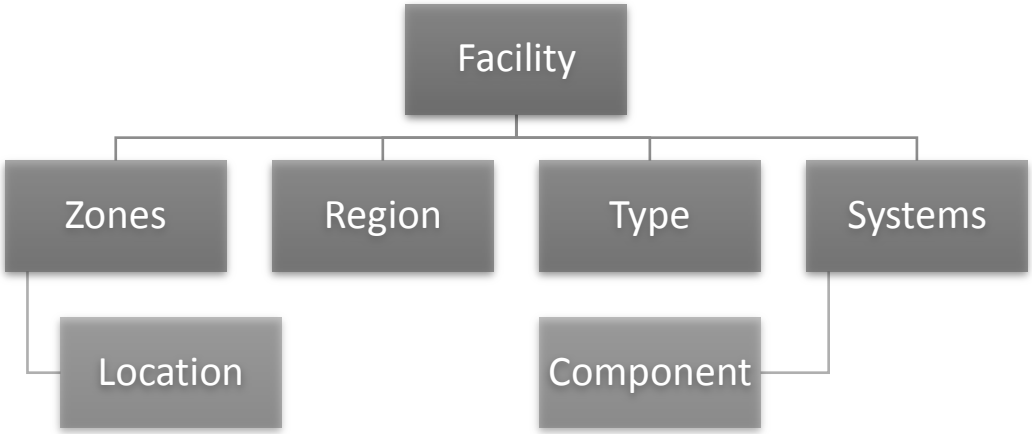
Stage 0 Strategy | Stage 1 Brief 1 | Stage 2 Concept 2 | Stage 3 Definition 3 | Stage 4 Design 4 | Stage 5 Build & Commission 5 | Stage 6 Handover & Closeout 6 | Stage 7 Operation & End of Life

Template: **EA14**
Plan of Work: **Environment Agency Plan of Work 2014**

	EA0: Identification	EA1: Prioritising	EA2: Project Start-up	EA3: Business Case Development	EA4: Detail Planning	EA5: Contract Award and Construction	EA6: Contract Complete and Closeout	EA7: Operation and End of Life
Supplier Information Manager:	EA	CONS	CONS	CONS	CONS	CONT	CONT	EA
Stage Status:								

Ref	Deliverable	N/F	Ass	Cap	O/F	3DMF	Role	LOD	Role	LOD	Role	LOD	Role	LOD	Role	LOD	Role	LOD	Role	LOD	Role	LOD
A000	**Site Conditions / Discovery** 3									4												
A001	Area of Study	N	N	B1	pdf		EA	LOD1	EA	LOD1	EA	LOD2	CONS	LOD3	CONS	LOD3						
A002	Site Boundaries	N	N	B1	pdf								CONS	LOD3	CONS	LOD4	CONT	LOD5	CONT	LOD5		
A003	Topographic Survey(s)	Y	N	B1	pdf		EA	LOD7	EA	LOD7	EA	LOD7	CONS	LOD4	CONS	LOD4	CONT	LOD6	CONT	LOD6		
A004	LIDAR	Y	N	B1	pdf																	
A005	Laser Scans (Point Cloud)	Y	N	B1	pdf																	
A006	Utilities Survey	Y	N	B1	pdf		EA	LOD7	EA	LOD7	EA	LOD7	CONS	LOD4	CONS	LOD4						
A007	UXO Assessment	Y	N	B1	pdf		EA	LOD7	EA	LOD7	EA	LOD7	CONS	LOD3	CONS	LOD4						
A008	Geotechnical Survey(s)	Y	N	B1	pdf		EA	LOD7	EA	LOD7	EA	LOD7	SICONT	LOD4	SICONT	LOD4						
A009	Contaminated Land Survey	Y	N	B1	pdf		EA	LOD7	EA	LOD7	EA	LOD7	CONS	LOD4	CONS	LOD4						
A010	Geotechnical Report	N	N	B1	pdf								CONS	LOD4	CONS	LOD4						
A011	Land Registry Searches	N	N	B1	pdf								EA	LOD4	EA	LOD4	EA	LOD6	EA	LOD6		
A012	Schedules of Condition (inc. existing designs)	N	N	B1	pdf		EA	LOD7	EA	LOD7							EA	LOD6	EA	LOD6	EA	LOD6
A013	Weather/ Tide/ Flow/ Hydraulics/ Hydrology	N	N	B1	pdf		EA	LOD7	EA	LOD7	EA	LOD7	CONS	LOD7	CONS	LOD7	CONT	LOD7	CONT	LOD7		
A014	OS Data Mapping	N	N	B1	pdf		EA	LOD7	EA	LOD7							CONT	LOD6	CONT	LOD6	CONT	LOD6
A015	BGS	N	N	B1	pdf																	

Figure 5-7. Information delivery plan



Note: The following areas in the data model are not shown for clarity: Contact, Assembly, Connection, Spare, Resource, Job, Impact, Document, Attribute, Coordinate, Issue.

Figure 5-8. COBie Schema from BS 1192-4 Showing Only the Overview Structure

The use of COBie as a data schema has many advantages. Modeling applications within which data are generated and stored can export data in this schema as defined by an ISO standard. Newer facility management applications are being released which are able to read the COBie schema and can thus facilitate the transmission of data peer-to-peer, thus automating the flow of data. Even if software is not able to read the applications, the benefit of having data from the supply chain in a consistent and standardized format means routines can be written to extract data from the COBie file. This routine need only be written once for a translation to work multiple times across projects and stages.

Figure 5-9 shows an example of a COBie file used to state information requirements. This shows the required name for each attribute for a modelled outfall structure. The point at which information is required is given in the "Value" column. This is the gateway stage aligned to that in Figure 5-7. The structure of this portion of the Information Requirement is that a detailed delivery of information can be requested at a specified portion of the project development at the asset level. This enables delivery of key data to drive earlier or better decisions. Overall, this implies better understanding of TCO and the impacts of different engineering design, specifications and procurement strategies.

Development of the asset level information prior to procurement means that there is a greater level and granularity of information received at the required stage, facilitating the evaluation of the depreciation, operating costs, maintenance, and decommissioning.

Name	RowName	Value	Unit
Element Type	AIMS:structure: outfall: apron	LOD3	n/a
Element Weighting	AIMS:structure: outfall: apron	LOD7	n/a
Element Width	AIMS:structure: outfall: apron	LOD3	m
Element Condition	AIMS:structure: outfall: outfall pipe	LOD7	n/a
Element Description	AIMS:structure: outfall: outfall pipe	LOD3	n/a
Element Material	AIMS:structure: outfall: outfall pipe	LOD3	n/a
Element Not inspected	AIMS:structure: outfall: outfall pipe	LOD7	logical
Element not expected Reason	AIMS:structure: outfall: outfall pipe	LOD7	n/a
Element Revetment	AIMS:structure: outfall: outfall pipe	LOD3	logical
Element Sequence	AIMS:structure: outfall: outfall pipe	LOD7	n/a
Element Slope	AIMS:structure: outfall: outfall pipe	LOD3	Degrees
Element Type	AIMS:structure: outfall: outfall pipe	LOD3	n/a
Element Weighting	AIMS:structure: outfall: outfall pipe	LOD7	n/a
Element Width	AIMS:structure: outfall: outfall pipe	LOD3	m

Note: The required attributes are in the Name column and the Stage this value is required is given in the Value Column. Units are also specified. This extract is taken from Environment Agency COBie file for an Outfall, Attributes tab.

Figure 5-9. Extract of a COBie File Outlining the Required Information for an Outfall

Results

The case study presented here is a real life application of BIM for the procurement of services by the UK government department, the Environment Agency, in line with the BIM Level 2 standards as set out by the UK BIM Task Group and the British Standards. The whole life view of the procurement process has set out the standards by which asset information is structured (COBie), the attribution required, by whom and at each stage of the project life cycle.

The asset level information requirements were derived to meet the current information needs of the Environment Agency and reflect only that which is held by the current systems. The Environment Agency spent more than one year developing the framework, aligning its supply chain, reviewing the data requirements and building tools such as the Information Delivery Plan to enable BIM processes on its projects. The estimated saving in having the supply chain deliver information that is hand typed into the facility management system is valued at over $2.8 million per year in time savings alone.

This framework and methodology was tested during 2015 and then applied to all procured projects nationally starting January 2016. As of March 2016, more than 50 projects have been aligned to the BIM Level 2 requirements. The results of these developments are not fully realized but early indications include:

- Consistent naming conventions to documents and thus easy information storage and retrieval in the Client Data Environment across all new projects and document types.
- Standardization of content being developed in line with COBie information deliverables. Current processes are manual but automation is looking likely to increase efficiencies.

- Software vendors (AutoDesk and Bentley) developed federating tools that import and export COBie data files in SQL, XML, and XLSX formats. This unlocks data from a model and thus enables the delivery of data in industry standard formats.
- Supply chains are creating structured data in the COBie data model with the attribution requirements specific to the Environment Agency assets.

These benefits will compounded by the reduction of time to locate data, an increase in efficiency across the supply chain, and better quality of data overall. Future developments will build upon These benefits and will include:

- Automated verification of deliverables against the Information Delivery Plan
- Delivery of residual risks and environmental data at asset level
- Performance requirements for new assets
- Sensory/feedback from assets
- Comparison of sensory feedback against performance requirements and thus improvements in future procurement processes
- TCO estimating (OPEX)
- Just in time intervention or "sweating" an asset based on good quality data baselined against design criteria and historical sensory data

Implementing BIM

To successfully implement BIM within an organization there are a number of items that need to be reviewed and put in place to provide a holistic framework that meets the organizations needs for information, the capabilities of the supply chain and the management of people and technology to realize that ambition.

Information Modeling for Asset Management

To successfully manage the information across multiple projects and assets and during various phases, an organization needs to understand and document the decision-making process for an asset or multiple assets. This can be placed into matrix format with review stages as headings and rows of questions. The deliverables required to answer the questions can then be placed in the matrix. Table 5-1 is an example of this method.

Table 5-1. Example of Organization Information Needs for Project Level Cost

Questions	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
How much will it cost?	Optioneering report	Full Business Case	Outline Design Cost Estimate	Tender evaluation report	Out turn Cost	Actual Cost

The matrix can then be refined to standardize the outputs needed and provides a mechanism that links asset management needs and information requirements together. This then forms the basis for the data drops or information exchanges as outlined in Figures 5-3 and 5-5.

At the highest level, the resulting matrix provides documents as Information Requirements from the supply chain. The same methodology can be applied to more granular level of detail as the BIM maturity of the supply chain and organization grows. The target for this methodology would be to provide asset level attribution requirements linked to Information Models. This can be presented in a tabular format of international standard such as COBie.

Plan of Work

The next step is to use the resulting matrix and formulate a Plan of Work. This would empower the supply chain to understand and provide the information requested in the formats specified. This can range from data extraction from three-dimensional models, analysis packages to spreadsheets, and databases linked to models.

As a result of this approach, the organization making the request for information leaves the responsibility for providing the information using the best solutions and technologies available to those who know them. By providing a clear framework, there is opportunity for three-dimensional models, animations, advanced visualizations as well as reduction in data transfer across systems, linkages across facility management tools and all the other value adds that BIM models can provide. This mechanism provides the means to enable BIM in a consistent, standardized and timely manner with minimal changes to both client and employer organizations.

Alignment of Tools/Systems

The Plan of Work will enable information and data to be transferred at the right time, to the right level of detail and to the right person. To fully see the benefits, an organization may need to review their internal IT systems being used and review tools that may be able to extract, receive or use BIM data in a meaningful way with minimal rework. If new IT is required, the business case justification can often be proved in a comparison of time saving against re-inputting data or lost time finding information.

The use of an International Standard for data delivery such as COBie means that all asset level data delivered will be of a consistent format and if any tools are required to be developed, they can be developed once to extract or read this data and re-purpose for asset management needs.

Alignment of the Team

Another part of any BIM implementation will be in training of people to understand the new concepts that BIM will bring and new processes. Any change to an organization may cause some alarm to team members. An approach that has been successful is to identify BIM champions or points-of-contact within each office and supply chain, and meet with those well in advance of any implementation. This allows them to engage in the -making process and provide insight from their perspective and their teams, which often leads to better workflows and buy-in from each party. This early engagement also allows issues to be mitigated well before any actual implementation. A period of 12 months of regular engagement before implementation is seen as ideal as this allows understanding of BIM; the development of standards, workflows, and agreements; and some early adopter projects and trials.

Airports Implementing BIM

Airports worldwide are starting to adopt and implement BIM, whether as part of government initiatives or better asset management practices. This implementation would lead to capital and operational expenditures savings.

London Gatwick Airport has implemented BIM as part of the UK BIM initiative. This initiative has the goal of reducing the cost of government construction projects by 20 percent while assuring compliance with the EU's carbon emissions standards.

Denver International Airport is the largest airport in the US in terms of area (53 square miles) and the fifth busiest airport in the US. The airport leadership and facilities management realize the challenge in managing the existing and future assets at the airport. The airport is striving, through BIM implementation, to make the maintenance activities more efficient and reliable. Additionally, they expect that construction activities within the airport to be faster and more coordinated between the different entities. This is will positively reflect on the services provided by the airport to its stakeholders, including passengers.

Conclusion

For the aviation industry, there are four main strands of works that could be implemented to enable effective use of BIM and provide the framework by which better asset management can be delivered.

The first stage is to develop an understanding of the information requirements in an organization. This will define the data required, by when, the format and by whom. The second strand is to build on these information requirements and develop a Plan of Work that formalizes these requirements. This will enable effective lie cycle analysis and TCO studies to be undertaken earlier to better inform asset management decisions. The third stage is to review the existing systems and review any alignment changes or developments required to enable the flow of data into existing systems. This will dramatically reduce the time required to locate, read and input data from the supply chain. The final strand, and the most important one, is to engage with teams both internally and externally to adopt BIM as a new standard. This is a shift in operation and thus best managed by BIM champions and early engagement. The early engagement will bring everyone together early and work as a team. This will maximize the impact of BIM and reduce any hesitation during adoption.

In conclusion, with careful development of standards, processes and the supply chain, a client organization can set a framework for the use of BIM in delivering good quality data for asset management at any point in the asset life cycle. The presented case study was for the procurement of new assets and the data created from design. But the principles shown can be adopted to existing assets to bring about a paradigm shift in the way we think about assets and asset management.

CHAPTER 6

O&M Ready – Connecting Life Cycle Elements

As previously defined, asset management is a set of practices focused on sustaining assets throughout their whole life cycle. It considers the short- and long-term strategies and the alignment between the different business units and stakeholders. To render the full benefit of an asset management program requires these different parts to be integrated. This chapter discusses the concept of O&M Ready as the means to connect various operational processes and integrate the life cycle phases of the asset.

O&M Ready Defined

O&M Ready evaluates industry's best asset/facility management practices and the facility manager's future O&M needs. The requirements from O&M Ready are incorporated in the design and construction delivery process. The O&M Ready process has been used across industries including transportation, water resources, facilities, and power and energy in both private and public sectors.

O&M Ready has application for airports since they traditionally have multiple departments that apply different tools and standards for asset maintenance. Having these different asset management processes in place at airports' business units establishes communication and operational gaps (Figure 6-1). In order to close these gaps, a systematic view of asset procurement and ownership needs to be established. Upfront planning, design, and procurement level decisions set the tone for proper asset management planning and a full understanding of the assets' whole life cycle.

During the initial phases of a new project (planning and design), a significant opportunity exists to provide careful thought and insight into enhancing the commissioning process. The value of making this effort is clear when one considers that design and construction expenditures, the so-called "first costs" of a facility, typically account for 5 to 10 percent of the total life cycle costs while O&M costs typically are 60 to 85 percent. O&M Readiness brings attention to the facility manager's needs and interests as they relate to the greater part of the assets' life – the O&M phase.

Figure 6-2 illustrates how O&M Ready fills the procurement gap and supports a robust, reliable, repeatable, and sustainable process.

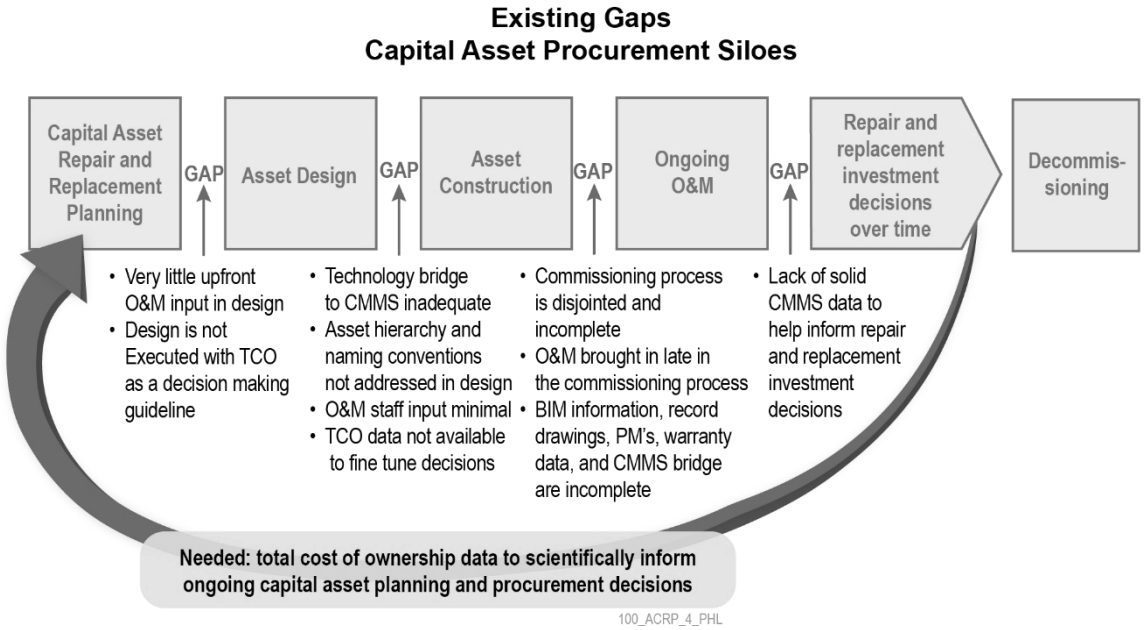


Figure 6-1. Closing the gaps in existing procurement process

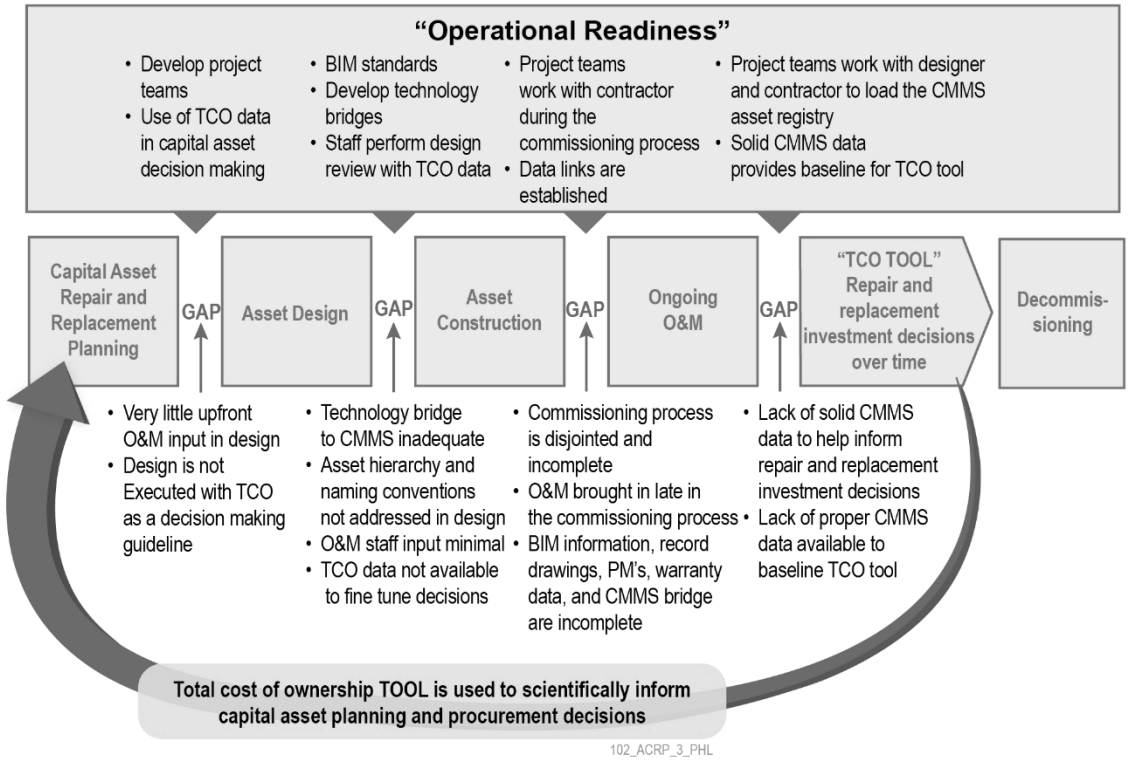


Figure 6-2. Operational Readiness, the approach to closing the procurement gaps

Benefits of O&M Ready

Although O&M Ready is a fairly a new concept in asset management, it has showed a high degree of interest by staff who directly manage assets as part of their work responsibilities. The following are a few benefits that stem from implementing O&M Ready (Fortin 2007).

- Integration of technologies, as appropriate, facilitate converting data into knowledge for accurate decision making (i.e., operational and renewal/replacement).
- Having preventive maintenance programs ready at turnover ensure timely asset protection, reduce risk of premature failure, and support warranty claims.
- Proper preventive maintenance programs control impacts of deferred maintenance and reduce risks.
- The use of condition monitoring tools such as oil analysis, infrared and vibration analysis helps identify installation defects that normally go undetected and reduce asset life.
- Reliability centered design establishes proper spare part inventory quantities for critical assets.
- Consistently, the organization experiences a smoother transition from design and construction to the O&M phase of the asset life cycle.

Implementing O&M Ready at Airports

As part of the research informing this guidebook, airport personnel were asked to rate (scale: 1-10) twelve operational readiness statements, based on their relevance to successfully implementing TCO.

Figure 6-3 presents the ranking of the 12 statements based on the individuals' input.

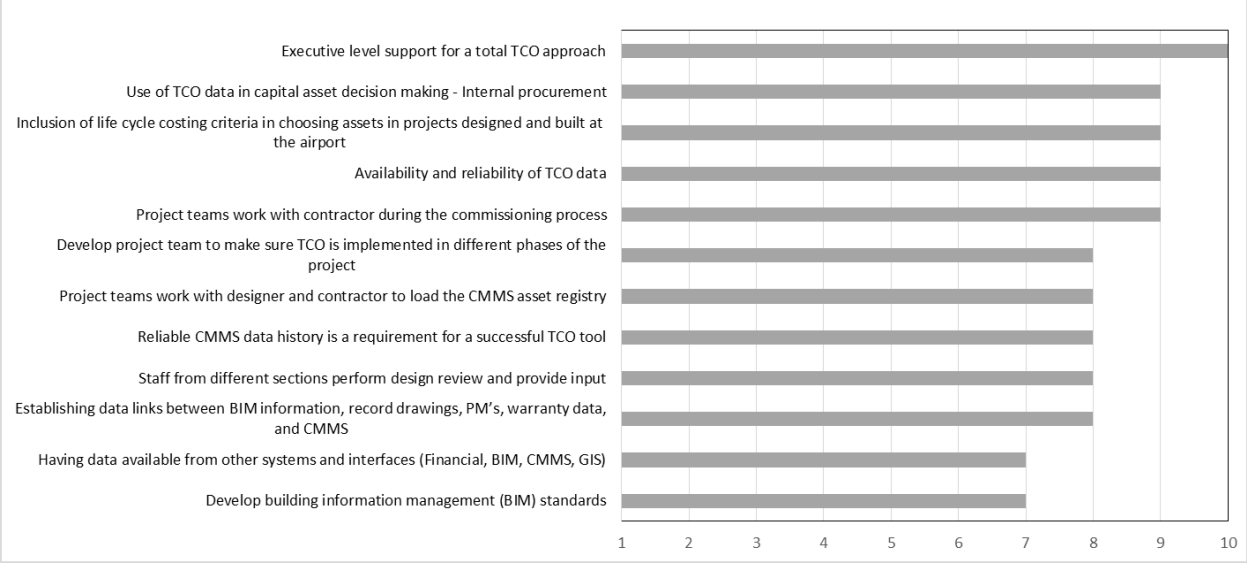


Figure 6-3. Statements rated based on their relevance to successfully implement TCO in terms of considering operational readiness

All the statements have an average score of 7 and above, indicating that those surveyed felt all are at least somewhat relevant to successful implementation. The top five statements from the list are:

- Executive level support for a total TCO approach (score: 10)
- Use of TCO data in capital asset decision making – Internal procurement (score: 9)
- Inclusion of life cycle costing criteria in choosing assets in projects designed and built at airport (score: 9)
- Availability and reliability of TCO data (score: 9)
- Project teams work with contractors during the commissioning process (score: 9)

Implementing O&M Ready

From this survey, it is clear that the most important drivers for implementing O&M Ready implementation are: leadership buy-in and availability of data and information. Based on this and additional research, the following activities will help to ensure successful implementation of O&M Ready at airports (Fortin 2007):

- Create owner-developed equipment turnover specifications – these specifications detail the requirements such as naming, preventive maintenance program, spare parts, and asset labeling/bar coding
- Initiate third-party development of the new equipment's preventive maintenance program for use in a CMMS
- Include design review processes that consider reliability concepts such as reliability, availability, and maintainability, and reliability centered design
- Standardize asset data/information for use with various management technology systems
- Consider use and integration, as appropriate, of facility management software systems such as CMMS, BIM, energy management systems, GIS, computer-aided facility management, and financial management systems
- Employ stricter equipment installation specifications requiring verification with state-of-the-art tools
- Recommission critical equipment assets to identify operational and performance issues before warranty expiration
- Supply enhanced training programs that provide staff adequate and regular training during the warranty period

CHAPTER 7

Asset Commissioning and Turnover Process

To exhibit components of the O&M Ready process within a real situation, this chapter discusses the new asset turnover process as a best practice within an asset management program, using the Metropolitan Sewer District of Greater Cincinnati as an example.

Case In Point: MSDGC

The Metropolitan Sewer District of Greater Cincinnati (MSDGC) is located in Cincinnati, Ohio. MSDGC manages and operates the wastewater collection, treatment, and disposal systems, to serve around 800,000 customers within Hamilton County, Ohio. The wastewater treatment division operates and maintains seven treatment plants and more than 100 smaller facilities that process an average of 180 million gallons of sewage per day. The majority of its facilities were built in the 1950s and contains more than 16,000 discrete assets that are critical to meet the operational needs.

As any public utility, MSDGC faces many challenges such as tight budgets, increased regulatory requirements, retiring workforce (knowledge/capacity), and aging/degrading infrastructure. In 2007, the wastewater treatment division started instituting the initial blocks and elements of a modern asset management program. The program included an updated asset hierarchy, equipment strategies, modern planning and scheduling practices, and maintenance key performance metrics.

Through the implementation of this asset management program, the proactive work ratio has improved to 50 percent; reliability levels are stabilizing; the maintenance work order cost reduction was around $500,000 in 2012 and the same in 2013; the monthly emergency failure rates decreased by 55 percent; and the documented cost avoidance was over $650,000 due to proactive maintenance activities. The personnel within the program kept on building on one success after the other to achieve a world-class asset management program.

Turnover Process

A well-documented turnover process, such as is in place at MSDGC, closes the gaps between the business units and stakeholders during the different phases of a project. It also establishes a robust asset commissioning process to reduce risk and better manage cost. The turnover process at MSDGC is illustrated in Figure 7-1. As shown in the figure, many parties are involved in the new asset turnover process, including:

- Wastewater Treatment (WWT) Reliability Group
- Design Engineer Consultant

- Construction Contractor
- WWT Planning Group
- WWT Predictive Maintenance Group

The turnover process starts during the design phase with the following activities:

- The design engineer consultant develops the piping and instrumentation diagram to 90 percent completion.
- The WWT reliability group populates CMMS with the functional location numbers.
- The reliability group provides the list of functional location numbers and specifications.
- The reliability group along with the design engineer assign the functional location numbers on the piping and instrumentation diagrams.
- The reliability group develops asset records and assigns assets to the associated location record in CMMS.

Once the design phase activities are completed, the design phase starts. The design phase includes the following activities:

- The design engineer consultant and construction contractor attach the appropriate electronic documents (submittals, bill of materials, final O&M manuals, and as-built drawings) to assets in CMMS.
- The construction contractor develops spare parts record and special tools record in CMMS.
- The WWT reliability group, design engineer consultant, and construction contractor update asset locations and records in CMMS to capture changes during construction.
- The WWT planning group places the asset identification tag on assets.
- As part of the WWT reliability group, the reliability centered maintenance (RCM) team (operations, maintenance, and engineering) performs RCM analysis for qualifying systems.

Once the contractor completes their work, the turnover phase starts for O&M. This includes the following activities:

- The WWT planning group updates the maintenance strategy based on RCM output such as job plans, predictive maintenance, preventive maintenance, and routes.
- The WWT planning group decommissions old assets, locations, and spare parts in CMMS.
- The WWT predictive maintenance group performs predictive maintenance baseline testing on the new assets, enter the new asset in Tango (software that manages facility's reliability information to create accountability and proper procedures are taken to repair or eliminate failures), and update the predictive software and insight oil website with new asset data.

Results

Through this documented turnover process, the communication between the different parties is clear and the responsibilities are identified. The different maintenance activities for this asset are documented in the asset management system. Additionally, the spare parts are identified and the critical ones become part of the storeroom inventory.

Collectively, these activities have a significant impact on the TCO for the asset and reduces the risk on the organization, where the asset will directly add value to the system.

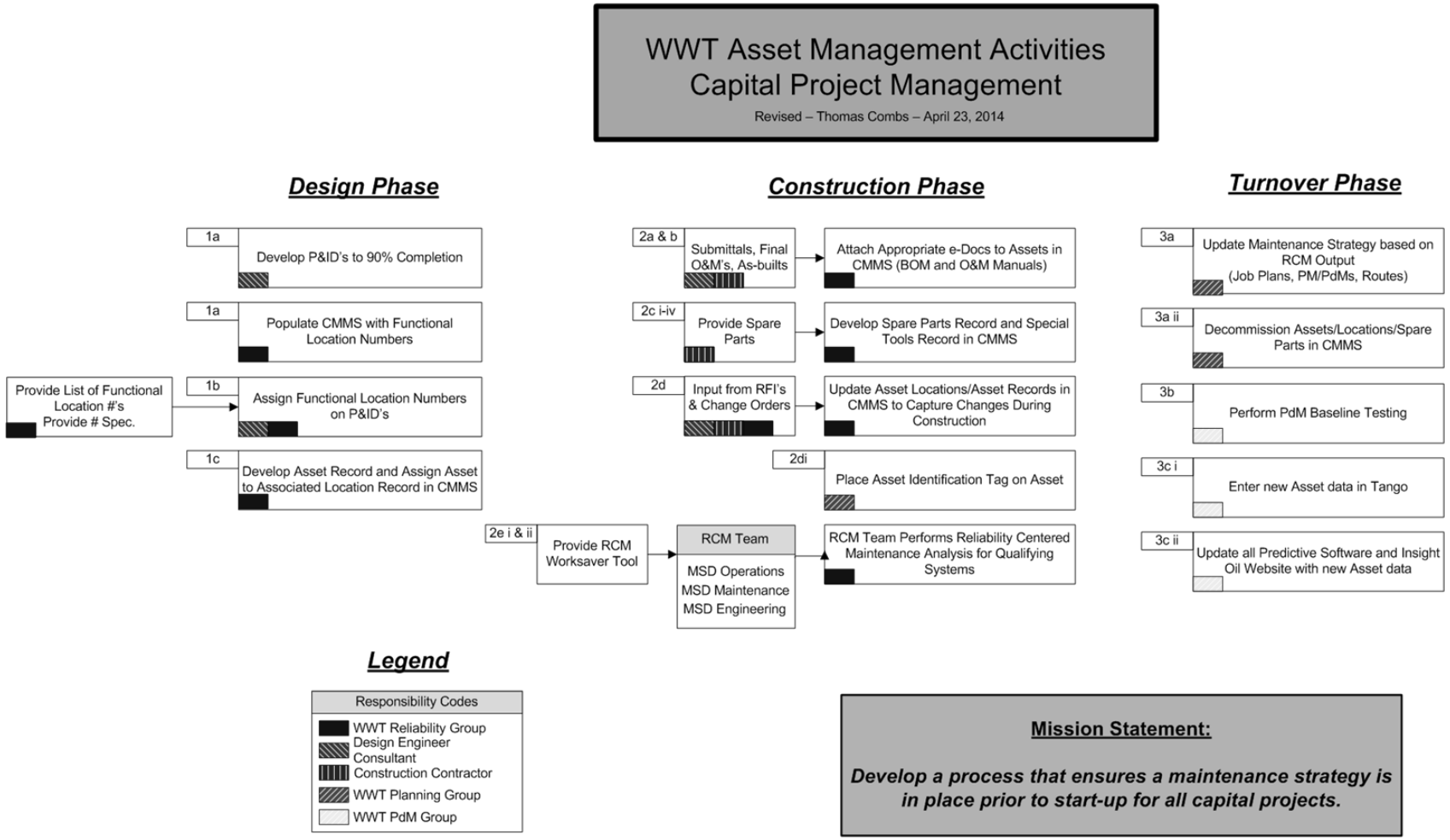


Figure 7-1. Example of a capital project asset management activities at MSDGC

CHAPTER 8

Case Studies

Case study participants chosen for incorporation into this guidebook have relevant experience in implementing asset management and TCO methods throughout their organizations. This chapter provides a range of perspectives, by presenting case studies of airports and non-airport organizations and a vendor with relevance to the airport industry.

Airports

All three of the airports that are covered in this case study analysis are classified as large hub airports. They are:

- Toronto-Pearson International, Canada (YYZ)
- Phoenix Sky Harbor International Airport, US (PHX)
- Hartsfield-Jackson Atlanta International, US (ATL)

Toronto Pearson International

YYZ is the largest and busiest airport in Canada. The airport is a hub for around 400,000 flights and in 2015 it served more than 41 million passengers. Over the last 2 years, the airport has seen unprecedented growth of around 7 percent. It is considered the second largest access point to North America, second only to JFK International Airport. US passengers come from Europe through YYZ, and process through customs and border control, arriving subsequently into the US as domestic passengers. The focus in YYZ is about improving passenger flow and creating dwell-time so transit passengers have an opportunity to enjoy the travel experience.

An independent non-profit authority, the Greater Toronto Airports Authority (GTAA), manages the airport. The GTAA operates within the south-central region of Ontario on a commercial basis to set the fees for their use and to develop and improve the facilities. Approximately 1,500 employees are employed directly by the GTAA. Airport Planning and Technical Services (APTS) that includes engineering, maintenance, project management, and technical performance employs 350 employees.

Asset Management Program at GTAA

In the 1970s, Transport Canada made a decision to computerize systems. An airport maintenance management system (AMMS) was developed and deployed to all airports in Canada at that time. When Canadian airports were subsequently transferred to private management, they were given AMMS for their own internal management. From 1996 until the current time, the system has been in place and has been managed and developed internally by GTAA. The AMMS at GTAA has robust data and detail, with

processes and workflow built into the software, although additional maintenance tools for pavement management and total cost complete the full asset management program at the airport.

Other systems that exchange data with AMMS include:

- Maximo, computerized maintenance management system
- Oracle financial system
- Chronos, time management system
- Perspective incident management system
- Fuel dispensing system
- Scheduling via spreadsheet tool (Scheduler – an in-house application)
- MicroPaver, pavement management system
- SCHAD, work order mobile application
- AQUAdata, for condition assessment for sewer, stormwater, and potable water systems
- Drawing data management system
- GIS

One deficiency in the AMMS data is for maintenance done by outside contractors, in particular, for contractors maintaining elevators. These contractors maintain data in their own asset management system. Because of the additional cost required to enter data into the AMMS, that data has not been available directly.

Asset Management Usage

GTAA acknowledges that the aviation industry cycles through many challenges, relative to changing economics and commuter trends. This recognition has driven the implementation of their asset management program, designed to help staff understand and address the following financial challenges that face GTAA:

- Problematic future budgetary allocation
- Competing capital priorities leverage the business case
- Lack of resources, especially highly trained and specialized technicians and supervisors

It is understood that these challenges impact every business unit within the airport.

A specific example of use of the AMMS is a report that they use to identify risks. Approximately 9 years ago, staff established system hierarchies with component breakdown. For each system, they developed a probability of failure, i.e., risk-based profiles for the systems. Each year, staff validates that model and, from the risk profiles, produce a document of high-risk systems and risk mitigation measures.

Maximo Implementation

Challenges in managing the AMMS and the need for a full-featured asset management system has led the airport to implement Maximo as a new asset management solution.

GTAA has collaborated with other airports that have had successful asset management system rollouts with the intention of leveraging their successes and lessons learned. These collaborations have affected the methods being used at GTAA. Their implementation has been methodical, and considered. Currently, the Maximo Inventory module is live and owned by APTS. The Fleet and passenger boarding bridging modules were scheduled for April 2016, with a full rollout expected by the end of 2016. Initial interfaces are in construction and will be integrated with Oracle to enable the exchange of data between the airport financial systems. Other interfaces will be built as the system matures. Asset data from AMMS is being migrated to Maximo, but the difficulties of migrating asset history are creating barriers to completion.

Training is being scheduled for users at a time just before the rollout through the Maximo system provider (EDI). Two types of trainings will take place: super-user and end-user. In addition, changes in the organization to fully use the features within Maximo have catalyzed organizational restructuring to support the implementation (see Governance section).

There are some challenges as the new system comes online. A primary challenge is in getting staff and management buy-in to system and process change – the human factor. Accordingly,, GTAA has ensured there is strong leadership at APTS, championing the advantages and necessity of the change, as well as early, frequent, and relevant communications about the project. The philosophy at GTAA has included collaboration and inclusion. Strategies used for the Maximo rollout at GTAA, shared by APTS include the following:

- Change process is sustainable only when people are on board
- Leaders have to sell the idea
- Good change management is pivotal
- Good communication requires explaining to all staff what is going on, and giving people time to adjust
- Involve people
- Show the employees the value
- Do not make change seem arbitrary; show them that the change is beneficial

Challenges in the Program

- Additional challenges in an overall asset management program include:
- Ensuring asset management objectives are established and compatible with organizational objectives
- Ensuring integration of asset management systems into the airport’s procurement processes
- Continual improvement and managing risks
- Promoting cross-functional collaboration between the business units
- Finding the correctly qualified resources in a small market; asset management specialization is hard to find, particularly in management
- During the commissioning, documentation that is turned over to the airport is not always adequate
- During specification process, the right assets are not necessarily specified
- Stakeholder reviews are allowed, but many do not take the time

- Most contractors think that the asset's data should be developed after commissioning instead of during the project
- Smaller projects are harder to manage because they do not have the same level of governance

Getting people on board is difficult. The advantages/disadvantages of an asset management program do not show up for years. An example cited during the interview was:

> *It is hard to get people excited about one elevator lasting longer than another. Most pressures are more immediate than cost of ownership.*

It may become apparent to management that the benefits of the asset management program are invaluable to the airport as it matures. As managers and leaders begin to realize the utility provided, there may be disciples from within the airport. Some of these expected benefits from the Maximo implementation will include:

- Proactive risk management based on historical costs
- Having ready-access to performance dashboards
- Producing accurate reporting (monthly, quarterly, and annual)
- Improved data-driven decision making
- Tracking labor cost through integration with Oracle financial system

A challenge for longevity of the project may be maintaining the leadership's dedication to the project through future transitions. A group of asset management leaders will need to be established to carry on the program.

Standards Implementation

GTAA is implementing and embracing the concepts of the asset management standards ISO 55000 and PAS 55; however, it is not looking to be certified in it. Additionally, the airport is certified in environmental management standards ISO 14001. The asset management program started within the facilities business unit and then was implemented throughout the airport.

Key Performance Indicators

The GTAA has established KPIs that were established at GTAA's leadership and used in the underlying business units. By adopting these KPIs at the leadership level, it ensures alignment throughout the organization with a focus on performance goals. GTAA's vision, goals, values, and behaviors is presented in Figure 8-1.

Source: GTAA

Figure 8-1. GTAA's vision, goals, values, and behaviors.

Asset Management Governance

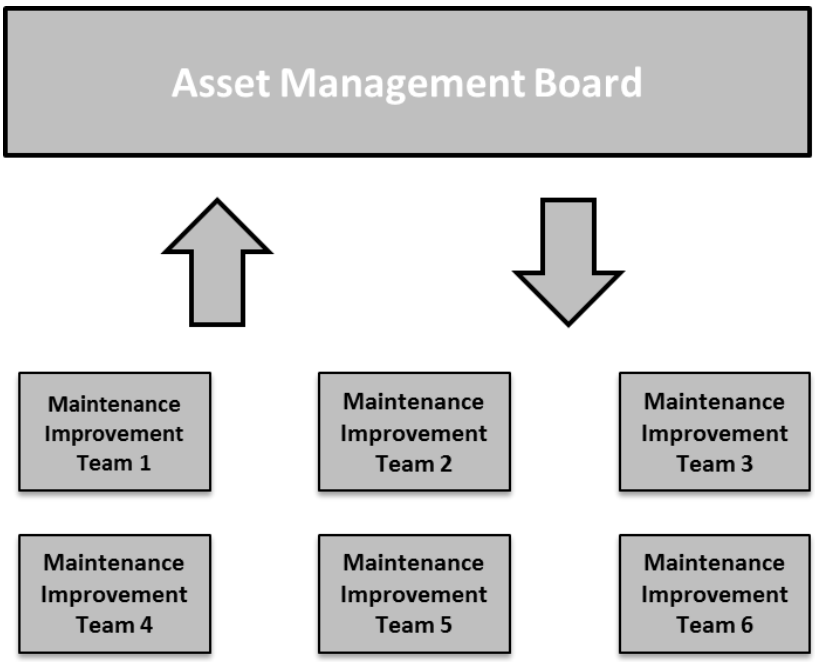
To achieve these benefits from Maximo, GTAA established a governance model in 2013 (Figure 8-2). The governance model integrates the functions at both the land (terminals) and air sides (aviation). The governance model is divided into two parts:

- Asset Management Board
- Maintenance Improvement Teams

This model makes sure that there is continuous communication between the different business units. Additionally, this model gets people on board and drives the efficiency in implementation.

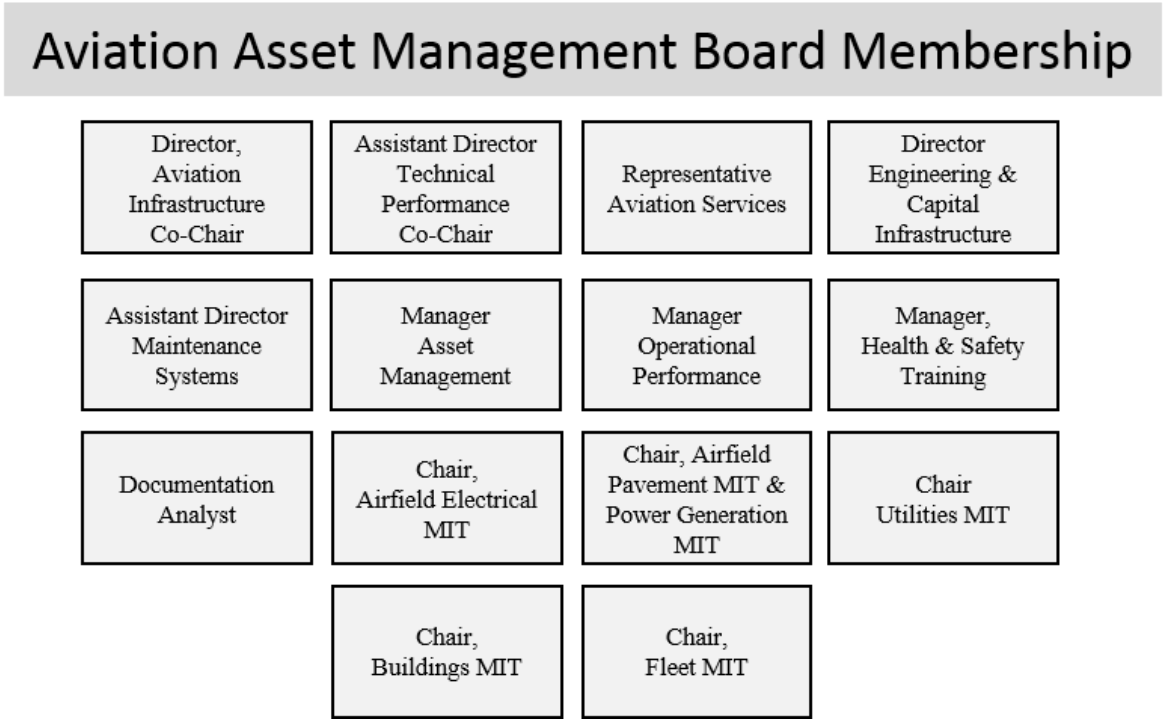
"Build a great process but you need the people to make it happen," Mike Riseborough.

Figures 8-2, 8-3, 8-4, and 8-5 illustrate the aviation and terminals asset management boards and the maintenance improvement teams.



Source: GTAA

Figure 8-2. Asset management board and maintenance improvement teams' relationship.

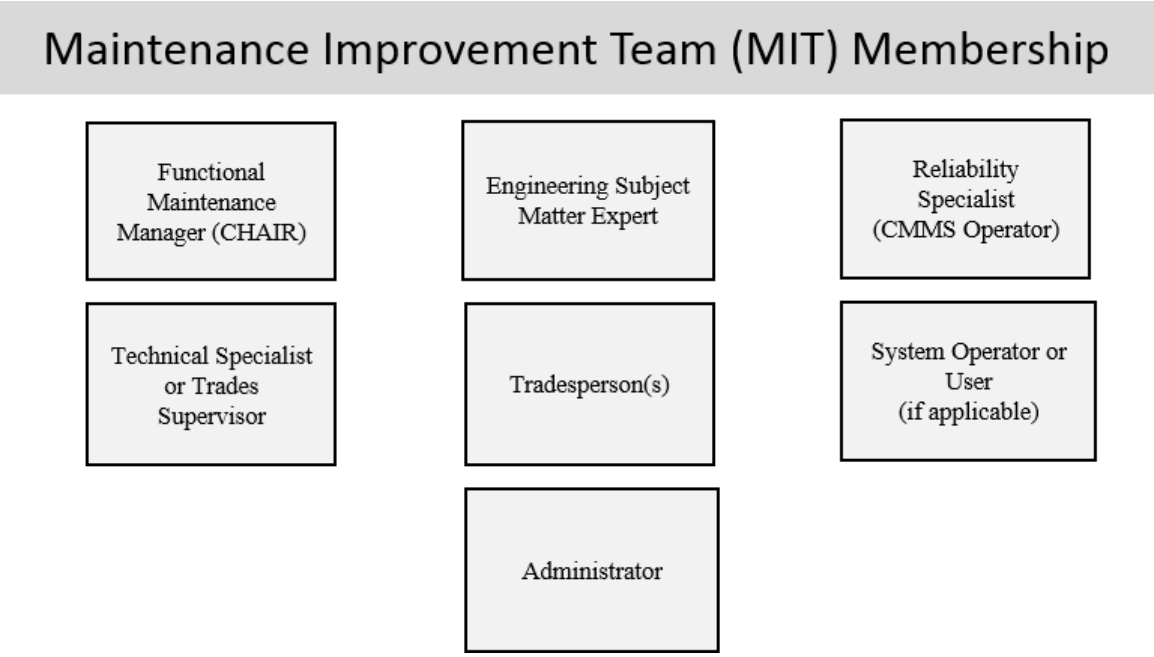


Source: GTAA

Figure 8-3. Aviation asset management board.

Source: GTAA

Figure 8-4. Terminals asset management board.



Source: GTAA

Figure 8-5. Maintenance improvement team.

The governance model includes maintenance improvement team and supervisors from different fields. The team members:

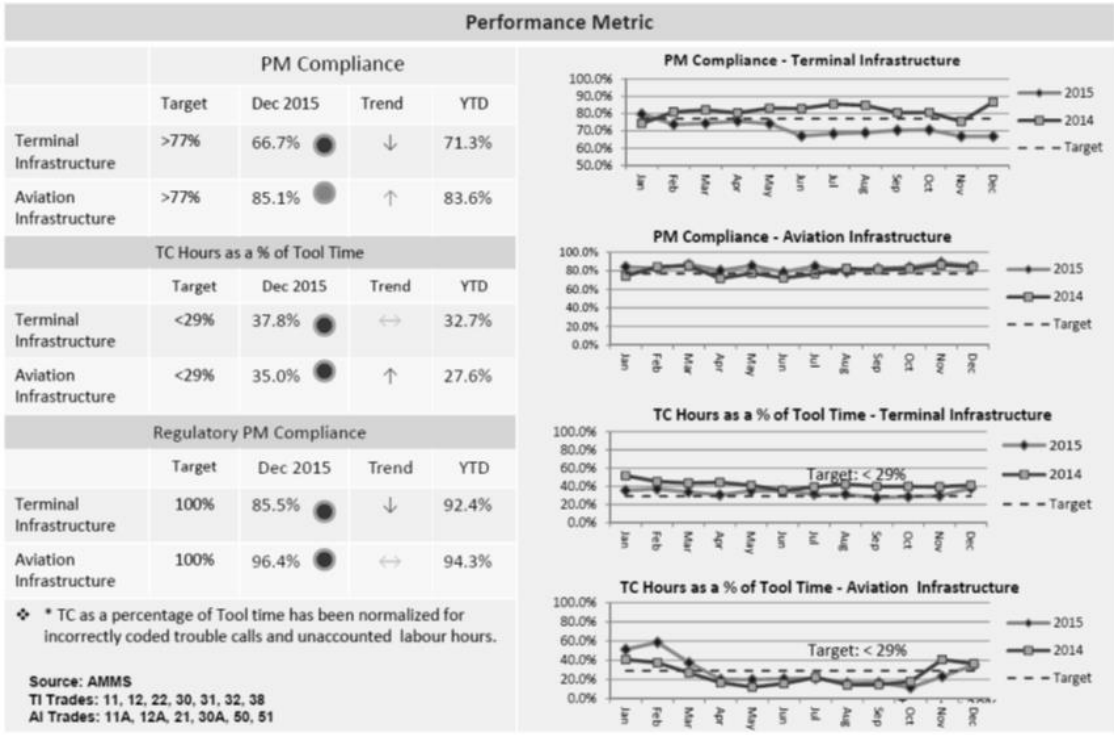
- Look at the performance on monthly basis
- Document what they have done and how they can improve it

Figures 8-6 through 8-10 present various performance metrics that were measured at GTAA during December 2015. Figure 8-6 presents the key performance metrics and their performance, Figure 8-7 presents the preventive maintenance compliance performance metric, Figure 8-8 presents the baggage performance metric, Figure 8-9 presents the passenger boarding bridges performance metric, Figure 8-10 presents the people moving devices performance metric. Figure 8-11 shows the calculations equations for these metrics.

Performance Metric	Target	Dec 2015	YTD
Baggage Service Availability	99.5%	99.8%	99.9%
Degraded Mode % normalized for construction	<4.6%	1.1%	1.5%
Jams*/1000 (over 1 min)	<3.6	3.2	2.9
PBB – Service Availability **	97.4%	98.6%	99.1%
Elevators	96.0%	96.6%	95.9%
Escalators	96.0%	96.0%	95.5%
Moving Walkways	96.0%	97.5%	95.7%
HSW - FEM11 ***	95.0%	98.0%	89.8%
HSW - FEM12	95.0%	95.3%	91.0%
HSW - FEM12 Normalized for GTAA Holds and Approved Outages		98.9%	93.9%
Automated People Mover	99.5%	99.7%	99.3%

*Jams: Baggage unable to move due to being stuck
**PBB: Passenger Boarding Bridges; ***HSW: High Speed Walk; FEM: Alias of specific unit.
Source: GTAA

Figure 8-6. Key performance metrics during December 2015.



Performance Metric

	Target	Dec 2015	Trend	YTD
PM Compliance				
Terminal Infrastructure	>77%	66.7%	↓	71.3%
Aviation Infrastructure	>77%	85.1%	↑	83.6%
TC Hours as a % of Tool Time				
Terminal Infrastructure	<29%	37.8%	↔	32.7%
Aviation Infrastructure	<29%	35.0%	↑	27.6%
Regulatory PM Compliance				
Terminal Infrastructure	100%	85.5%	↓	92.4%
Aviation Infrastructure	100%	96.4%	↔	94.3%

❖ * TC as a percentage of Tool time has been normalized for incorrectly coded trouble calls and unaccounted labour hours.

Source: AMMS
TI Trades: 11, 12, 22, 30, 31, 32, 38
AI Trades: 11A, 12A, 21, 30A, 50, 51

Source: GTAA

Figure 8-7. Preventive maintenance performance metric during December 2015.

Performance Metric

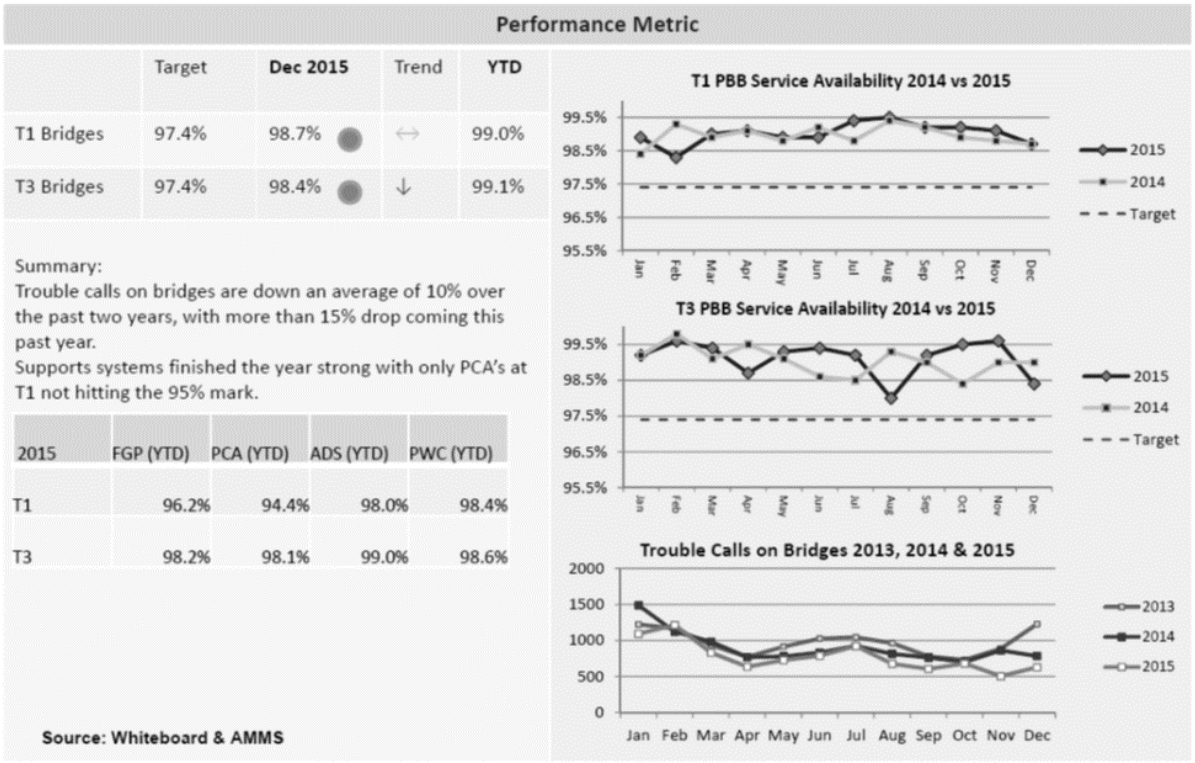
	Target	Dec 2015	Trend	YTD
T1 Baggage	99.5%	99.8%		99.9%
Jams/1000* (all Jams)	<3.6	5.8		5.1
Jams/1000 Over 1 min	<3.6	4.2		3.7
Degraded Mode %		18.5%		20.0%
Degraded Mode % Normalized	<4.6%	1.4%		1.6%
Read Rate		89.1%		90.0%
T3 Baggage	99.5%	100%		99.8%
Jams/1000 (all Jams)	<3.6	4.6		4.0
Jams/1000 Over 1 min	<3.6	1.4		1.5
Degraded Mode %		21.6%		20.6%
Degraded Mode % Normalized	<4.6%	0.83%		1.3%
Read Rate		89.1%		88.8%

Source: Glideview and Webview

*Jams: Baggage unable to move due to being stuck

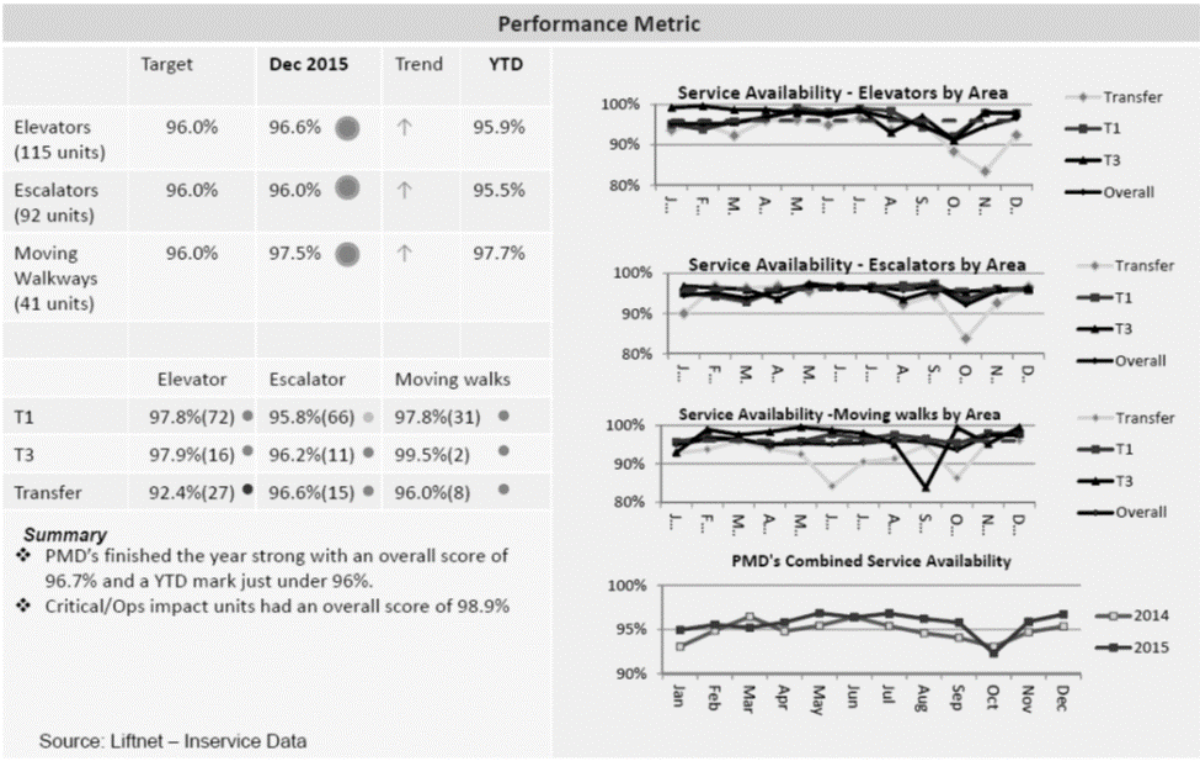
Source: GTAA

Figure 8-8. Baggage performance metric during December 2015.



Source: GTAA

Figure 8-9. Passenger boarding bridges performance metric during December 2015.



Source: GTAA

Figure 8-10. People moving systems performance metric during December 2015.

PBB Calculations

$$SA_{Bridges} = \frac{\#\ of\ Bridges\ x\ Total\ Operating\ Time - Total\ Out\ Of\ Service\ Time}{\#\ of\ Bridges\ x\ Total\ Operating\ Time} = \frac{(86\ bridges\ x\ \#\ of\ hours\ in\ Month - Total\ Out\ Of\ Service\ Time(PBB,ALV,CPY)\ (hrs)}{86\ bridges\ x\ \#\ of\ hours\ in\ Month}$$

PMD's

$$SA_{elevators} = \frac{\#\ of\ Units\ x\ Total\ Operating\ Time - Total\ Out\ Of\ Service\ Time}{\#\ of\ Units\ x\ Total\ Operating\ Time} = \frac{(115\ x\ \#\ of\ hours\ in\ Month - Total\ Out\ Of\ Service\ Time\ (hrs)}{115\ x\ \#\ of\ hours\ in\ Month}$$

$$SA_{escalators} = \frac{\#\ of\ Units\ x\ Total\ Operating\ Time - Total\ Out\ Of\ Service\ Time}{\#\ of\ Units\ x\ Total\ Operating\ Time} = \frac{(92\ x\ \#\ of\ hours\ in\ Month - Total\ Out\ Of\ Service\ Time\ (hrs)}{92\ x\ \#\ of\ hours\ in\ Month}$$

$$SA_{moving\ walks} = \frac{\#\ of\ Units\ x\ Total\ Operating\ Time - Total\ Out\ Of\ Service\ Time}{\#\ of\ Units\ x\ Total\ Operating\ Time} = \frac{(41\ x\ \#\ of\ hours\ in\ Month - Total\ Out\ Of\ Service\ Time\ (hrs)}{41\ x\ \#\ of\ hours\ in\ Month}$$

$$SA_{High\ speeds} = \frac{Total\ Operating\ Time - Total\ Out\ Of\ Service\ Time}{Total\ Operating\ Time} = \frac{(18\ hrs\ x\ \#\ of\ days\ in\ month - Total\ Out\ Of\ Service\ Time\ during\ 0500{-}2300\ (hrs)}{18\ hrs\ x\ \#\ of\ days\ in\ month}$$

Baggage

$$SA_{Baggage} = \frac{Total\ Operational\ Hours - Total\ time\ of\ all\ Operational\ Impact\ Events}{Total\ Operational\ Hours}$$

Source: GTAA

Figure 8-11. Performance metrics calculations equations.

Total Cost of Ownership

GTAA implements TCO in its procurement processes. TCO has been in place since 1999/2000 and is mainly used for key large assets that move people such as elevators, escalators, automatic people movers, transportation systems, and baggage handling systems.

The development of the TCO process was across the airport organizational business units. The business units, including executive management, finance, planning, engineering, facilities, and IT. The executive management team was the main driver for TCO and provided the needed support to make it happen. During the initial TCO implementation phase, some barriers were from operations; however, through communication and joint collaboration, these issues were overcome.

TCO currently resides in facilities, engineering, and IT; however, every business unit has a seat at the table and cross collaborates with one another. This cross-collaboration ensures the sharing of challenges and opportunities across functions and inspires innovation. Through collaboration, barriers are removed and the success of the TCO implementation airport-wide is assured.

One of the procurement challenges that faced the airport before implementing TCO was knowing the market and the services provided by the vendors and the quality of the services they provide. Therefore, TCO was a good approach to deal with these challenges. Specifically, the benefit of TCO as a procurement model is that it puts the vendors on the hot seat for reliability and operating the assets for a period of time along with performance guarantees. In addition, it makes sure the vendors understand the project, deliverables, and that they follow the testing, commissioning, acceptance, and turnover (TCAT) process.

The criteria used in the TCO model are the following:

- Robust nature of the equipment being selected (experience with that equipment)
- Drive reliability
- Cost of maintenance over time
- Initial purchase price
- Maintenance and replacement activities

- The TCO results are used to:
  - Select vendors
  - Evaluate vendors and their provided services
  - Evaluate the assets
  - Financial analysis (cost/benefit)
  - Develop business case

According to GTAA, the difficulties of TCO is knowing the market; for example, knowing if the vendor has a service arm or not and their experience in the Canadian market.

The TCO has been successful and very valuable at GTAA; one example is in the area of escalator procurement. The vendor through the TCO process was accountable to deliver on promises, which reduced the risk on the airport. Additionally, through the TCO process, the relationship between the airport and the vendor personnel has become stronger at multiple levels within both organizations. This makes operating and maintaining the system easier and more efficient.

Procurement

The finance business unit is leading the procurement process at GTAA. The airport procurement function process is mainly structured according to the following:

- Functional manager develops the scope
- Scope gets reviewed and posted by the finance procurement team
- Procurement team manages the process and makes sure everything is documented properly and communicated clearly between internal and external teams

The procurement methods that are implemented at GTAA depend on the product and service. For example, if an important service is being procured with a high value, then the procurement process vendor evaluation follows the following process:

- 50 percent for price
- 50 percent scope details and services provided
  - Like work
  - Experience
  - Bid quality
- Safety structure

The procurement evaluation team consists of the functional manager, supervisors, procurement representative, operations, and an outside entity. Each person ranks the submission independently and the team meets and decides. The recommendation goes to senior management for approval and execution.

The airport industry is a very tight market in procurement and faces many challenges to have a robust procurement process, including:

- Vendor diversity
- Highly qualified vendors

GTAA uses TCO in its procurement processes especially large assets such as elevators and escalators.

One procurement example at GTAA, is when TCO helped modify the future procurement approaches of large systems. The airport, as part of the procurement package, wanted the vendor to install, operate and maintain the asset. There was a 7-year O&M agreement attached to the service agreement. The vendor that was chosen did not have a service arm as part of its operations. After the system was installed, many operational and maintenance challenges occurred for airport personnel and the vendor because the lack of experience and not having that service capability within their organization.

This made GTAA revisit its procurement approaches within TCO. This event triggered the procurement team members to pay a closer attention to the submittals from vendors and expand their knowledge about the market and the capabilities of the different vendors.

The procurement business unit has specific and quantifiable written cost objectives, such as:

- Improvement and continual growth
- Obtain value for the money
- Mitigate and reduce risk

- Maintain a good supply chain
- Improve vendors lead times

The above objectives are mainly at the procurement functional level. However, the specifications are the ones that manage the service level. These objectives are evaluated mainly according to the asset that is being procured, whether it meets the specifications and the cost or not.

An excerpt of a recent tender (bid) package for a maintenance and repair services of elevators, escalators, and moving walks is presented in Appendix A1.

O&M Ready at Toronto Pearson International Airport

GTAA has a process in place to include the different business units in the planning, design, commissioning, and O&M of the assets. The forms of interaction include but not limited to plans review, specification development, provide as-built drawings, and asset details. During the commissioning phase, a team from different business units get together to get on the same page.

GTAA has a robust process and standard in place called TCAT (Appendix A2). Additionally, the airport has a business case evaluation process in place that facilitates project-related communication between these business units. With these different processes in place, silos can be broken down and more communication happens.

Some of the biggest gaps in the turn over process of assets at GTAA that need more attention from the contractor's side, where they should provide the following documents:

- Complete set of as-built drawings
- Warranties
- Special tools
- Specifications

Currently, as part of the procurement process at GTAA, the project manager and procurement are making sure contractors understand and acknowledge that this information is part of the deliverable during the procurement and commissioning process of assets.

Phoenix Sky Harbor International

The City of Phoenix owns and operates the Phoenix Airport System, which includes, in addition to PHX, airports at Deer Valley, Phoenix-Mesa, and Goodyear.

PHX is dubbed "America's friendliest airport" and is the main airport for the Greater Phoenix area. PHX serves more than 100 domestic and international destinations and is Arizona's largest and busiest airport. In 2015, PHX served 44 million passengers, making it one of the 10 busiest airports in the US by passenger count. PHX is a hub for American Airlines and is a focus city for Southwest Airlines.

With 1,200 daily flights—about 500 of them nonstop—PHX is one of the most convenient airports in the US, with 17 competitively priced carriers serving PHX. The airport is located in the middle of Greater Phoenix, less than 10 minutes from downtown.

The airport provides a free electric people mover from downtown to the airport. Commissioned in 2013, the PHX Sky Train is an automated train to transport Valley Metro Light Rail passengers from the 44th Street/Washington Street light rail station.

PHX employs 800 full-time equivalent employees, with about one-half of these in the Facilities and Services Department. A total of 14,000 employees work for the City of Phoenix. The airport is managed as a department of the City. The current aviation director manages the Aviation Department. Three assistant aviation directors report to the aviation director; each is responsible for a set of business units. In addition, the assistant chief counsel, the corporate strategic business planner, and the human resources supervisor report directly to the director.

Each of the three assistant aviation directors has a stake in the asset management process at PHX. One assistant manages Technology and Planning Environmental & Community Noise Reduction Program, both of which are involved currently in the asset management program. Likewise, the other assistant manages Facilities & Services, one of the largest stakeholders in the asset management program. The third assistant has Operations, Design & Construction, and Financial Management, all with large stakes in asset management.

Synopsis

The FAA classifies PHX as an international, large hub airport. The airport is operating mature systems, applications, and products (SAP) system that is widely accepted and used by diverse stakeholder groups. The functional use of the system has expanded to include some asset management functionality. The system is used to manage a wide list of assets, including:

- Energy management systems
- Specialized hardware and security cameras
- Automated Critical Asset Management System (ACAMS)
- IT equipment
- Part 139 assets
- Common use equipment, buses and fleets, generators, elevators, escalators, and moving walkways
- Inventory
- Jet bridges
- HVAC
- Gates and wedge barriers
- Airfield lighting (lighting vault, control system, sensors and accessories, conduits, cabling, and light fixtures),
- 400-Hertz ground power
- Roofing and flooring
- Fire systems
- Central plant
- Air handling equipment
- People mover equipment and other equipment associated with aircraft parking, ramp area, roadways, runways, taxiways, bridges, people mover vehicles, shuttles, drainage, fuel infrastructure, lighting,

tanks, baggage, HVAC, plumbing, elevated bridges, parking garage/lots, passenger terminals, passenger loading bridges, administration buildings, maintenance facilities, pump stations, wastewater treatment facilities, and signage

While SAP provides a warehouse for a great deal of data for thousands of the airport's assets, it does not provide much of the functionality that the airport would like to have to manage its assets proactively.

SAP at PHX

History

PHX began using SAP under a citywide mandate to facilitate integration with financial systems. Originally developed as an organization-wide database for multiple applications, i.e., financial, assets, operations, procurement, inventory, administration, and human resources applications, SAP was first used centrally at the City of Phoenix in the early 1990s. It was subsequently rolled out to the City's different business units. The Airport Department began using SAP in the mid-1990s.

The SAP system is data rich, with 20 years' worth of data. The collection of asset data began early in the implementation. The collection of condition data has been ongoing since the mid-2000s under a contract with Faithful and Gould, with the rental car facility project. The database currently holds many thousands of asset records.

Usage

PHX uses SAP to generate and track work orders, schedule proactive and preventive maintenance, track maintenance history, and monitor asset condition. Other applications, discussed in the following section, are used to track FAA Part 139 discrepancies and maintenance history, and provide safety management entries and workflow for maintenance.

Business process and work flow for asset decision making and maintenance are not generally implemented in SAP, although some business units do store maintenance plans in the integrated document management system.

Maintenance supervisors use an 80/20 rule in prioritizing their maintenance activities. The maintenance supervisors conduct scheduling and planning of maintenance activities and produce work orders from the SAP system. Maintenance cost tracking is also conducted through SAP.

Data in SAP is tied to the GIS. The asset database connects these different assets based on their location. (This is one of the challenges PHX has in their asset management program, where they cannot roll the assets from a child to parent [system of assets). The various asset elements (children) have a quick response code. This code links the assets' metadata to that specific asset or element.

PHX has in its asset database in excess of 18,000 data lines. (These data are static and are not updated in real time.) The collected data are checked for quality assurance and quality control in house prior to entering and updating the SAP system. Additionally, whenever the GIS data are updated, these updates automatically get reflected in SAP. In addition to SAP, the airport uses web-hosted fleet asset management software, FASTER Asset Solutions.

Related Software

The Facilities and Systems Department energy business unit manages the airport's specialized hardware, and implemented Honeywell's Organization Buildings Integrator (EBI) building automation software to

manage it. Those specialized systems include closed-circuit television, fire alarm, automation, security systems, and variable frequency drives. EBI provides an integrated platform for these systems, and PHX uses the following modules:

- Digital video manager to improve operational efficiencies and performance
- Energy manager to monitor, validate and optimize energy usage
- Life safety manager to monitor and control fire alarm systems
- Security manager to integrate information from security, access control systems and surveillance devices

The cost of managing and updating EBI is high and requires more resources than are available to the airport. Because of this, only specific functionalities of EBI are in use and updated. There is an effort to integrate EBI with SAP, but that status is not known.

PHX uses the document management module within Primavera Unifier Capital Management System to manage asset documents such as budget, specifications, and requests for information. Unifier is integrated with SAP. Commissioning documents provided by vendors (e.g., asset manuals, lists of critical assets, maintenance schedules, etc.) are also stored in Unifer and linked to the assets stored in SAP.

PHX developed an in-house mobile work order application for SAP that is called FieldPort. The Part 139 tracking entries are not tied directly to work orders in SAP. There is reporting capability for FAA compliance within the FieldPort application.

One of PHX's plans is to implement a Predictive Maintenance Program by installing a command wall from that will provide the users with real time condition of the assets.

Additional Needs

While SAP holds many years of data for many of the airport's assets, it is not an asset management system nor a maintenance management system. It lacks some basic functionality that would make it a better tool for the airport. Assets in SAP are not in a hierarchical catalog by system, nor are they geo-located, although a location description is given for each asset. Generally, workflow is not included for processes, and metadata is not standardized for each asset. Naming conventions (General Ledger codes) are loosely standardized, with some departments using more stringent standards than others do.

It is widely perceived that SAP is not user friendly. It was intended that SAP would provide cost data to allow managers to make decisions. The perception that SAP data are not reliable prevents its use for that purpose. That perception may stem from SAP's user-unfriendliness instead of actual data unreliability.

PHX does not have a formal, accredited management process in asset management such as ISO 55000 (Asset Management Standards), ISO 9000 (Quality Management Standards), and ISO 14000 (Environmental Management Standards). However, there are plans to adopt and implement these accredited management processes, especially ISO 55000, in the near future.

Procurement

PHX is financially independent from the city, as the airport-generated revenue is used for its capital and operational budgets. Airport-generated funds must be consumed by the airport and cannot be used outside the airport system.

However, the City largely governs procurement. The independent procurement authority at the airport is typically $5,000, depending on the department and contract. Purchases above the designated authority require City Board approval.

The City Finance Department handles the aviation division's procurements and accounts payable. For those procurements, the airport works with Finance to develop a request for proposals (RFP) for citywide procurements. There are some airport-specific procurements, however, that are handled entirely within the airport division.

PHX implements various procurement methods including low bid, request for qualifications/RFP, approved vendor lists, and on-call contracts. It is possible for the airport to purchase from vendors outside the provided list based on quality, specifications, requirements, or other factors.

The airport has published guidelines for purchasing. Those are available online.

eProcurement

The City has recently implemented a new procurement system, eProcurement. The eProcurement system is used across the airport and was implemented to facilitate and improve purchasing citywide. With the new system, the procurement process has changed so buying is done primarily at the City.

The procurement process starts with entry by airport staff into SharePort to request a purchase. After purchase approvals, Aviation Supply enters the request into eProcurement. If the procurement is over $5,000, the request goes to a City buyer; aviation staff purchases procurements under $5,000. Within the eProcurement system, the airport has less control over procurements. The approval process has less checks on payments to vendors.

All procurements for warehouse supplies (inventory) are done in the eProcurement system. That system is integrated with SAP. A module in SAP, Inventory Manager, automates replacement of inventory. Inventory Manager tracks movement of supplies. When movement of a particular item slows down, the Inventory Manager orders fewer of that item (i.e., there is a lower minimum number on hand).

Capital Projects

Projects are chosen for funding by a committee of airport deputies. This committee meets to prioritize projects 6 months out. The mandates for prioritization are typically safety, security, and failures. A business case is drafted to determine the costs, scope, and schedule for project.

Within the airport, a panel reviews bids received from procurement requests. That panel has the flexibility to determine procurement criteria used to select the successful bid based on specific project needs. After selection, the City Streets Department handles contracts for the airport.

A section within the Financial Management Division analyzes all capital assets. When a project is 90 percent complete, assets are capitalized. To help in tracking capital costs, the airport uses a capital management system called Primavera Unifier. Within that system, the most common source of error is estimated costs.

Total Cost of Ownership

PHX has data, tools, resources, and personnel that will allow them to have a successful implementation of a TCO system throughout the entire airport; however, TCO is not fully adopted at PHX. Nevertheless, there are pockets of excellence within the airport that utilize parts of TCO. Currently, the main challenges towards implementing a full TCO system throughout PHX, are the following:

- Silo processing of data
- Lack of a good hierarchy in the asset catalog within SAP

PHX decided to go down the path of TCO in procurement because data are available and the airport will be able to manage and operate the assets more efficiently and reduce the cost of ownership. This better procurement will translate is saving future O&M funds and direct these saving to other capital projects.

Additionally, in order to achieve a comprehensive procurement process, various stakeholders within the different levels of the organization provide input and report back to senior management, business unit heads, facility management teams, etc.

Through its data rich system, PHX has the ability to search and allocate various data throughout the assets' life cycle. PHX implements a form of TCO approach in its procurement processes. However, in the next strategic plan TCO will become an official initiative, with resources assigned.

The airport tracks KPIs and performance, weekly, monthly and annually. Implementing performance measures allows the airport to focus on results, not the activities required to achieve them. While performance measures are not a complete picture for success, they do serve to change processes that are stuck in old and nonproductive ways, if the right measures are chosen.

Hartsfield-Jackson Atlanta International

Hartsfield-Jackson Atlanta International Airport (ATL) is the world's busiest and most efficient airport, serving an average of 275,000 passengers and handling 2,500 aircraft arrivals and departures on a daily basis. ATL is also a major U.S. hub for domestic and international travel, offering service to more than 150 U.S. destinations and nearly 70 international destinations in more than 45 countries. And with more than 63,000 employees on campus, the Airport is the largest employer in Georgia.

In 2015, ATL became the first airport in the world to host more than 100 million passengers in a single year, and this year it is on track to top 105 million guests. As a result of this continuous growth, ATL could face challenges related to facility conditions, aging infrastructure and capacity requirements. Increased usage also boosts the demand on maintenance and facilities services.

Fortunately, ATL is continuously improving its facilities and operations to keep pace with the demand and quality of services provided to its passengers. Recently, ATL completed a 2030 Master Plan. The plan includes development, upgrades and additions to the airfield, terminals, gates, landside, cargo and support facilities.

A Sustainable Management Plan (SMP) was also developed to accompany the Master Plan and will be integral in both the short- and long-term projects at the Airport. Both plans will have a direct impact on asset management and procurement processes.

Total Cost of Ownership Module

The Total Cost of Ownership (TCO) is a more recent buzzword, and it means different things to different people, organizations and industries. At ATL, TCO has been defined by the Asset Management business unit as the annual cost to maintain an asset for the intended life of that asset per square foot. The annual cost includes various life cycle expenditures, including utilities, operating and maintenance, capital projects, rent, and most recently insurance associated with Airport assets.

The TCO module is also used for renewal and replacement scenarios to allow asset managers, planners and senior leadership to visually see the impact of "doing nothing" versus implementing an improvement. This scenario-based analysis provides an outlook of the cost impact over a specified period of time, and it even demonstrates the return on investment after implementation.

The inception of TCO at ATL began by increasing its overall awareness, including its features and benefits. Although the City of Atlanta has a policy that considers the life cycle analysis of products and services in development, manufacturing, use and disposal at the end of product life, TCO was not fully implemented throughout the Airport.

The adoption of TCO was conducted through the Department of Aviation's Asset Management business unit. Upon approval, senior leaders wanted the Airport planning process to include the TCO perspective to make better financial capital decisions. Thus began an initiative Airport-wide. Frequent meetings were conducted to explain its importance. As a result, various Airport division representatives came to understand that successful TCO implementation relies upon cross-departmental information, especially in ensuring accuracy of input and output information.

The Asset Management business unit, through its continuous TCO messaging and coordinating cross-Airport efforts, is currently developing a communication plan to promote efficiency and sustainability in the areas of procurement, design, operations, maintenance and decommissioning.

The associated costs for each asset reside in different databases throughout the organization. They include the following:

- Utility costs for the Airport's assets in the City of Atlanta's Utility Management System (UMS);
- Maintenance costs for the Airport's assets in Maximo, a software program used for managing ATL work orders and capturing material and labor costs;
- Life cycle replacement costs hosted in a database by VFA, an asset management software that models data later verified by the organization for accuracy;
- Capital cost data maintained within Enterprise Project Management System (EPMS), which captures all project-related information. With the necessity to begin capturing these costs, EPMS was deployed with a specialized module for TCO. ATL now has the line-of-sight to life cycle costs associated with many of the assets within the ATL portfolio.

ATL considers TCO to be a supplemental resource that allows all business units to have a synonymous view of the actual costs of owning assets. This form of information-sharing will help determine costs beyond procurement and construction, assist in better decision-making, and forecast estimated costs for major renewal and replacement initiatives.

Sustainable Procurement Policy

ATL is also working closely with the City of Atlanta to develop a Sustainable Procurement Policy. Through this policy, the City and Airport seek to become a model for sustainability for its customers, suppliers, employees and the community at large.

The purpose of this policy is to encourage the use of recycled and environmentally preferable products and services whenever practical, provided the products perform satisfactorily and are available at a reasonably competitive price. This policy encourages the use and reuse of recycled or recyclable supplies and materials as a City goal to minimize environmental impacts related to City practices and operations and divert items from landfills.

Within ATL, the policy will be communicated from a "top-down" delivery from senior management and carried out by decision makers within each department. The policy is expected to be directly communicated to vendors through contracting requirements.

The main objectives of the green procurement policy are to:

- Identify materials for which a life cycle approach can be applied before procurement
- Develop comprehensive green procurement guidelines for all Department of Aviation divisions
- Develop a comprehensive listing of environmentally friendly products available locally and regionally that are comparable to conventional materials currently procured, and that are economically feasible and suitable for ATL
- Develop a listing of suppliers and vendors that provide local/regional, environmentally friendly products
- Make recommendations to update the procurement system to encourage bidders to include environmentally sustainable products in all bids, such as requirement for specific percentage of environmentally friendly products
- Establish protocols for supply chain sustainability validation surveys and audits

Sustainable Construction Manual

Next, the Airport's new $6 billion capital improvement program, consists of new construction as well as renovations and repairs to existing buildings. Although there have been project-specific sustainable construction requirements on some projects such as the pavement recycling program, a comprehensive manual that outlines sustainable construction requirements for all projects is being developed. The Sustainable Construction Manual will establish guidelines for all construction work conducted at ATL.

The Sustainable Construction Manual will include research on Leadership in Energy and Environmental Design (LEED) green building standards as well as other recognized sustainable building industry standards and guidelines used by other airports. Researching sustainable construction practices, costs to implement these practices and the savings realized will provide a basis for the guidelines presented in the manual.

From a procurement standpoint, building with viable products will allow more sustainable ways to decompose or reuse building material at the end of its useful life. The Sustainable Construction Manual will allow for disposal costs to be calculated in the TCO in advance of procurement.

Through the implementation of TCO, adoption of a Sustainable Procurement Policy and having a Sustainable Construction Manual in place, ATL can review the entire life cycle and its impact to the Airport's triple bottom line. Aligning these policies and procedures encourages ATL to make conscious decisions on sustainably maintaining its infrastructure and realizing its impact on surrounding communities.

Non-Airports

Two non-airport organizations are included in this case study: Network Rail; and Kone. The findings with Network Rail are relevant in that the railroad company functions much as an airport in terms of passengers and facilities, and has also had extensive experience in implementing TCO. It is one of the pioneers in asset management and TCO worldwide.

As one of the preferred suppliers for installing and maintaining people moving systems, KONE provides dedicated, on-site, call-out and maintenance teams 24-hours-a-day, 365 days a year at airports worldwide. Its practices are highlighted in the included case study.

Network Rail

NR in the UK is the owner, operator, and infrastructure manager for the railway network in England, Scotland, and Wales. NR maintains and develops the physical infrastructure of the rail network. Additionally, NR ensures the efficient management of the assets on short, medium, and long term, while taking into consideration the future expansions and development throughout its service areas.

As the owner of the rail infrastructure, NR provides the operating companies access to the rail network. It is funded through a mixture of access revenue, paid to it by train operating companies and through government grants. It is licensed under the British Department of Transport.

The main responsibilities of NR are:

- Operating the network
- Managing performance
- Directing service recovery
- Setting timetables
- Allocating capacity
- Leading industry planning
- Maintaining, renewing, and developing the network

NR has a diverse set of assets. These assets include 20,000 miles of track, 40,000 bridges and tunnels, 2,500 railway stations (only manages 19 of them, other stations are managed by other operating companies). In addition to the signals, wires, and level crossings. NR also employs around 35,000 employees.

Over the past 20 years, the passenger numbers have doubled. It is estimated that around 4.5 million passengers use NR daily. There are around 1.7 billion passenger journeys taken on the railway every year. Currently, NR is investing more than 25 billion British pounds (36 billion $US) to grow and expand its infrastructure between 2014 and 2019. However, through these global financial challenges, NR is working on maintaining the value for money in their decision making process.

Asset Management

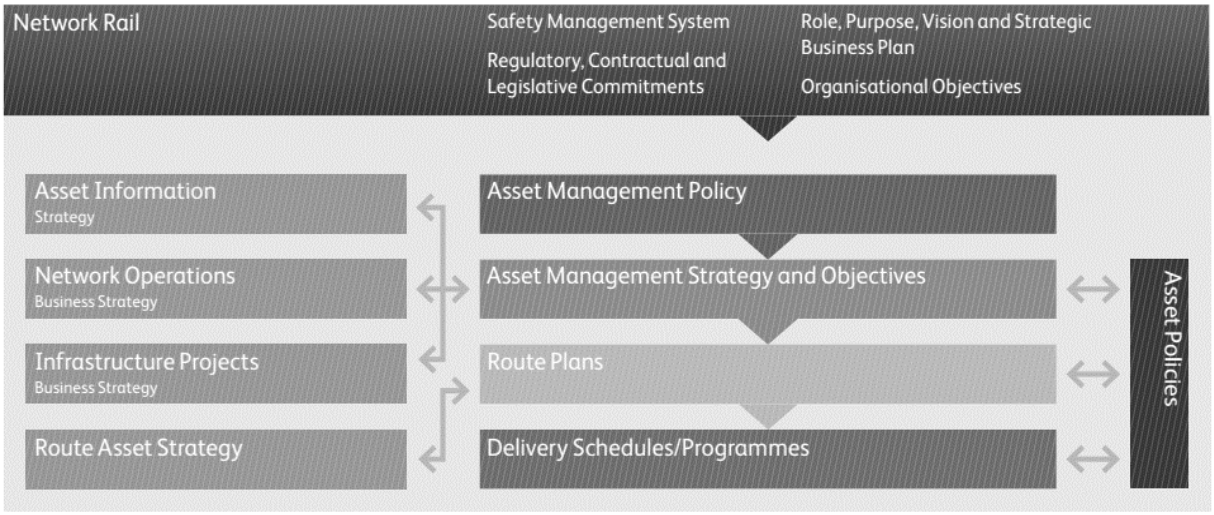
NR is one of the most progressive organizations when it comes to asset management throughout the world. It implements PAS 55 UK asset management standards (equivalent to ISO 55000) throughout its planning, engineering, projects, and operating routes functions.

NR's main asset management message to its stakeholders that it "supports the delivery of the promise by planning, delivering, and making available an infrastructure that supports the current and future timetable safety, efficiently and sustainably." NR has an asset management policy that describes the overall approach for a sustainable asset management.

Additionally, NR has an asset management strategy that serves two purposes: identify the high level objectives and targets for the infrastructure, and roadmap to improve on NR following link http://www.networkrail.co.uk/aspx/12210.aspx.

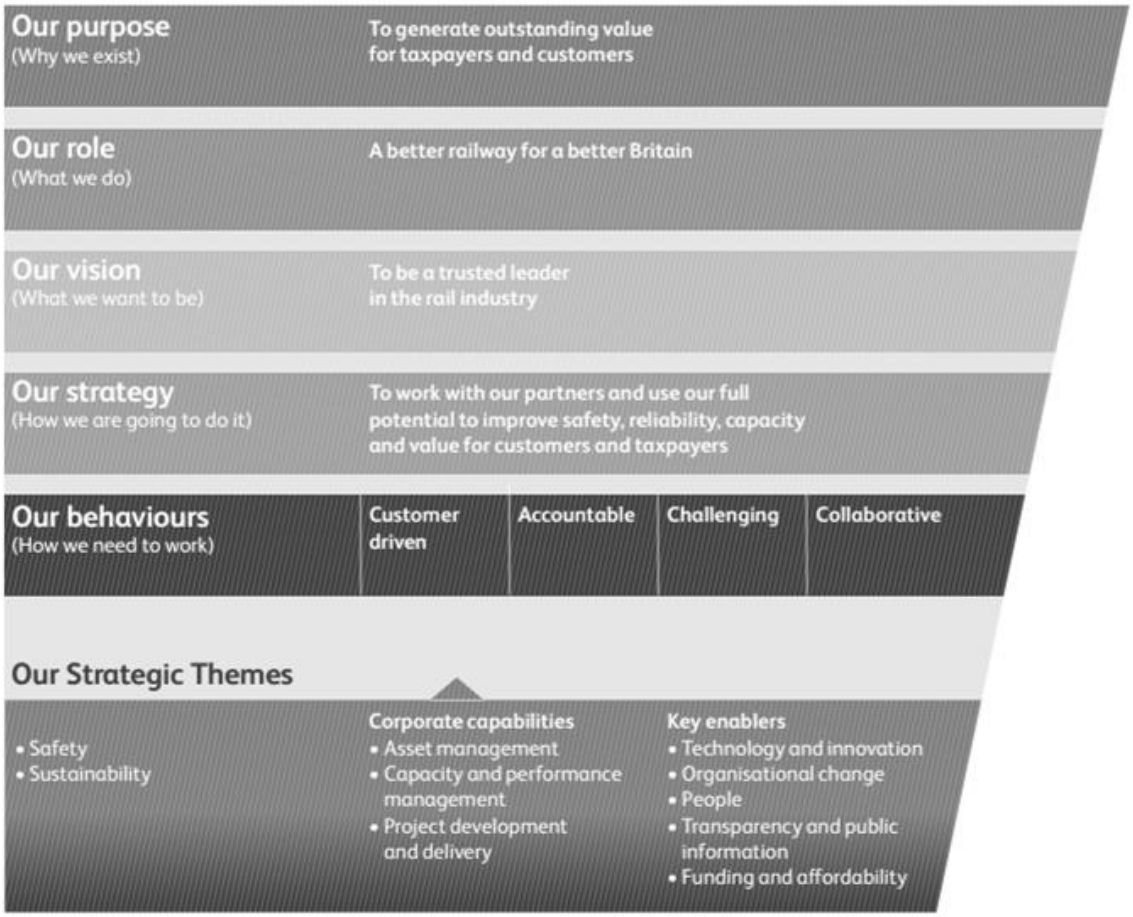
NR's asset management strategy, objectives, and the relationship with other key documents in the asset management system and key overarching documents are illustrated in Figure 8-12. The purpose, vision, strategy, themes and strategic behaviors are presented in Figure 8-13.

Even though NR has an established and robust asset management program, it is continuously working on integrating the business functions such that they work towards a common goal. One of the main challenges NR envisions is the consistency and depth of implementation across a functionality and geographic diverse organization.



Source: Network Rail

Figure 8-12. Asset management strategy and objectives, and the relationship with other key and overarching documents in Network Rail's asset management system



Source: Network Rail

Figure 8-13. Network Rail's purpose, role, vision, strategy, and strategic themes

Computerized Maintenance Management System (CMMS)

NR has implemented CMMS for more than 10 years. It has in place more than one CMMS system. For example, there is one for the operational assets (trains) and another one for the properties (stations). The system that NR has in place is named "ELLIPSE". ELLIPSE is managed through both NR and third parties.

NR uses multiple separate asset data systems. However, there is an initiative underway to integrate the asset information known as Asset Data Store with the GIS/Logical Model known as Railway Infrastructure Network Model.

Most of the inventory data from the assets is entered manually in the data management system. The condition data is mostly uploaded in real time from equipment such as handheld devices or from measurement trains.

NR implements a Whole Life Cycle Costing (WLC) approach in managing its assets. WLC refers to TCO over the asset's life cycle. It uses WLC in managing capital and operational expenditures of the assets. At NR, the CMMS is used to track costs such labor, plant, material, etc. However, the system is not used to charge back costs to other functions within the organization.

WLC

NR utilizes WLC in procuring all major railway infrastructure assets. The following list provides some of the breadth of decisions that are currently, or could be in the future, supported by WLC.

- Selection of assets for installation on new or existing infrastructure
- Comparison of product designs, new technologies
- Assessment of suppliers, warranties
- Timing of renewal versus continued maintenance
- Alternative renewal options; e.g., conventional renewal, refurbishment, upgrade
- Costs and benefits of remote monitoring
- Optimization of inspection/maintenance regime
- Make or buy; e.g., design, maintenance
- Comparison of timetable changes
- Impact of vehicle characteristics on infrastructure; e.g., bogie stiffness
- Application of operational restrictions (gauge, RA, line speed, etc.)
- Selection of access regime; e.g., blockade
- Determination of inventory levels for spares holdings
- Capacity/capability improvements in enhancement schemes
- Optimization of local decisions on specific assets; e.g., timing/type of next intervention
- Improvements in weather resilience/climate change adaptation
- Prioritization of work linked to service provision; e.g., improvements in safety, punctuality, environmental performance, etc.

WLC is part of the proposals' submittals by vendors. The main objectives of WLC are to balance risks, costs, and performance over a minimum period of 35 years. An example of contract specific requirements for the design of key infrastructure is presented in Appendix B.

Before implementing WLC as part of NR procurement processes, the organization faced many challenges such as lack of information about the assets about their life costs and performance (including lack of framework for undertaking the asset and evaluating it). In order to overcome these challenges, senior management believed that implementing WLC would assist in informing the organization about the assets financial performance throughout its life cycle. Additionally, regulators in the UK started requesting/mandating it as part of the reporting and analysis.

WLC development included the different business units within NR such as financial, procurement, engineering, planning, O&M, and facilities management. The main initiators were the executive directors of planning, engineering, and finance. WLC is an independent business unit within NR. The Head of WLC is the owner of the overall approach and methods.

The introduction and implementation of WLC at NR was not an easy task throughout the organization. For example, the implementation in central functions was relatively straightforward. On the other hand, the

implementation in projects and maintenance was more difficult because of the number of teams and personnel involved, and the competencies required. Overall, the WLC principles have been widely accepted throughout NR and are rarely challenged. Furthermore, the implementation of WLC has resulted in consistency in decisions with strong evidence base.

The main success factors behind this effective implementation of WLC were the buy-in from the employees, ease of implementation, external stakeholders support, commitment to competency development, and mandating the WLC process. However, the most important factor for success was securing funding "internally and externally" (linking investment approvals to WLC).

WLC has been widely implemented across NR and it has positively affected the relationship between the different functions within NR. The main user of the WLC outputs is the procurement function. At the beginning of the implementation, the process was slower, however now it has caught up and got up to speed. In part, the procurement function had to modify requirements and update policies. One of the requirements that was impacted was the vendor/supplier requirements, and this change was based on the WLC data. NR used WLC to justify a shift from vendor conventional to partial renewal in some circumstances that delivered significant cost savings.

KONE - Mechanical People-Moving Systems Vendor

Founded in 1910, KONE is a manufacturer and worldwide supplier of elevators, escalators, passenger conveyors, auto doors, and turnstiles. KONE provides both maintenance and technical support for all of its products. The company provides innovative and eco-efficient solutions to its airport clients, under the core goal of enabling people to move safely, smoothly, comfortably, and without interruptions.

Experience with TCO

The procurement division at KONE is structured and aligned to respond to airport equipment supply and technical support needs. This alignment has been created through both structured communication and close proximity of KONE and airport personnel, as they work together to provide the expected level of service to stakeholders.

Airports and other clients KONE serves, especially in the UK, heavily consider life cycle costs and reliability of the assets as they are procured. Developing and using a life cycle-based equipment selection process has created collaborative relationship between airports and KONE, which has enabled airports to continually address their needs and levels of service. KONE has similarly collaborated with its other clients, such as the London Underground, to develop a TCO tool for their assets.

KONE has discovered that in order to have a successful implementation of TCO and provide expected value and desired outcomes to its airport clients, service contracts need to be long-term (10-20 years) and to include planned asset upgrade and replacement programs. The advantage of having these longer term service agreements is that they provide the ability to strategically plan for interventions, upgrades or replacements, prolonging the life and performance of the assets over a longer period of time. Historically, the investments in these areas has been slow and have not adequately addressed the growth, expansions, and types of services that the airports are currently experiencing.

TCO in Proposals

One of the challenges that KONE faces when responding to calls for proposals or qualifications is the life cycle expectations by the owner. For example, the London Underground runs a 40-year asset life expectation for its escalators. From the first day of providing service to this client, a vendor must consider

and plan for a five-year component upgrade/replacement intervention to meet expectations. Table 8-1 is an example of the life cycle strategy for escalators that London Underground uses.

KONE collects TCO data from assets it manages and uses it to calculate life cycle costs, and could use it to improve asset reliability and passenger experience. The collected data includes: planning and design, installation and commissioning, operation, maintenance, and disposal. This information, however, is not shared with the clients unless requested as part of the proposals. Although this currently-collected data is being fully utilized in work for the London Underground, it is not being fully leveraged in day-to-day operations and maintenance activities completed on behalf of airports.

Table 8-1. – Escalators life cycle

Asset Life Cycle	Impacted Asset Element
Installed - year 1	
Modification 1 - year 5	Handrails, tracking systems, clean.
Modification 2 – year 10	Handrails, tracking systems, clean, non-destructive testing inspections , motors and bearings
Modification 3 - year 15	Handrails, tracking systems, clean, non-destructive testing inspections , motors and bearings, Refurb Motor Gear Box , renew chains, controller upgrade.
Modification 1 – year 20	Handrails, tracking systems, clean.
Modification 2 - year 25	Handrails, tracking systems, clean, non-destructive testing inspections , motors and bearings
Modification 3 – year 30	Handrails, tracking systems, clean, non-destructive testing inspections , motors and bearings, Refurb Motor Gear Box , renew chains, controller upgrade.
Modification 1 – year 35	Handrails, tracking systems, clean.
Replaced - year 40	

Discussion

Case study subjects undertaken for this project were airports, a non-airport organization, and a vendor with a mature program in TCO/WLC.

- Toronto-Pearson International, Canada (YYZ)/Greater Toronto Airports Authority (GTAA)
- Phoenix Sky Harbor International Airport, US (PHX)
- Hartsfield-Jackson Atlanta International, US (ATL)
- Network Rail, UK (NR)
- KONE

The case studies were conducted over 1 or 2 days onsite at PHX and YYZ, and remotely with ATL, NR, and KONE. Asset management implementation practices within each organization were examined, as well as the benefits to the organization from the program. Also evaluated were the business objectives, technical and business problems and challenges, the solution that was implemented, and ways that the asset

management program benefited organizational efficiency, procurement practices and total cost of asset ownership.

The primary purposes of the case studies were to evaluate:

- Implementation process
- Lessons learned
- Best practices
- Benefits of the program
- Impact on decision-making
- Future plans

All of the airports in the studies are large hub airports. Attempts to engage small and medium airports in case studies failed. It is a conjecture of the research team that the research topic requires a more mature asset management program and that there are fewer small and medium airports with mature programs, thus more difficulty in finding study subjects. The compromise was to engage small and medium airports in validating the TCO Tool.

Although NR is a railway network in England, Scotland and Wales, and not an airport, the organization deals with passengers and journeys in a similar fashion. There are stations from which passengers embark, and those passengers journey through stations to final destinations. Statistics showing the number of flights/journeys and passengers annually are in Table 8-2.

Table 8-2. Annual Number of Flights/Journeys and Passengers

Organization	Toronto-Pearson International	Phoenix Sky Harbor International	Hartsfield-Jackson Atlanta International	Network Rail
Flights/Journeys (thousand)	400	438	912.5	1,700
Annual Passengers (millions)	41	44	91.25	16,425

The implementations of the asset management programs are mature in each instance, with the newest being about 10 years old and the oldest from the 1970s—nearly 40 years ago. That program is in GTAA, where the Canadian government developed a software internally for use at all its airports. When the airports were privatized, that software was turned over to the airports for their own further development. Because of the longevity of the program and the commitment of the airport to it, the GTAA program is used across the airport for business decisions, risk management, procurement, operational, executive and TCO decisions. It is integrated with many of the airport's other applications. The success of the program continues with a transition to a commercial off-the shelf software currently in implementation process. The program resides within facilities, engineering, and IT. However, all the business units collaborate with one another. A governance model for asset management ensures good decision-making and all-airport engagement.

PHX's success in capturing data for its assets airport-wide puts them in an excellent position to leverage a full-blown asset management system. The airport is using software mandated by the City of Phoenix, but

they do not have the full functionality of an asset management system with work flows and decision-making tools. The focus of executive leadership at the airport is pushing towards better decision-making tools for financial responsibility and implement a robust and reliable asset management program.

The program at ATL is continuously working on improving the facilities and operations to keep up with the increasing number of passengers. In order to keep up with this fast pace growth, the airport looked into adopting and implementing TCO to make better financial decisions. Additionally, to allow the business units to be on the same page in terms of the actual cost of owning the assets. ATL is linking the implementation of TCO with a green procurement policy and a green construction manual. The policy will assist in driving the incorporation of sustainability in the procured products and services. The manual will establish green construction guidelines for all work at ATL.

KONE as an international provider of mechanical people-moving systems has dealt with different types of clients and different types of procurement methods. Every client is different in their needs and their approaches towards procuring, operating and maintaining their assets. Considering life cycle and TCO improves the quality of services provided by the vendor and the services provided to the stakeholders. The reliability of the systems increases and the capital and operational budgets can be better managed.

Synthesis of Results

Every case study was unique in its TCO, procurement, and asset management journey. The participants had a common goal, which is striving to become more efficient and effective in managing their assets throughout their entire life cycle.

There are many lessons learned that can be gained from these case studies. The participants throughout their journey did not get things right from the first time. However, they are learning from their experiences and are introducing adjustments to their processes and technologies. This section will highlight these main findings.

Toronto Pearson International

- Toronto airport, like any other airport, has many challenges, especially financial. These challenges include; future budgetary allocation, competing capital priorities, and lack of highly trained technicians.
- KPIs were established and adopted by the leadership. These KPIs ensured alignment throughout the organization with a focus on performance goals.
- Toronto airport has a governance model that integrates both the land and the air sides. This model is divided into; asset management board and the maintenance improvement teams. The main goal for this model is to make sure that there is continuous communication between the different business units. Also this model gets people on board and drives efficiency in implementation.
- TCO has been in place since 1999/2000. It is mainly used for key large assets such as people moving systems, transportation systems, and baggage handling systems.
- The development of TCO was across the airport's business units. There were barriers during the initial implementation from operations; however, through communication and joint collaboration these issues were overcome.
- TCO currently resides in engineering, facilities, and IT. However, every business unit has a seat at the table and cross collaborates with one another. This collaboration gets everyone on board and allows everyone to understand the challenges that everyone is facing.
- One of the procurement challenges that faced the airport before implementing TCO was knowing the market and the services provided by the vendors in addition to the quality of these services.

- Toronto airport has a robust process and standard in place called TCAT (testing, commissioning, acceptance, and turnover). Also there is business case evaluation process in place that facilitates communication between the business units.
- The main benefit of TCO that it assures the quality of the services provided by the vendors. Additionally, it makes sure that the vendors understand the project, the deliverables, and that they follow the TCAT process.
- The procurement evaluation team consists of functional manager, supervisors, procurement representative, operations, and an outside entity. These evaluations are done independently and then the team meets and decides.
- The airport industry is a very tight market in procurement and faces many challenges to have a robust procurement process in terms of ; vendor diversity and highly qualified vendors.

Phoenix Sky Harbor

- Phoenix airport operates a mature systems, applications, and products (SAP) system that is widely accepted and used by diverse stakeholder groups. This system includes a wide range of assets such as; energy, security, IT, inventory, jet bridges, people moving systems and HVAC.
- While SAP provides a warehouse for a great deal of data for thousands of airport's assets, it does not provide much of the functionality that the airport would like to have to manage its assets proactively.
- The airport is financially independent from the city, as the airport-generated revenue is used for its capital and operational budgets.
- The City largely governs procurement. The independent procurement authority at the airport is typically $5,000, depending on the department and contract. Purchases above the designated authority require City Board approval.
- The airport implements various procurement methods including low bid, RFQ/RFP, approved vendor lists, and on-call contracts.
- The City has recently implemented a new procurement system, eProcurement. The eProcurement system is used across the airport and was implemented to facilitate and improve purchasing citywide.
- Projects are chosen for funding by a committee of airport deputies. This committee meets to prioritize projects 6 months out. The mandates for prioritization are typically safety, security, and failures.
- TCO is not fully adopted at PHX. Nevertheless, there are pockets of excellence within the airport that utilize parts of TCO.
- The airport decided to go down the path of TCO in procurement because data are available and the airport will be able to manage and operate the assets more efficiently and reduce the cost of ownership. This better procurement will translate is saving future O&M funds and direct these saving to other capital projects.

Hartsfield-Jackson Atlanta International

- Atlanta airport is facing many challenges such as the aging infrastructure along with the continuous growth in the number of passengers. The facilities condition and capacity is not growing at the same pace as the number of passengers, which impacts the services provided to the passengers and does not meet the levels of service set by the stakeholders.
- The TCO journey at the airport started with getting the airport's leadership on board through educating them about TCO and its benefits. Although, the City of Atlanta already has a policy in place that considers the life cycle analysis, it was not fully adopted at the airport.
- The adoption and implementation of TCO throughout the airport was 1 conducted through the Asset Management business unit.

- The airport considers TCO as a supplemental resource that allows all business units to have a synonymous view of actual costs of owning assets. Decision making will still be prioritized in a manner that benefits particular business units, in which competing priorities remain.
- The airport is developing a sustainable procurement policy. The purpose of this policy is to incorporate sustainability criteria into how and what products and services are procured.
- Through the implementation of TCO, adoption of a green procurement policy, and having a green construction manual in place, the airport can take into account the TCO and its impact to the airport's triple bottom line.

Network Rail

- Network Rail is one of the progressive organizations when it comes to asset management throughout the 30 world. It implements PAS 55 UK asset management standards (equivalent to ISO 55000) throughout its planning, engineering, projects, and operating routes functions.
- Even though NR has an established and robust asset management program, it is continuously working on integrating the business functions such that they work towards a common goal.
- Network Rail utilizes WLC in procuring all major railway infrastructure assets. Many decisions are based on WLC.
- Before implementing WLC as part of NR procurement processes, the organization faced many challenges such as; lack of information about the assets about their life costs and performance. To overcome these challenges, senior management believed that implementing WLC would assist in informing the organization about the assets financial performance throughout its life cycle. Additionally, regulators in the UK started requesting/mandating it as part of the reporting and analysis.
- WLC principles have been widely accepted throughout the organization are rarely challenged. Also decisions became consistent with strong evidence base.
- Network Rail used the WLC to justify shift from vendor conventional to partial renewal, which delivered significant cost savings.

KONE

- KONE utilizes TCO data in the procurement, operations, and management of its installed assets. It has developed a tool that would assist in achieving this.
- Long term agreements between airports and vendors are key for the success of implementing TCO and to achieve the expected value and outcomes from the assets.
- One of the key challenges for the vendors when providing TCO info during proposals is not knowing the clients' life cycle expectations
- KONE collects TCO data from its assets to produce comprehensive life cycle costs. This data would provide better asset reliability and passenger experience.
- TCO information provided by KONE complements the TCO implementation discussion provided by Toronto airport; such as having long duration contracts between the airport and the vendor.

CHAPTER 9

Total Cost of Ownership Tool

There are two components to the ACRP project "Considering Life Cycle Costs in Airport Asset Procurement." The first part is this Guidebook, and the second part is development of a systematic TCO approach to asset procurement (software tool) to improve decision-making and optimize the use of capital and operating funds. This chapter discusses the development, methodology, parameters, assets, operating system of the tool, as well as the accompanying user's manual including a video tutorial series.

Principles

The software tool requirements emerged from the compilation and syntheses of the industry leading practices that started with the literature review and further defined throughout the survey and airports' interviews. The team's TCO modeling experience, in addition to input from a focus group of airport staff, assisted in identifying a framework that leverages the collective knowledge of the industry in developing the TCO Tool. The framework for the tool focused on usability and applicability to airports of all sizes and needs.

The TCO Tool was developed to attain the following principles:

- Easily modified to accommodate any size airport; additional complexity can be introduced by increasing granularity.
- Applicability to the entire procurement process from project planning through decommissioning.
- Capability to inform yearly capital (repair and replacement) budgetary decisions.
- Ability to run "what if" scenarios regarding the timing of asset procurement and intermediate repair and replacement interventions.

The developed Excel-based TCO Tool can be customized to any set of airport-driven scale parameters, large, medium, or small.

Methodology

In developing the TCO Tool, a step-wise methodology was employed, as described in the following points.

- **Pre-Defined Assets**. The tool is populated with a list of 18 assets. The tool includes the common life cycle of each asset class starting with pre-procurement, procurement, operations, maintenance, and disposal. Each phase of the life cycle is divided into different parameters. These parameters are based on related activities within each element.

- **Inputs**. Inputs for the tool include the asset hierarchy of each primary asset down to Uniformat Tier 2 (parent and child) for each class. Inputs of the related values within each life cycle parameter for the asset elements. Additionally, there is input for the analysis period and the expected asset cycle. Each asset element life cycle is divided into capital and O&M to reflect the differences in the cycle (number of years) for each of them. The capital reflects the expected age of the element and the O&M reflects the annual or other periodic activities that are conducted on the asset. From the research effort it was found that input values are unique to each airport and so the tool allows for manual input of this information
- **Combined Dashboard**. The combined dashboard brings together all the primary asset classes into a single rolled up management tool. The dashboard would include; summaries by primary asset class, life cycle with and without smoothing, histograms that show the cost per life cycle phase, and sensitivity analysis.

The TCO Tool methodology data flow diagram is presented in Figure 9-1.

TCO Parameters

The life cycle of the assets is divided into five main phases:

- Pre-procurement
- Procurement
- Operations
- Maintenance
- Disposal

Table 9-1 breaks down the parameters related to each phase.

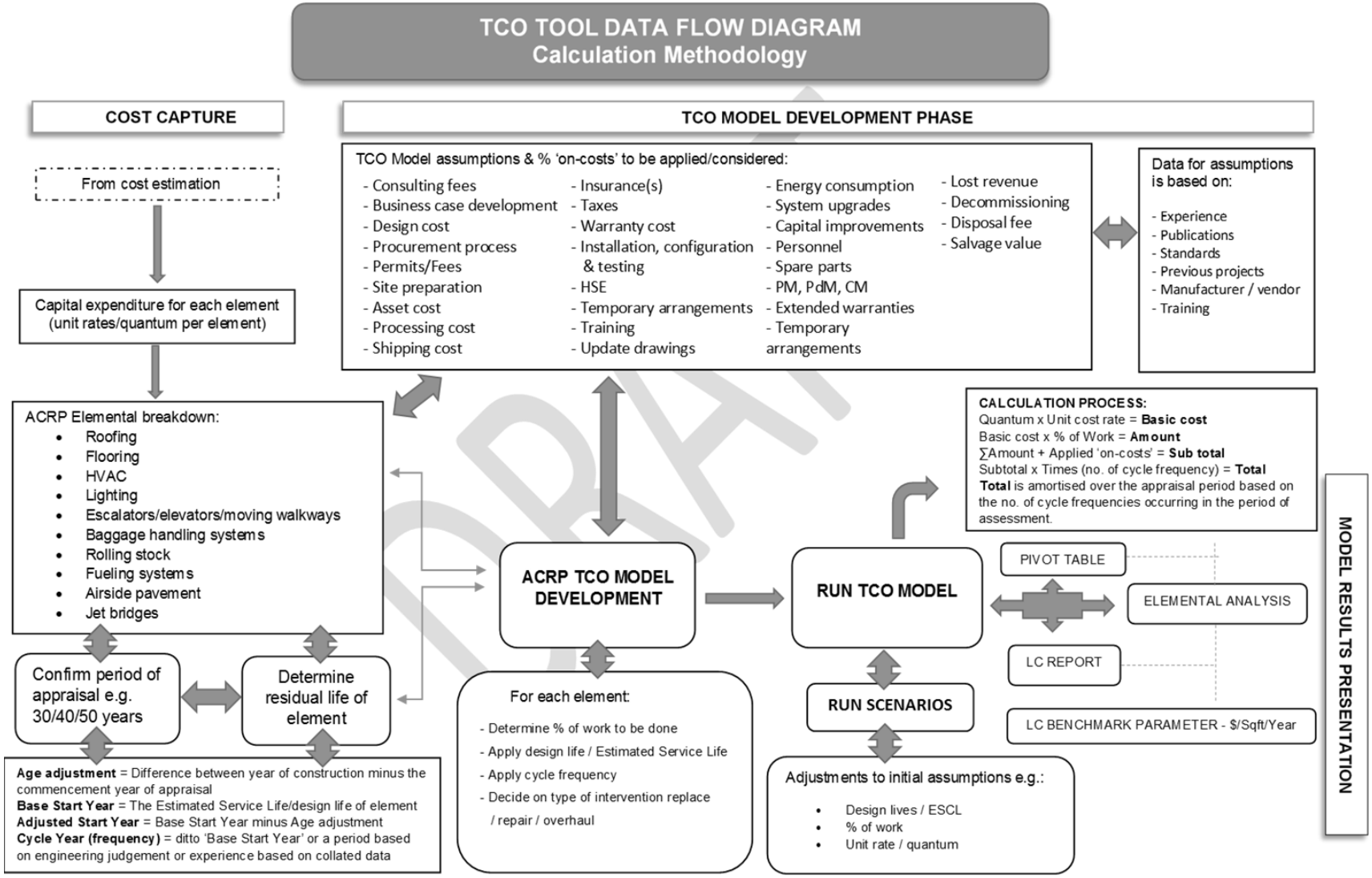


Figure 9-1. TCO Tool methodology data flow diagram

Table 9-1. TCO Tool Parameters

Parameter	
1	Pre-procurement
1.1	Consulting Fees
1.2	Business Case Development
1.3	Design Cost
1.4	Procurement Process/Documentation
1.5	Permits/Fees
2	Procurement
2.1	Site Preparation
2.2	Asset Cost (Equipment, Material, etc.)
2.3	Processing Cost
2.4	Shipping Cost
2.5	Insurance Cost (shipping)
2.6	Taxes
2.7	Warranty Cost
2.8	Installation, Configuration, and Testing
2.9	Health, Safety, Environment (HSE)
2.10	Temporary Arrangements (During Installation Activities)
2.11	Training & Professional Development
2.12	Annual Insurance (Equipment)
2.13	Disposal Fee of Old Equipment - if applicable
2.14	Salvage Value of Old Equipment - if applicable
2.15	Update in house Shop Drawings

Parameter	
3	Operation
3.1	Energy Consumption
3.2	System Upgrades (Software, hardware, firmware)
3.3	Capital Improvements (building enhancement costs)
3.4	Personnel (management/operator/engineer)
3.5	Health, Safety, Environment (HSE)
3.6	Training & Professional Development
3.7	Operational Impact
4	Maintenance
4.1	Personnel (management/operator/engineer)
4.2	Spare Parts
4.3	Health, Safety, Environment (HSE)
4.4	Training & Professional Development
4.5	Preventive Maintenance
4.6	Corrective Maintenance
4.7	Predictive Maintenance/Testing Equipment/Facilities
4.8	Extended Warranties
4.9	Temporary Arrangements (During Maintenance Activities)
4.10	Lost Revenue
5	Disposal
5.1	Decommissioning Cost
5.2	Shipping Cost
5.3	Disposal Fee of Old Equipment - if applicable
5.4	Salvage Value of Old Equipment - if applicable

TCO Assets

The list of assets in the tool include the following assets:

- Roofing

- Flooring (terrazzo, marble, carpet)
- HVAC
- Lighting
- Escalators
- Baggage handling system
- Rolling stock
- Fueling systems
- Airside pavement*
- Jet bridges
- Information technology (IT) systems
- Video management and storage systems
- Video storage systems
- Video surveillance systems
- Access control systems

Table 9-2 lists the considered (prepopulated in the tool) assets and their elements.

Table 9-2. List of Considered Assets and Their Elements

Asset Elements			Asset Elements	
1	**Roofing**		10.6	Electric carts
1.1	Roof structure		10.7	ARFF emergency response equipment
1.2	Roof material		10.8	Snow removal
1.3	Drainage system		10.9	Dump trucks (heavy equipment) sweepers, water trucks, bucket trucks, fuel trucks
1.4	Expansion joints		10.10	Tractors (off road/rubber removal)
1.5	Sealing material		11	Fueling Systems
2	**Flooring (Terrazzo)**		11.1	Transport pipelines
2.1	Base material		11.2	Vehicles
2.2	Terrazzo		11.3	Fuel storage tanks and trucks
2.3	Expansion joints		11.4	Filtration
2.4	Manage existing material (asbestos, lead, hazardous material)		11.5	Pumps
3	**Flooring (Marble)**		11.6	Dispensing equipment
3.1	Base material		**12**	**Jet Bridges**
3.2	Marble		12.1	Ground power (electric)
3.3	Expansion joints		12.2	Mechanical system (control system)

Table 9-2. List of Considered Assets and Their Elements

Asset Elements	
3.4	Manage existing material (asbestos, lead, hazardous material)
4	**Flooring (Carpet)**
4.1	Base material
4.2	Carpet
4.3	Expansion joints
4.4	Manage existing material (asbestos, lead, hazardous material)
5	**HVAC (At Terminal/Buildings)**
5.1	Control system
5.2	Furnace
5.3	Heat exchanger
5.4	Evaporator Coil
5.5	Condensing unit
5.6	Refrigerant lines (chill water distribution system)
5.7	Condensing water distribution system
5.8	Cooling tower
5.9	Chill water pumps
5.10	Evaporative coolers
5.11	Air handling equipment
6	**Lighting (At Terminal/Buildings)**
6.1	Control system (electric)
6.2	Conduits
6.3	Wiring/Cabling
6.4	Light fixtures
6.5	Sensors/Accessories
7	**Escalators/Moving Walkways**
7.1	Control system (electric)

Asset Elements	
12.3	Tunnel
12.4	Accessories
12.5	Potable water system
12.6	HVAC
13	**IT Systems**
13.1	Servers, workstations and displays
13.2	Network equipment (including switches and routers) and cabling
13.3	Mobile devices including tablets and mobile phones
13.4	Scanners and other devices
13.5	Storage devices (direct attached storage [DAS], network attached storage [NAS], and storage area network [SAN]
13.6	Software
13.7	Power backup and distribution systems
14	**Video Management& Storage Systems**
14.1	Mobile data terminals (handheld devices)
14.2	Emergency call stations
14.3	Servers, workstations and displays (including large displays for video walls)
14.4	Video management software
14.5	Network equipment (including switches and routers) and cabling for distributing video
15	**Video Storage System**
15.1	Video recorders
15.2	Video Storage (DAS, NAS, and SAN)
15.3	Video Storage Software
15.4	Servers, workstations and displays
15.5	Network equipment (including switches and routers) and cabling for distributing video
16	**Video Surveillance System**
16.1	Cameras

Table 9-2. List of Considered Assets and Their Elements

Asset Elements	
7.2	Mechanical system (motor, chain/pallets, guides/rollers)
7.3	Accessories (e.g. hand rails)
8	**Elevators**
8.1	Control system (electric)
8.2	Mechanical system
8.3	Passenger car
9	**Baggage Handling Systems**
9.1	Control system/Programmable logic controller
9.2	Mechanical system
9.3	Electrical system
9.4	Accessories
10	**Rolling Stock**
10.1	Light duty vehicles
10.2	Monorail
10.3	Baggage transport
10.4	Tug truck
10.5	Shuttles

Asset Elements	
16.2	Network equipment (including switches and routers) and cabling for distributing video, and/or legacy analog devices for distributing signal to analog cameras
17	**Access Control System**
17.1	Software
17.2	Servers, workstations, and displays
17.3	Network equipment (including switches and routers) and cabling for distributing signal, and/or legacy analog switches for distributing signal to legacy analog devices
17.4	Field equipment, including contacts, power supplies, controllers, readers, portal hardware, biometrics, offline readers, keypads, request to exit buttons, battery backups, locks, gates and turnstiles, etc.
18	**Airside Pavement**
18.1	Surface (asphalt/concrete)
18.2	Subsurface (base material)
18.3	Joint seals
18.4	Surface painting

The TCO Tool inputs are provided from across the organization, such as from Facilities and Infrastructure and Project Management. The asset data inputs include condition, age, and historical spending patterns of facilities for the ability of airport managers to make capital decisions such as repair, rehabilitate and/or replacement.

The TCO Tool will be able to:

- Develop and vet development alternatives
- Run different funding scenarios

- Estimate all-inclusive costs related to the assets' life cycle
- Estimate the impacts of variations of asset management strategies
- Estimate the amount of energy/utility consumed per component use

System Requirements

The TCO Tool is developed in Microsoft Excel 2013*. Excel is part of Office 2013 and Office 365 ProPlus. The standard system requirements to operate the tool (Excel 2013) are available on https://technet.microsoft.com/en-us/library/ee624351.aspx.

User's Manual

The TCO Tool user's manual is presented in Appendix C. Additionally, a video tutorial series is available with this tool. This series is divided into two main parts; general tool overview and a step by step example. In total there are five tutorial videos:

1. Introduction to the tool
2. Input information about the project, assets, and analysis assumptions
3. Input asset procurement information
4. Results
5. Example

CHAPTER 10

Procurement Best Practices Implementation

After deciding to adopt any new asset management program, methodology, or tool comes the implementation process. This chapter describes the means to ensure that an organizational initiative is successful and has sustainable benefits.

Introduction

Success in the implementation of best practices rests mostly on the organization having committed executives and leadership teams. The end goal from these initiatives, in addition to improving performance and productivity, is a timely ROI.

Unfortunately, whenever a new initiative is introduced within an organization, studies have shown that around 70 percent of these change initiatives fail to meet expectations. This is a very high percentage for initiatives to fail, taking into consideration its financial impacts on the organization as well as a potential impact on the employees in terms of moral and relationship with their leadership.

The leading root cause for these initiatives' failure is the lack of establishing an execution strategy from the leadership. This execution strategy is the main force behind launching a successful initiative. It is considered the roadmap that will assist every team member to successfully navigate the change effort to achieve the intended outcomes and expectations.

A recent execution strategy publication "Why Execution Fails and What to Do About It" (Fortin 2016) outlines a proven methodology for successful program implementation: DELTA FORCE. The methodology defines the strategy and execution process steps, as well as the critical success factors necessary to achieve desired results.

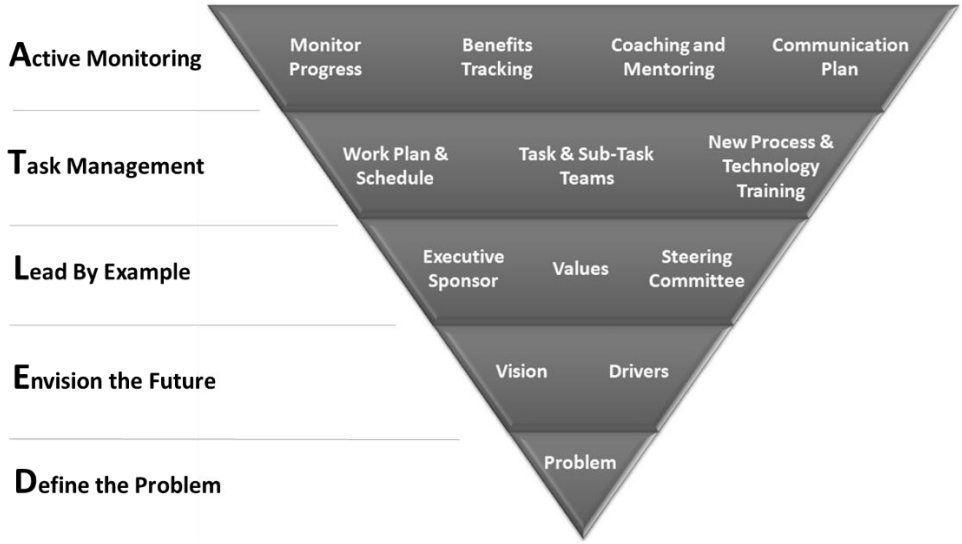
Execution Process Methodology

There are many execution process methodologies in the industry that could be employed to ensure a procurement best practices program will deliver value. The main focus of these methodologies is mainly to define "what" needs to be improved. Once the "what" is defined, usually the "how" to make the change stick and sustain it, is missing.

The DELTA FORCE attempts to fill this void by providing a framework for execution (Fortin 2016). These attempts are summarized below.

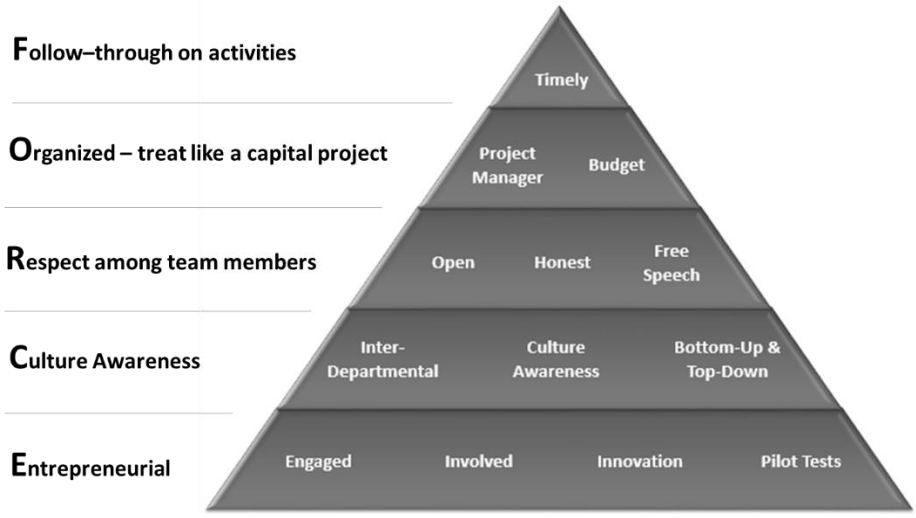
- DELTA – Strategic Execution Process
  - **D**efine the problem
  - **E**nvision the future
  - **L**ead by example
  - **T**ask management
  - **A**ctive Monitoring
- FORCE – Strategic Execution Imperatives
  - **F**ollow through – actions and activities
  - **O**rganized – Treat initiative as a Capital project
  - **R**espect among team members
  - **C**ulture awareness
  - **E**ntrepreneurial spirit encouraged

The DELTA is an effective execution strategy that can be utilized when leaders decide to shift from an existing condition to a one that is considered more efficient and effective. This process is presented in Figure 10-1. The FORCE should be used in conjunction with the DELTA to establish the critical success factors for the new project or program. These execution imperatives are presented in Figure 10-2.



Source: Why Execution Fails and What to Do About It

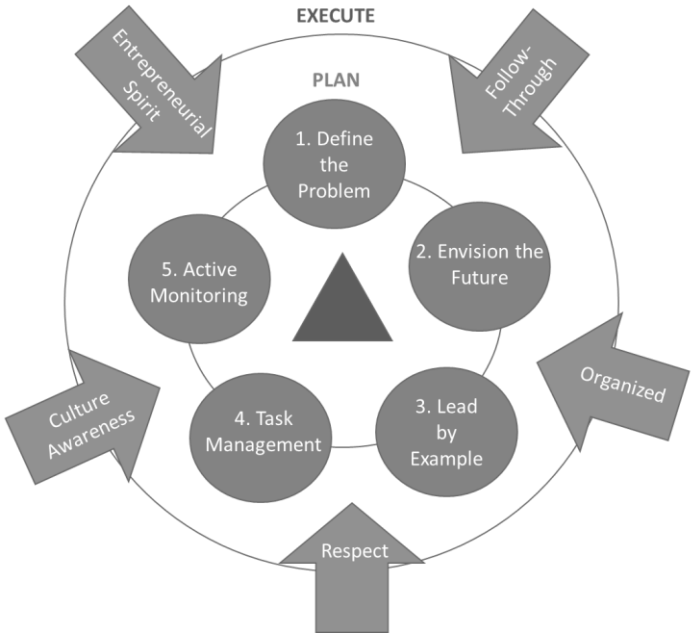
Figure 10-1. DELTA execution process



Source: Why Execution Fails and What to Do About It

Figure 10-2. FORCE execution excellence imperatives

The DELTA FORCE life cycle (Figure 10-3) illustrates the interaction between the DELTA and the FORCE elements and their interaction.



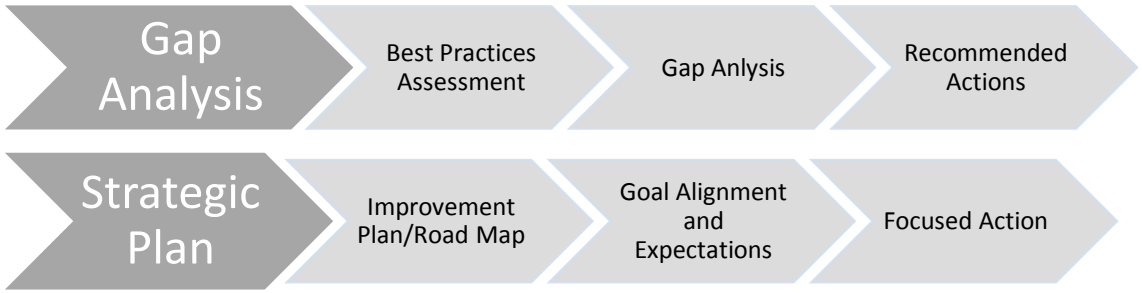
Source: Why Execution Fails and What to Do About It

Figure 10-3. DELTA FORCE life cycle view

Strategic Plan

If a procurement best practices strategic plan is not in place, the DELTA five-step planning process can help develop a strategic plan. The process helps in identifying the gaps and the methods to close these gaps.

The strategic plan is developed by including stakeholders from across the organizational functions (Engineering, Financial, Procurement, Technology, Services, Operation and Maintenance, etc.) and different levels of employees from within each function (senior, mid, and junior level staff). The strategic planning process is presented in Figure 10-4.



Source: Why Execution Fails and What to Do About It

Figure 10-4. Strategic planning process

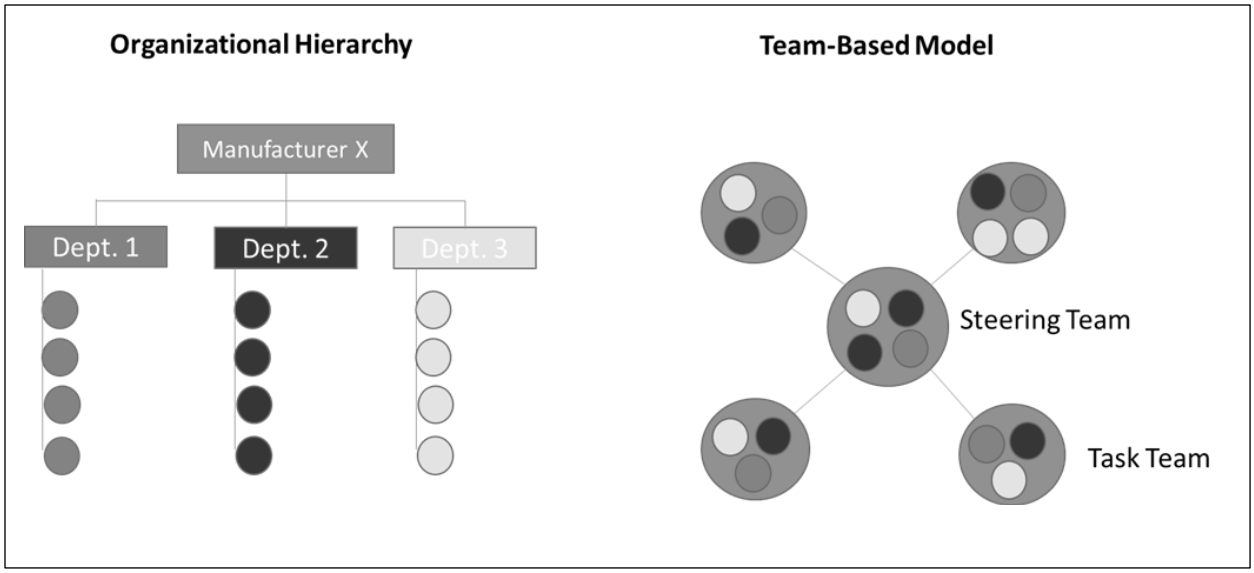
Governance

A senior management representative should be assigned responsibility for the change initiative as the executive sponsor. This person represents corporate commitment to the project, is held accountable for success/failure to peers and ensures appropriate resources are made available to the implementation team.

Once the strategic plan has been approved and actions detailed in an improvement plan, it is strongly recommended that both a cross-departmental steering committee and an overall project manager be assigned to the effort.

The steering committee is usually made of mid to upper management to provide general direction, cross-departmental coordination, and support individual actions and task teams assigned to execute the strategic plan. Assignment of a full time project manager is a critical success factor to be responsible to the executive sponsor and steering team to execute all elements of the plan.

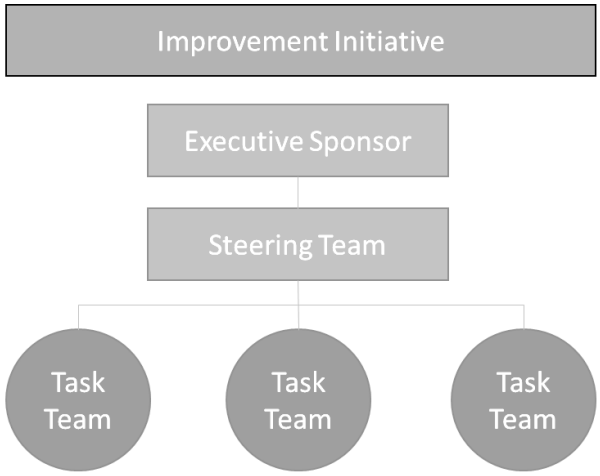
Actions can be assigned to individuals and in some cases task teams that can also be cross-departmental. This team-based implementation model is presented in Figure 10-5, and team based organizational structure in Figure 10-6. Figure 10-5 illustrates that team members are assigned from different departments and assigned to a project team.



Source: Why Execution Fails and What to Do About It

Figure 10-5. Team-based implementation model

In addition to subject matter experts, Figure 10-6 shows that each team should also have efficient meeting management roles such as leader, facilitator, and a scribe to capture meeting outcomes. A cadence of accountability should also be established such as monthly progress reporting.



Task Team Organization

- Sponsor (from Steering Team)
- Leader
- Facilitator
- Scribe
- Cross-functional membership

Source: Why Execution Fails and What to Do About It

Figure 10-6. Team-based organizational structure

All teams should be guided by a formal team charter that details objectives, a list of actions/activities with target completion dates, participant names and roles, and expected benefit statements. A sample procurement best practices steering committee charter is presented in Figure 10-7.

Procurement Improvement Program
Steering Team Charter

Mission: The Procurement Improvement Program (PIP) steering team will provide oversight and guidance to developing and implementing procurement best practices.

Members: Procurement, Engineering, Construction, Operations, Maintenance, and Finance

Executive Sponsor: Chief Operating Officer (COO)

Deliverables + Schedule:

1. Conduct a best practices gap assessment (Q1)
2. Review assessment and develop improvement plan (Q2)
3. Determine what support and organizational resources are needed to support the PIP (Q3 and Q4)
4. Develop schedule and forum for updates to executive staff (Q1-Q4)

Key Activities:

- Attend steering committee/Task team meetings
- Ensure appropriate staffing resources are assigned to the PIP initiative
- Review and comment on studies, reports, and staff recommendations
- Monitor PIP schedule
- Provide quarterly PIP progress updates to executive staff

Expected Benefits:

- Timely implementation of PIP best practices
- Organization-wide involvement and initiative communication
- Cost savings and improved customer service levels

Charter Date:

Endorsements:

Source: Why Execution Fails and What to Do About It

Figure 10-7. Procurement improvement program team charter

Communication Plan

Once the strategic plan is defined and documented, and the DELTA FORCE elements become the execution roadmap, a communication plan must be in place to successfully inform the stakeholders of the initiatives benefits, participants, and schedule as well as allow forums to address any of their concerns.

A communication plan consists of four main components. These components deal with the Who (audience), What (message), How (platform), and When (schedule). The following is an example of these components.

Who (Audience)

- Leadership
- Vendors
- Employees
- Regulators

What (Message)

Internal

- Procurement best practices such as TCO are the future direction
- Procurement best practices include all related functions and employees
- Executive leadership's support to this initiative
- Business processes and decision making alignment
- Active engagement and collaboration is expected from everyone during implementation
- Continuous communication and discussion between different functions
- Training and professional development will be provided to employees
- Introduce accountability within the processes

External

- Provide vendors/suppliers information about procurement changes
- Request feedback from vendors/suppliers

How and When

How and When would assist in providing details about the communication platform that these messages (What) will be issued to the different (Who). The platform can be a newsletter, e-mail, video, presentation, etc. Depending on the message, it can be communicated monthly, quarterly, or yearly depending on the topic and its importance. Establishing a communications team to lead such efforts is recommended.

CHAPTER 11

Asset Management Future at Airports

Asset management is a dynamic science that is continuously evolving and advancing with technological advancements, as presented in Figure 11-1. Although asset management has been established and implemented for many years at different industries, the aviation industry is lagging in implementation and realization of benefits.

Airports of the future are facing two main challenges:

- Maintaining assets with constrained and reduced budgets
- Improving the quality of services provided to passengers and airlines

Airports are becoming destinations and are regarded as small cities. Passengers are requesting more and enhanced services to accommodate their long traveling hours. Airlines are requesting airports provide better services to accommodate their passengers while waiting on their trips. Additionally, airport managers are looking for ways to increase their revenue to reduce their financial dependency on government and local authorities. These changes and demands increase the need to utilize asset management best practices in operating and maintaining airports' facilities.

In answer to the question, "What innovations do airports envision in the next 5 to 10 years in the field of asset management, procurement, total life cycle, and in CMMS?" airport managers responded with the following insights.

- Implement and use BIM to provide more accurate data and predictive life cycle analysis
- Implement predictive maintenance as part of the maintenance activities
- Implement enhanced asset management technologies

The real asset management challenge that faces airports is timing associated with investing capital to build capacity just in advance of need. Airports are sweating their assets to ensure full value before investing in new capacity. This places pressure on the asset management teams to plan and design well, purchase smart, and implement robust, precise maintenance programs and processes complimented with highly trained and motivated staff. A CMMS and/or EAM is foundational to delivering these needs. In addition, thorough and readily available documentation, reporting capabilities and a well-designed executive level supported governance model is key to excellence in asset management.

Figure 11-1. The dynamics of airports in the future

CHAPTER 12

Final Words

Airports are complex organizations composed of a high number and variety of assets operating under demanding conditions and economies. The tradition for airports to operate under functional governance structure, using lowest-cost purchasing policies has encouraged a linear approach to procurement rather than an integrated asset management framework that consistently drives success in other industries. There is ample opportunity for the airport industry to realize substantial benefits by adopting a different operating model—one which allows the organization to operate and maintain all its assets in a way that balances costs with risk while meeting service expectations.

This new operating model—asset management under a total cost of ownership model—is in itself a multi-faceted practice area. It is designed to span and fully integrate design, procurement/construction, commissioning, operations, maintenance, and decommissioning processes. It is challenging, if not impossible, to represent all of these aspects and tools in a single manual.

Faced with that complexity, this guidebook is intended to be concise rather than comprehensive. It hones-in on proven tools, methodologies, and real-world examples that are most relevant to airports in an effort to help staff evaluate and begin adopting practices that makes sense to their operations. Taken as a whole, the recommended practices in this guidebook can help airports control their operational expenditures, optimize reliability, and mitigate many types of organizational risk. It is also possible, however, for organizations to see benefits from adopting one or two of the methods described in these pages, focusing on areas of highest concern or accessibility.

To recap the main points of this guidebook:

- Adopting a Total Cost of Ownership (TCO) approach to procurement is a way airports can assure that they use funds wisely to procure and employ assets that, across their entire life of service, will be able to meet their operational responsibilities;
- Integrating sustainability into infrastructure decisions will allow airports to optimize their use of resources in a way that also supports their operational, social, and financial objectives;
- Building Information Modeling (BIM) is one way airports can maintain information about individual assets, and also see how each asset impacts the system as a whole, enabling a more reliable overall operation;
- O&M Ready is a way to integrate all aspects of asset management across business units and stakeholders to render the full benefits of their asset management program; and
- Lastly, airport organizations should try to keep sight of the fact that no asset management program or tool can be successful without ensuring that people are onboard with the work process changes that are required; executing successful change requires careful planning with plenty of communication, training, and engagement of the workforce.

As complicated as adopting these practices may appear at first blush, the airport industry is well-positioned to take advantage of the industry experience represented in these pages. It behooves the industry to begin immediately, as the challenges represented by stiff economies, aging infrastructure, and unending customer demands are not expected to fade.

CHAPTER 13

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CHAPTER 14

Glossary

A

Acquisition - The process by which the airport comes into possession and ownership of a fixed asset (examples: purchase, donation, construction, eminent domain or foreclosure).

Acquisition Cost - Cost incurred in getting the product/service to the point of use (inbound freight, sourcing, receiving, inspection, storage, etc.)

Adequate Facility/Structure/Space - A facility/structure/space that is fully capable of supporting its current use without modification or repairs (beyond currently funded routine maintenance) and has an acceptable level of reliability

Airport Asset Management Plans - describe the activities and investments in infrastructure and assets required to achieve and maintain service outcome standards in the short- and long-term, according to the airport's master plan or strategic plan for servicing customers, the community, and other stakeholders.

Airport Cooperative Research Program (ACRP) - an industry-driven, applied research program that develops near-term, practical solutions to problems faced by airport operators.

Airport Property - All property owned by the Airport, whether purchased, leased, confiscated, donated received by eminent domain, constructed or annexed. Airport property may include supplies, real property, police property, capital assets and controlled items.

Airport Improvement Program (AIP) - provides grants to public agencies—and, in some cases, to private owners and entities—for the planning and development of public-use airports that are included in the National Plan of Integrated Airport Systems.

Airport Master Plan - is a concept of the long-term development of an airport. The plan displays this concept graphically and documents the data and logic upon which the plan is based.

Alteration - Work required to adjust interior arrangement or other physical characteristics of an existing facility/structure so that it may be more effectively adapted to or utilized for a new or changes use.

Annual Annuity - annual payments required to cover the cost of future planned investments.

Annual Plan - a document produced annually by an organization to inform stakeholders of its objectives, intended activities, performance, income, and expenditure required for a period of one financial year. It may also indicate anticipated future short-term income and expenditure.

Area - The way the airport subdivides the airport campus into areas. The combination of campus designation and area designation may define the general location of a facility.

Area/Gross Square Footage (GSF) - A unit of measure representing the cumulative total of an organization's building(s) inclusive of all floors to the outside faces of exterior walls. Defined as the sum of the floor areas on all levels of a building that are totally enclosed within the building. Measure exterior building gross area to the outside face of exterior walls, disregarding canopies, cornices, pilasters, balconies and buttresses that extend beyond the wall face and courtyards that are enclosed by walls but have no roof. The building exterior gross area of basement space includes the area measured to the outside face of basement or foundation walls. Exterior bridges and tunnels that are totally enclosed, constructed areas connecting two or more buildings are included in building exterior gross area. This measurement indicates total constructed space and is useful for building efficiency and construction cost comparisons.

Asset - an item of plant, equipment, or infrastructure that contributes to the function of a "system" so that the "system" can provide a service to a community or group of customers. An "asset" is continually maintained, refurbished, replaced, or upgraded so that the system provides an ongoing, minimum level of service. An asset has a capital replacement value and is depreciated over its useful life. OR

A physical component of a facility which has value enables services to be provided and has an economic life greater than 12 months. Dynamic assets have some moving parts, while passive assets have none. OR

Capital investments maintained by the airport's accounting system. The maintenance department typically refers to an asset as any item of physical plant or equipment. It is used to describe items such as buildings, facilities, systems and components that are controlled by the airport and from which a benefit is derived. For industry purposes these items are considered fixed assets deployed or intended to be deployed in an operational environment.

Asset Accounting - recording and tracking of asset-related incoming and outgoing cash flows.

Asset Group - a group of like assets (e.g., valves) or a group of assets that comprise a system (e.g., pump system).

Asset Hierarchy - a framework of segmenting an asset base into appropriate classifications. The asset hierarchy can be based on asset function, asset type, or a combination of the two.

Asset Life Cycle - The asset life cycle is the time span from when the asset is placed in service through its eventual replacement or disuse. How the asset's life cycle is managed is dependent on the strategies and goals of its management. These strategies normally include training, maximizing utility, preventive maintenance, evaluation and when use will stop.

Asset Management (AM) - as defined by NAMS, a systematic approach to the procurement, maintenance, operation, rehabilitation, and disposal of one or more assets. Asset management integrates the utilization of assets and their performance with the business requirements of asset owners or users. Asset management is all about the continuous alignment of asset performance to meet service delivery outputs to deliver the desired outcomes. A management paradigm and a body of management practices that is applied to the entire portfolio of infrastructure assets at all levels of the organization, which seeks to minimize the total cost of acquiring, operating, maintaining, and renewing the organization's assets within an environment of limited resources while continuously delivering the service levels customers desire and regulators require at an acceptable level of business risk to the organization.

Asset Management (AM) - as defined by PAS 55 is systematic and coordinated activities and practices through which an organization optimally and sustainably manages its assets and asset systems, their associated performance, risks, and expenditures over their life cycles for the purposes of achieving its organizational strategic plan.

Asset Management Information System (AMIS) - computer-based software system for collecting and analyzing data, and extracting meaningful information on the performance of existing assets and their operating costs to aid in asset management decision-making. AMIS is often also referred to as an organization asset management system (EAMS).

Asset Management Plan (AMP) - document that identifies the short- and long-term service delivery requirements of the portfolio of assets belonging to an organization. It provides a framework for managing an asset, or group of assets, from within the asset portfolio.

Asset Management Policy - sets the framework for the management of airport infrastructure and assets. Most policies include

- Organizational context and importance of asset management,
- Overall vision and goals of the organization and supporting asset management vision and goals,
- Executive and key position roles and responsibilities, and
- Audit and review procedures.

Asset Management Framework - system of processes, procedures, practices, support systems, organizational roles and responsibilities, and policies used to enable sound management decisions for the optimal management of physical assets.

Asset Management Strategy - strategy for asset management covering the development and implementation of plans and programs for asset creation, operation, maintenance, rehabilitation/replacement, disposal, and performance monitoring to ensure that the desired levels of service and other operational objectives are achieved at optimum cost.

Asset Management Steering Committee - committee of people that have come together within the organization to design and build the asset management program. These people establish the program and enforce the ideas and practices within the organization.

Asset Performance - measurement of the achievement of predetermined outputs arising from the existence and operation of assets using a range of performance targets that measure the individual and collective contribution an asset makes toward service delivery and/or business outputs.

Asset Registry—a record of asset information considered worthy of separate identification including inventory, historical, financial, condition, construction, technical, and financial information about each.

Asset Rehabilitation - work performed on an existing asset to ensure that its performance capacity and capability meets its predetermined performance target. It does not refer to work that transforms the asset to an "as new" condition. Painting a room and replacing its floor covering, milling and repaving a section of road, all fall within this category.

Asset Renewal - replacement or reconstruction of an existing asset with a new asset. The resultant asset is transformed to an "as new" condition. Demolishing and rebuilding new classrooms or a hospital ward fall within this category. Renewal is comprised of:

- Repair: normal periodic maintenance, minor in nature, anticipated in the normal operation of the asset; no enhancement of capabilities;
- Refurbish/Rehabilitation: replacement of a component part or parts or equivalent intervention sufficient to return the asset to level of performance above minimum acceptable level; may include minor enhancement of capabilities; typically funded out of capital budgets;
- Replace without enhancement: substitution of an entire asset with a new or equivalent asset without enhancement of capabilities; and
- Replace with enhancement: substitution of an entire asset with a new or equivalent asset with enhanced capabilities.

Asset Replacement Cost - full replacement costs associated with a given asset expressed in current dollars.

Assignable Square Feet - A term used to describe areas that may be occupied and is acceptable for a designated purpose or function. It does not include walls, stairways, corridors, restrooms, parking facilities, or mechanical space.

Attributes - a data item related to an asset.

B

Best Appropriate Practice - a method or technique that has shown results superior to those achieved with other means and that is used as a benchmark (business dictionary).

Best Value - is about achieving the nearest possible match to your functional requirements for the best price. It is not about taking the lowest priced option. It is the optimum combination of whole life cost and quality (or fitness for purpose) to meet the user's requirement.

Building Core and Service Area - Defined as the floor area of a facility, which is necessary for the operation of the facility and is not available for general occupancy. This may include the following: building lobbies, mechanical rooms, electrical rooms, telephone (communications) rooms, restrooms, custodial rooms, loading docks and utility tunnels that are not used for any other purpose.

Building Projections - A convector, baseboard heating unit, radiator, or other building element located in the interior of a building adjacent to a wall that prevents the use of that space for furniture, equipment, circulation or other functions.

Business Improvement Plan - plan produced by an organization that translates the objectives contained in an annual plan or asset management plan into detailed work plans for a particular, or range of, business activities. Activities may include marketing, development, operations, management, personnel, technology, and financial planning.

Business Risk Exposure (BRE) - a metric to expresses risk. BRE is determined as the product of the probability of failure and the consequence of failure.

C

Common Support Areas - Facility assignable area includes the area devoted to common support services. Common support area is the portion of the facility usable area not attributed to any one occupant but provides support for several or all occupant groups. Examples of common support areas are: cafeterias, vending areas, auditoriums, fitness facilities, building mailrooms and first aid rooms. These may be separately identified as a sub-category of facility assignable area if required.

Computerized Maintenance Management Systems (CMMS) - act as a focal point of information systems supporting best practice asset management.

Condition Assessment - technical assessment of an asset based on a physical inspection, for the purpose of determining its condition and remaining useful life relative to a defined standard.

Consequence of Failure (CoF) - the resultant consequence of an asset failure expressed in triple bottom line (TBL) terms (social/community, economic, and environmental/regulatory).

Construction - means all constructed facilities, buildings and infrastructure. A construction is defined as a physical setting used to serve a specific purpose. A construction may be within a building, or a whole building, or a building with its site and surrounding environment; or it may be a constructed facility, which is not a building, such as a bridge, road or railway for instance. The term encompasses both the physical object and its use.

Cost-Benefit Analysis - Analysis which quantifies in monetary terms as many of the costs and benefits of a proposal as feasible, including items for which the market does not provide a satisfactory measure of economic value

Critical Assets - assets for which the financial, business, or service-level consequences of failure are sufficiently severe to justify proactive inspection and rehabilitation. Critical assets have a lower threshold for action than non-critical assets. OR

Critical assets asset systems are assets and/or asset systems that are identified as having the greatest potential to impact on the achievement of the organizational strategic plan

Current Replacement Cost - cost of replacing an existing asset with an appropriate modern equivalent asset.

D

Decay Curve Development - is the process by which asset time to failure data records are analyzed to develop a graph of the deterioration in asset condition time.

Decision Support Tools - used by asset managers to determine the best alternative among a set of feasible alternatives. The alternatives may be potential solutions to a range of questions related to strategic planning, airport development, outsourcing, and asset renewal or replacement.

Decommission - activities required to take an asset out of service.

Demand Capital Plan - describes the capital projects that have been identified for the purposes of meeting the predicted growth and demand requirements over the planning period.

Depreciated Replacement Cost - replacement cost of an existing asset less an allowance for water or consumption having regard for the remaining economic life of the existing asset.

Design Life - Service life intended by the designer.

Design Life Options - The design life is the service life intended by the designer or provided by the vendor for an asset. The design life positively or negatively is impacted by operational and maintenance activities and environmental conditions such as warm and cold weather. The user may increase or decrease the design life for the asset based on their previous knowledge and experience with the asset or by implementing maintenance best practices that increase the asset's service life.

Discounted Payback - Like the payback approach, except it considers the present value of cash flows.

Disposal - Activities necessary to dispose of decommissioned assets.

E

Economic Failure - when the asset is no longer competitive with asset options that are available in the market place for delivering the same or improved function.

Economic Life - period from the acquisition of the asset to the time when the asset, while physically able to provide a service, ceases to be the lowest cost alternative to satisfy a particular need. The economic life is at the maximum equal to the physical life but obsolescence will often ensure that the economic life is less than the physical life.

Enterprise Asset Management Systems (EAMS) - a maintenance management system that operates across the organization to include the management of all physical assets owned by the organization. OR

Refers to the management of assets to the benefit of the organization as a whole and not limited to a specific area such as a department, location or division. It includes the entire process of managing the airport's assets throughout its life cycle from initial planning, designed use, installation, training, operations, maintenance and eventual replacement.

Equivalent Uniform Annual Cost (EUAC)—payment required to fund the life cycle cost over the service life of the asset.

Excluded Area - Fully enclosed spaces with adequate clear headroom that are not intended for, or are not suitable for occupancy by people or equipment, but not spaces that are temporarily unusable due to flood, fire damage, construction or renovation activity.

F

Facilities - A "facility" is an installation of assets that facilitates a process or function. Assets within a "subsystem" can be classified as either linear or non-linear. Non-linear assets occupy a bound space and can be modeled as part of a parent-child hierarchy. Linear assets are continuous with linear properties. Facilities are the non-linear installations of assets within a subsystem and underground structures like pipes and valves are considered linear assets.

FAA - the federal aviation administration of the United States.

Facility Assignable Area - Calculated by measuring the portions of the floor used to house personnel, furniture, support areas and common support areas. Each assignable area is measured to the outside of the enclosing wall or furniture panel except in the case where a wall or furniture panel is common to more than one assignable area. In this case measurements are taken to the center of the wall or furniture panel. This measurement is useful for detailed programming, planning, allocating and layout of space.

Facility Condition Assessment (FCA) - An inspection and assessment of facilities producing a complete account of system and component deficiencies and a list of remediation scenarios. FCA results inform maintenance and capital renewal planning.

Facility Interior Gross Area - Defined as the building exterior minus the thickness of the exterior walls.

Facility Management - Primary function is to make sure buildings operate at maximum efficiency through the optimal integration of people, processes and technology. Includes HVAC, electrical, plumbing, lighting, cleaning and security.

Facility Management Information System - The integration of several computer systems that are each designed to perform a specific function. An example would be the integration of an electronic document management system and a Computerized Maintenance Management System (CMMS) to manage facilities and the associated information.

Facility Rentable Area - Calculated by subtracting major vertical penetrations, interior parking space and void areas from facility interior gross area.

Facility Usable Area - Calculated by subtracting the primary circulation and the building core and service areas from the facility rentable area. It is area that can be assigned to occupant groups. This measurement is useful for programming, planning and allocating space.

Finished Surface - A wall, ceiling or floor surface (including glass) as prepared for tenant or occupant use. Excluding the thickness of any special surfacing materials such as paneling, furring strips and carpet.

G

GAP Analysis - assessment of the current level of practice in asset management. The gap is the difference between current practices and the best appropriate practice for that organization. It is sometimes referred to as a maturity assessment.

General Aviation Airports (GA) – airports are one of the two categories of civil aviation airports. GA airports cater to all flights other than military and scheduled airline and regular cargo flights, both private and commercial.

Geographic Information System (GIS) - a computer package that displays a map connected to a database. The package can typically combine features, such as roads and sewers, from different maps and overlay them on the same screen. To qualify as a GIS, such systems should also be able to reference a computer database for textual information, such as notes and dimensions, regarding features displayed on the map.

I

Impact Assessment - generally involves evaluating data collected on the material and energy inputs in terms of their potential environmental impact

Infor EAMS - software used by organizations to keep track of their assets, understanding that they meet environmental, compliance, and service requirements.

Infrastructure Assets - Stationary systems forming a network and serving whole communities, where the system as a whole is intended to be maintained indefinitely at a particular level of service potential by the continuing replacement and refurbishment of its components. The network may include normally recognized assets as components

Infrastructure Management - the discipline of managing infrastructure assets that underpin an economy, such as roads, water supply, wastewater, storm water, power supply, flood management, recreational and other assets.

Intergenerational Equity - ensuring that future generations are not burdened with the cost of the consumption of infrastructure by the current generations.

Internal Rate of Return (IRR) - A technique that equates the discounted cash flows from a project to an interest rate, the IRR.

International Infrastructure Management Manual (IIMM) - manual produced to give an understanding of asset management practices.

Interstitial Area - The area of load-bearing surfaces, located above or below occupied building floors that are not available for general occupancy due to inadequate clear headroom, but may contain building mechanical or electrical systems predominantly serving adjacent floors or provide access to such systems.

Inventory - In accounting terms, inventory is a record of current assets, which includes property and equipment owned (counting parts in stock, value of work in progress, and work completed but not sold). In maintenance terms it is frequently used to describe the list of equipment and spare parts currently held in stock.

Inventory Analysis - involves the collection of data about the products or services being investigated, and quantification of relevant material and energy inputs and outputs.

Inventory Management - The process by which inventory is controlled. Typically, this includes tracking usage of stock items, Optimization of stock levels and Control of costs.

ISO (International Organization for Standards) - organization known for producing and publishing international standards for all subject areas in the world. This organization forms a network between both the public and private sectors as it is not a government organization.

K

Key Performance Indicator (KPI) - quantitative or qualitative indicator of the quality of service, efficiency, productivity, or cost effectiveness of an agency, program, or activity that enables a comparison to be made for management purposes of performance against a standard target or norm. It may be a quantitative measure or qualitative indicator of performance.

L

Large Hub Airport - commercial service airports that have at least more than 10,000 passenger boardings each year and 1 percent or more of total passenger boardings within the United States in the most current calendar year ending before the start of the current fiscal year.

Level of Service - level of asset service determined by both the quality and the quantity of services provided by an asset under consideration. OR

The defined service quality for a particular activity or service area against which service performance may be measured. Service levels usually relate to quality, quantity, reliability, responsiveness, environmental acceptability and cost.

Life Cycle - is the life of a project/product/system for its conception through to end of life, decommissioning or disposal.

Life Cycle Assessment (LCA) - is a systematic set of procedures for compiling and examining the inputs and outputs of materials and energy and the associated environmental impacts directly attributable to the functioning of a product or service system throughout its life cycle.

Life Cycle Costing - sum of all recurring and onetime costs over the full lifespan or a specified period of an asset under consideration.

Life Cycle Cost Analysis - Any technique which allows assessment of a given solution, or choice from among alternative solutions, on the basis of all relevant economic consequences over the service life of an asset.

Life Cycle Process - cycle of activities that an asset goes through while retaining an identity as a particular asset.

M

Maintenance Managed Item (MMI) - MMI level is that level for maintenance detail elected for the organization asset register. The MMI could be a whole building in some systems, whereas in more sophisticated systems it could be a shaft beading on an electric motor. Best Appropriate Practice requires that the level of detail in the asset register should allow for the recording of data down to the MMI level. MMI refers to the lowest level of an asset's physical structure that is to be recognized within an asset register where the registry is structured as a nested hierarchy of physical assets. Typically, an MMI is set at that level of the hierarchy at which an asset is individually maintained or at which management decisions to repair, renew, or replace are made.

Maintenance Management - method of allocating resources to accomplish predetermined levels of service through planning, budgeting, scheduling, executing, and reporting and reviewing maintenance strategies and tactics.

Major Vertical Penetrations - Includes stairs, elevator shafts, utility tunnels, flues, pipe shafts, vertical ducts and their enclosing walls.

Management Strategies - the operations, maintenance, and capital investment strategies determined for the planning period. This may include changes to maintenance strategies to implement more proactive maintenance, or could include changes to emergency response plans for specific events.

Management Strategy Group (MSG) - assets of similar type that are managed and maintained in a similar way and have similar patterns of decay.

Management System - system to establish policy and objectives and to achieve those objectives. Note that the management system of an organization can include a range of subsets that collectively constitute the whole. These subsets usually include the following:

- Quality management system,
- Human resource management system,
- Fiscal management system,
- Asset management system,
- Information management system, and
- Environmental management system.

Manager, Asset Management Services - position within an organization that has the responsibility for the management of the Asset Management Services Team. The team's role is the implementation of the corporation's asset management improvement plan.

Master Planning - process of orderly planning of system's future improvement program that identifies the present and future needs and direction for developing the system's facilities.

Maturity Assessment - evaluation of the degree to which an organization uses recognized best practices and the availability of information required to plan for, and implement, improvements. The ultimate value of maturity assessment can only be realized in the context of an overall process improvement and organizational change program.

Maximum Potential Life (MPL) - the maximum length of time of an asset's life (including the maximum number of rehabilitations possible to extend asset life) up to which either the end of physical life, service life, or economic life (whichever occurs first) dictates that the asset be replaced, given the following definitions:

- End of physical life: when an asset physically stops working, collapses, or is otherwise nonoperational;
- End of service life: when an asset can no longer deliver what customers or regulators require it to deliver (e.g., "customer outrage"); and
- End of economic life: when an asset ceases to be the lowest cost alternative to satisfy a specified level of performance or service at an acceptable level of risk. Also, the time at which disposal or replacement of the asset results in the greatest cumulative production from the asset per cumulative dollar cost (or the "long run lowest average cost per unit of production," where "unit of production" for linear water pipe assets is "availability of water on demand").

Multicriteria Analysis (MCA) - is evaluation by establishing preferences between options by reference to an explicit set of objectives that the decision making body has identified, and for which it has established measurable criteria to assess the extent to which the objectives have been achieved.

N

Net Present Worth (NPW) - the Net Present Value (NPV) or NPW of a time series of cash flows both incoming and outgoing, is defined as the sum of the present values (PVs) of the individual cash flows.

Net Present Value (NPV) - A technique that discounts savings from the project and compares the discounted values to the investment required OR

is the sum of the discounted benefit of an option less the sum of the discounted costs. It represents therefore a single figure, which takes account of all relevant future incomes and expenditures for that option over the period of analysis.

Non-Hub Airport - commercial service airports that have at least more than 10,000 passenger boardings each year but less than 0.05 percent of total passenger boardings within the United States in the most current calendar year ending before the start of the current fiscal year.

O

Operations and Maintenance - activities related to the performance of routine, preventative, predictive, scheduled, and unscheduled actions aimed at preventing asset failure or decline with the goal of increasing efficiency, reliability, and safety.

Optimized Decision Making - An optimization process for considering and prioritizing all options to rectify existing or potential performance failures of assets.

Option Evaluation - is the process of considering different options in relation to how they perform against chosen criteria for evaluation.

Organizational Change - a process of change in an organization as a result of change in business processes, organizational structure, or culture within an organization.

Organizational Strategic Plan - overall long-term plan for the organization that is derived from, and embodies, its vision, mission, values, business policies, stakeholder requirements, objectives, and the management of its risks.

P

PAS 55 2008 (Publically Available Specification) - standards being used as the basis for development of an ISO standard, which are supported by American National Standards Institute and the International Infrastructure Management Manual.

Passenger Facility Charges (PFC) - a fee imposed by a facility owner, as an airport or those using the facility; typically added to the cost of a fare.

Payback - a technique that looks at how long it takes to recoup initial investment/outlay.

Performance Indicator - A qualitative or quantitative measure of service or activity used to compare actual outcome against a standard or other target. Performance measures commonly relate aspects such as safety, responsiveness, cost, comfort, asset performance, reliability, and sustainability.

Performance Management Framework - the component of the asset management system that monitors and manages performance from a strategic, whole of government, down to asset level performance. The performance management framework links performance goals, through appropriate performance measures, to activities for monitoring performance and actions to improve performance where monitoring indicates a need.

Performance Monitoring - Continuous or periodic quantitative and qualitative assessments of the actual performance compared with specific objectives, targets or standards.

Physical Effective Life (PEL) - the length of time (with no rehabilitations to extend life) from when an asset is commissioned and put in service until it physically stops working, collapses, or is otherwise non-operational. For an asset that cannot be rehabilitated, the PEL is equal to the maximum potential life (MPL).

Plan - Asset Strategic Plan (ASP) - this plan (developed at the asset level) along with the asset portfolio strategic plan are the only organizational strategic plans. In the areas of acquisition/refurbishment, operations, maintenance, and disposal, proposed annual programs are developed. Long-term strategies addressing all proposed asset life cycle issues and objectives are fundamental to the ASP. The ASP is "rolled-up" in summary format to form the portfolio strategic plan (PSP). The PSP enables the asset planner to prioritize performance improvement initiatives, and to level-out peaks in planned expenditure. It simply provides a big picture overview of the asset portfolio.

Primary Circulation - Defined as the portion of a building that is a public corridor or lobby. Further defined as space required for access by all occupants on a floor to stairs, elevators, restrooms and building entrances or tenant space entry points on multi-tenant floors.

Preventative Maintenance - a schedule of planned maintenance actions aimed at the prevention of breakdowns and failures.

Probability of Failure (PoF) - the "likelihood" that an asset will fail based on an assigned condition score. The PoF for this asset management plan is expressed as a score between 1 and 10 determined using a direct relationship between condition and probability.

Procurement - Procurement refers to the activities required to obtain goods and services from suppliers. It is needed to ensure that purchases are made at reasonable prices and from reputable suppliers. It is particularly important for the procurement group to focus on obtaining materials and services that are in short supply, and which could interfere with the operations of the business.

Public Private Partnerships (PPPs) - are relationships formed between the private sector and public bodies for introducing private sector resources and/or expertise in order to deliver public sector assets and services. This involves a long-term contractual arrangement lasting typically for 25 to 30 years between a public body and a private sector provider, where resources and risk are shared. PPPs can include different working arrangements from loose, informal and strategic partnerships to design build-finance-operate (DBFO) type service contracts and formal joint venture companies. PPP is primarily based on the Private Finance Initiative, which was introduced in 1992 in the UK.

Purchase Requisition - A written request that is issued internally to the purchasing department to purchase items, materials, or services

R

Rate of Depreciation - accounting practice that aims to distribute the cost or other basic value of a tangible asset less salvage value, if any, over the estimated useful life of the assets in a systematic manner.

Rehabilitation - project to rebuild or replace parts or components of an asset to restore it to a required functional condition and extend its life, which may incorporate some modification. Generally, involves repairing the asset to deliver it to original level of service without resorting to significant upgrading or renewal, using available techniques and standards.

Reliability - probability that a system performs a specified function or mission under given conditions for a prescribed time.

Remaining Life - time remaining until an asset ceases to provide the required service level or economic usefulness.

Renewal - project to upgrade, refurbish, or replace existing assets with assets of equivalent capacity or performance capability.

Repair - action to restore an item to its previous condition after failure or damage.

Replacement - complete replacement of an asset that has reached the end of its asset life, so as to provide a similar or agreed alternative, level of service.

Replacement Cost - cost of replacing an existing asset with a substantially identical new asset in current dollars.

Requisition - A request for an asset, item, tool, or service. The requested entity can be procured from a vendor, or it can be acquired by an inter-departmental transfer.

Residual Life - time left until failure; particularly important for managing high-cost and high risk assets.

Residual Value - The net market or recoverable value which would be realized from disposal of an asset or facility at the end of its life.

Return on Assets (ROA) - A ratio that considers annual average savings, compared to change in assets required.

Return on Investment (ROI) - A ratio that considers average annual savings, compared to initial investment value.

Risk - is the likelihood of a specific outcome, at some time in the future, combined with consequences that will follow in a particular context. Usually the outcome is defined as an unwanted event, but it could be an unintended benefit, which is an opportunity to add value.

Risk Assessment - process of establishing information regarding acceptable levels of a risk and/or levels of risk for an individual, group, society, or the environment. OR

is a technique for identifying targets of importance to a business and the construction, which enables an estimation to be made of both likelihood and consequences of failure to meet them.

Risk Cost - The assessed annual benefit or cost relating to the consequence of an event. Risk cost equals the costs relating to the event multiplied by the probability of the event occurring.

Risk Exposure - extent of risk faced by an organization that is expressed in terms of a numerical Formula representing the product of the likelihood and impact of a loss.

Risk Profile - describes how risk exposure is evaluated and identifies at risk assets.

Risk Management - is the systematic process of identifying and managing risks and opportunities for a project or business. OR

is a structured approach to identifying, assessing and controlling risks that emerge during the course of the policy*, program* or project* life cycle. OR

The systematic application of policies, procedures, methods and practices to the tasks of identifying, analyzing, evaluating, treating and monitoring risk. OR

The application of a formal process to the range of possible values relating to key factors associated with risk in order to determine the resultant ranges of outcomes and their probability of occurrence.

S

Service Life - is the period of time after installation during which a building*, or its parts*, meets or exceeds the performance requirements.

Service Life Planning - Service life planning, also known as service life design, is the preparation of the brief and design for the building* and its parts* to achieve the desired design life.

Service Potential - The total future service capacity of an asset. It is normally determined by reference to the operating capacity and economic life of an asset.

Small Hub Airport - commercial service airports that have more than 10,000 passengers boardings each year and at least 0.05 percent of total passenger boardings within the United States in the most current calendar year ending before the start of the current fiscal year, but less than 0.25 percent.

Space Planning - Space Planning is the process of analyzing current and future requirements relative to physical assets (i.e., type, condition, size, capacity, with respect to their ability to support and advance programs and activities at a level deemed appropriate by appropriate parties in concert with associated regulations, codes, mandates, and acceptable levels of performance). Space planning typically involves identifying each distinct type of activity covered by the program and defining the appropriate values relative to size, capacity, utilization rates, etc.

Stakeholders - are all members of society who have an interest in an organization's performance, success or the impact of its activities. We are all stakeholders, and there are many ways in which we experience our stakeholder status, for instance as:

- General public,
- Employees on-site and off-site,
- Travelers,
- By-standers affected by activities around us.

Strategic Plan - A plan containing the long-term goals and strategies of an organization. Strategic plans have a strong external focus, covering major portions of the organization and identify major targets, actions and resource allocations relating to the long-term survival, value and growth of the organization.

Suppliers - are construction providers and they include designers, consultants, building contractors and manufacturers of components.

T

Terminal Area Forecast - official forecast of aviation activity at FAA facilities; prepared to meet the budget and planning needs of FAA and provide information for use by state and local authorities, the aviation industry, and the public.

Total Cost Analysis - A technique used to develop a total cost for a purchased item/service, including purchase price, paperwork, quality costs, and so on.

Total Cost of Ownership (TCO) - TCO is a phrase that is used to describe all costs associated with the acquisition, use, and maintenance of a good or service OR

is a purchasing tool and philosophy which is aimed at understanding the true cost of buying a particular good or service from a particular supplier.

Triple Bottomline - triple bottomline accounting refers to expanding the traditional reporting framework to take into account ecological and social factors in addition to financial factors.

U

Utilization Rate - An indicator used to determine how efficiently available space is being used. Usually time-based in terms of month, quarter or year. (Utilization Rate = Occupied Space/Facility Usable Area)

V

Value - is the final output value from a business or personal activity, which results from a business process, such as manufacturing a product or delivering a service, or a personal activity such as running a home. It has three essential characteristics:

- Value can only be defined by the ultimate customer or user.
- Value is created by the provider.
- From the customer's point of view, providers exist in order to create value.

Value Analysis - A technique used to analyze the functional requirements of a given item in order to achieve the lowest costs given the performance needs

Value Engineering - A technique used to analyze the functionality of the design and manufacturing techniques for a given item OR

is incorporated into VM as a systematic approach to delivering the required functions at lowest cost without detriment to quality, performance and reliability. (CIRIA SP129). BS EN 12973: 2000 also defines VE as the term sometimes used for the application of value analysis to a new product which is being developed.

Value Management (VM) - is a structured approach to defining what value means to a client in meeting a perceived need by establishing a clear consensus about the project objectives and how they can be achieved. (CIRIA SP129). BS EN 12973: 2000 also defines VM as a "style of management, particularly dedicated to motivating people, developing skills and promoting synergies and innovation, with the aim of maximizing the overall performance of an organization". Applied at the corporate level, VM relies on a value-based organizational culture taking into account value for both stakeholders and customers. At the operational level (project oriented activities) it implies, in addition, the use of appropriate methods and tools.

W

Whole Life Cycle Cost (WLC) - is an economic assessment considering all agreed projected significant and relevant cost flows over a period of analysis expressed in monetary value. The projected costs are those needed to achieve defined levels of performance, including reliability, safety and availability.

Whole Life Costs - are the costs of all the items/activities that need to be considered in a WLC exercise.

Whole Life Value (WLV) - WLV of an asset represents the optimum balance of stakeholders' aspirations, needs and requirements, and whole life costs. OR

The benefits and costs associated with a built asset over its whole life taking account of the interests of all stakeholders affected by its construction and existence and its wider economic, social and environmental impact. There will be trade-offs between the various short-term project constraints (such as time, costs and quality) and the conflicts in stakeholders' longer-term interests and objectives.

Workstation - Defined as any type of space designated for occupant usage (either open or enclosed area), where an occupant can be seated.

CHAPTER 15

Abbreviations, Acronyms, Initialisms, and Symbols

ACRP	Airport Cooperative Research Program
AMMS	airport maintenance management system
APTS	Airport Planning and Technical Services
ATL	Hartsfield-Jackson Atlanta International Airport
BIM	building Information Modeling
CAPEX	capital expenditures
CH2M	CH2M HILL
CIPS	Chartered Institute of Procurement and Supply
CMMS	computerized maintenance management system
DAS	direct attached storage
EAM	Enterprise Asset Management
EBI	Honeywell's Organization Buildings Integrator
EPA	United States Environmental Protection Agency
FAA	Federal Aviation Administration
GA	general aviation
GTAA	Greater Toronto Airports Authority
HSE	health, safety, and environment
HVAC	heating, ventilation, and air conditioning
IFC	Industry Foundation Class
ISO	International Organization for Standardization
IT	information technology
KPI	key performance indicator
LEED	Leadership in Energy and Environmental Design

MRO	maintenance, repair, and operation
MSDGC	Metropolitan Sewer District of Greater Cincinnati
NAS	network attached storage
NR	Network Rail
O&M	operations and maintenance
O&M Ready	operation and maintenance readiness
OPEX	operational expenditures
PAS	Publically Available Specification
PHX	Phoenix Sky Harbor International Airport
PIP	Procurement Improvement Program
PPP	public private partnership
RCM	resource conservation measure
RFP	request for proposals
RMP	Resource Management Program
ROI	return on investment
SAN	storage area network
SAP	systems, applications, and products
TCAT	testing commissioning, acceptance, and turnover
TCO	total cost of ownership
UK	United Kingdom
VALE	Voluntary Airport Low Emissions
VERO	Visual Energy & Resource Optimization
WLC	whole life cycle cost
WLV	whole life value
WWT	wastewater treatment
YYZ	Toronto-Pearson International, Canada

APPENDIX A1

GTAA Bid Package Example

GTAA

Greater Toronto Airports Authority

COMPLETE REQUEST FOR TENDER PACKAGE TO BE RETAINED BY OFFERER

NUMBER: 2043086

FOR:

MAINTENANCE AND REPAIR SERVICES OF ELEVATORS, ESCALATORS, AND MOVING WALKS

AT TORONTO PEARSON INTERNATIONAL AIRPORT

Closing Date and Time:
November 30, 2015
3:00PM TORONTO TIME

Toronto Pearson International Airport

TABLE OF CONTENTS

This Request for Tender Package is comprised of the following documents:

The Tender and Acceptance shall be returned with the following:

1. All completed annexes and attachments;
2. Application for Safety Pre-Qualification as described in Schedule 2 to Annex "A" – Scope of Work.
3. Confirmation of availability of insurance as described in Annex D attached, entitled; "Insurance Conditions"; and
4. All other documents specified in this Request for Tender.

not liable to pay for such costs or to reimburse or to compensate tenderers in any manner whatsoever for such costs under any circumstances, including those circumstances described in IT13 under the heading in "Rights of GTAA", rejection of any or all tenders or the cancellation of this Request for Tender at any time.

IT 22 COMPLIANCE WITH LAWS

Each tenderer and any Person acting under the direction of a tenderer, must identify and comply with all Applicable Laws.

IT 23 DEFINED TERMS

All capitalized terms in this "Instructions to Tenderer" document and in any of the documents comprising this Request for Tender shall have the meaning assigned them in GC1 of Annex "C" titled "General Conditions". Similarly, the rules of interprepation set forth in GC1 shall apply in interpreting this Request for Tender.

• Experience and references • level of experience of staff • Value added approach (customer service and desired business outcomes) • Company culture • O&M work plan and Labour Strategy • Quality of Tender • Reliability and Code Compliance • Tenderer history of co-operative relationships and past dealings with past and current clients (including, as applicable, the GTAA) based, in part, on the performance of similar work by the Tenderer in previous projects awarded to the Tenderer in the last 10 years, claims history for the last 5 years, whether the Tenderer or its affiliates, subcontractors, or any individual associated with the Tenderer is or has been involved in any litigation or dispute or dispute resolution process with past and current clients (including, as applicable, the GTAA), briefly listing the nature and value of the claim and the applicable parties. These disputes shall include claims by or against the Tenderer or its affiliates, subcontractors, or individuals associated with the Tenderer . Any previous experience that the GTAA has had with the Tenderer or its proposed subcontractors or any individual associated with the Tenderer .	
Required Plans **Including:** • Transition Plan • Resource Plan • Safety Plan • Potential Risk and Mitigation Plan • other	10 points

Health and Safety, Environment	5 points

Part B; Cost Proposal – (40 points)

Compliant submissions shall be evaluated as follows.

The Cost Proposal with the Lowest overall cost Proposal will receive a score of 40 of 40 points; all other cost Proposal shall receive a smaller number of points as determined by the ratio of amount of each such Cost Proposal compared to the least expensive tender. The overall cost shall be determined by the GTAA based on the Tenderer submission.

EXAMPLE:

Based on the ratio of costs of each tender to the least expensive one., let's assume we have three tender each with a different cost: A costs $300,000; B costs $250,000; and C costs $275,000. Let us also assume that cost is worth 100 points.

Ratio of costs

The Tenderer with the lowest cost tender receives all 100 available points. All other Tenderers would receive a smaller number of points as determined by the ratio of their costs to the least expensive tender.

Tender	Cost	Calculation of Points	Points
A	$300,000	(250,000/300,000) x 100	83
B	$250,000	(250,000/250,000) x 100	100
C	$275,000	(250,000/275,000) x 100	91

1.3 Selection Method

Without limiting the generality of the GTAA's rights described elsewhere herein, the GTAA shall not be required to accept the highest ranked or lowest cost submission.

TA5 The tenderer offers to perform the Work for the following lump sum and unit prices (where applicable)

The following lump sum and unit prices (where applicable) below apply for both personnel (Contractor and Subcontractor, if applicable) and equipment.

1. All inclusive hourly rates shall include all travel time to and from the Work site, supervision, co-ordination, labour, trades tools and equipment (including maintenance, repair and replacement costs in respect thereof), overhead and profit and all other costs related to the performance of the Work under the Contract. The hourly rates shall start from arrival at job site and reflect only actual time performing the Work at the site. There will be no minimum charge.

2. For professional trades as defined by the Province of Ontario, the Contractor shall provide rates for trades persons licensed to work in Ontario. For all other disciplines the Contractor shall use only fully qualified individuals.

3. Statutory Holidays shall consist of New Year's Day, Good Friday, Victoria Day, Canada Day, Civic Holiday, Labour Day, Thanksgiving, Christmas Day and Boxing Day only.

All Inclusive (Lump Sum) Pricing

Tenderers may submit a tender for one or two or three packages or any combination thereof.

The GTAA reserves the right to enter into a contract or contracts with one or more tenders as determined by the GTAA in its sole discretion. Where the GTAA has elected to award only one or three packages of the work described herein to a tenderer or has elected to award different packages of the work to more than one tenderer, the Contract shall be only for that package or packages of the work which is indicated herein (Package 1 Annex A.1, Package 2 Annex A.2 and Package 3 Annex A.3) and the Contract price(s) shall be deemed to include only these packages.

The all-inclusive prices shall include all scheduled and non-scheduled maintenance, responding to and performing emergency Work, and carrying out repairs to all elevating device parts, components, or equipment, and/or replacing parts, components, or equipment.

The Work shall be performed in strict compliance with the operation and maintenance guidelines of the elevating device manufacturer and CSA B44-2007 (latest edition) Safety Code for elevating devices.

A. **Package 1 Annex A.1 : Lump Sum Price – Terminal Elevating Devices (Excluding High Speed Moving Walks)**

Year 1 April 1, 2016 – March 31, 2017	Year 2 April 1, 2017 – March 31, 2018	Year 3 April 1, 2018 – March 31, 2019	Year 4 April 1, 2019 – March 31, 2020	Year 5 April 1, 2020 – March 31, 2021
$	$	$	$	$

The annual lump sum price is payable in equal monthly installments and subject to the terms and conditions of the Contract.

B. **Package 2 Annex A.2 : Lump Sum Price – Outer Buildings Conventional Elevators**

Year 1 April 1, 2016 – March 31, 2017	Year 2 April 1, 2017 – March 31, 2018	Year 3 April 1, 2018 – March 31, 2019	Year 4 April 1, 2019 – March 31, 2020	Year 5 April 1, 2020 – March 31, 2021
$	$	$	$	$

The annual lump sum price is payable in equal monthly installments and subject to the terms and conditions of the Contract.

C. Package 3 Annex A.3: Lump Sum Price - High-Speed Moving Walks

Year 1 April 1, 2016 – March 31, 2017	Year 2 April 1, 2017 – March 31, 2018	Year 3 April 1, 2018 – March 31, 2019	Year 4 April 1, 2019 – March 31, 2020	Year 5 April 1, 2020 – March 31, 2021
$	$	$	$	$

The annual lump sum price is payable in equal monthly installments and subject to the terms and conditions of the Contract.

D. Package Discounts (tenderer to indicate any discounts if awarded more than one Package)

Year 1 April 1, 2016 – March 31, 2017	Year 2 April 1, 2017 – March 31, 2018	Year 3 April 1, 2018 – March 31, 2019	Year 4 April 1, 2019 – March 31, 2020	Year 5 April 1, 2020 – March 31, 2021
DISCOUNT FOR AWARD OF PACKAGE 1 AND 2 ($ or %)				
DISCOUNT FOR AWARD OF PACKAGE 2 AND 3 ($ or %)				
DISCOUNT FOR AWARD OF PACKAGE 1				

AND 3 ($ or %)				
DISCOUNT FOR AWARD OF ALL THREE PACKAGES ($ or %)				

1. Year 1: April 1, 2016 – March 31, 2017

Unit Prices

The Tenderer offers to perform the work for the Unit Prices (including all labour, materials, products, equipment, services and overhead, profit, disbursements and related charges) described in the following tables. Unit Prices listed are firm during the applicable period of the Contract.

These Unit Prices will be used for adjusting the Contract Price where changes are required in the Work forming a part of the Contract, and where quantities may be adjusted during the term of this Contract.

The following table is the Unit Price Arrangement for the purpose of additions or deletions to Work performed under a Lump Sum Arrangement including changes in the inventory of elevating devices or where elevating devices are removed from service.

a. Full Service: Regular Time Maintenance

PACKAGE 1: TERMINAL DEVICES EXCEPT HIGH SPEED WALKS			
Device	**# of Units**	**Monthly All Inclusive Cost per Unit**	**Annual All Inclusive Cost per Unit**
TRACTION PASSENGER ELEVATOR	35	$	$
TRACTION FREIGHT	6	$	$

ELEVATOR			
HYDRAULIC PASSENGER ELEVATOR	66	$	$
HYDRAULIC FREIGHT ELEVATOR	2	$	$
ESCALATOR TO 7000MM RISE	92	$	$
ESCALATOR OVER 7000MM RISE	3	$	$
PALLET STYLE MOVING WALK TO 30m	17	$	$
PALLET STYLE MOVING WALK OVER 30m	25	$	$
BELT STYLE MOVING WALK	6	$	$
BAGGAGE / MATERIAL LIFT	6	$	$
KONE MRL (eff. 6/1/16)	1	$	$
Total Portfolio	259		
LIFTNET MAINTENANCE	268	$	$

PACKAGE 2: GTAA OUTSIDE BUILDINGS			
Device	**# of Units**	**Monthly All Inclusive Cost per Unit**	**Annual All Inclusive Cost per Unit**
HYDRAULIC PASSENGER ELEVATOR	13	$	$
ACCESSIBILITY LIFT	1	$	$
DUMBWAITER	1	$	$
STAIR LIFT	1	$	$
Portfolio Total Units	16		
LIFTNET MAINTENANCE	1	$	$

PACKAGE 3: HIGH SPEED WALKS			
Device	**# of Units**	**Monthly All Inclusive Cost per Unit**	**Annual All Inclusive Cost per Unit**
HIGH SPEED WALKS	2	$	$
LIFTNET MAINTENANCE	2	$	$

b. Full Service: Over time Maintenance

PACKAGE 1: TERMINAL DEVICES EXCEPT HIGH SPEED WALKS			
Device	**# of Units**	**Monthly All Inclusive Cost per Unit**	**Annual All Inclusive Cost per Unit**
TRACTION PASSENGER ELEVATOR	2	$	$
TRACTION FREIGHT ELEVATOR	3	$	$
HYDRAULIC PASSENGER ELEVATOR	36	$	$
HYDRAULIC FREIGHT ELEVATOR	0	$	$
ESCALATOR TO 7000MM RISE	22	$	$
ESCALATOR OVER 7000MM RISE	9	$	$
PALLET STYLE MOVING WALK TO 30m	0	$	$
PALLET STYLE MOVING WALK OVER 30m	10	$	$
BELT STYLE MOVING WALK	0	$	$

BAGGAGE / MATERIAL LIFT	0	$	$
KONE MRL (eff. 6/1/16)	0	$	$
Total Portfolio	82		
LIFTNET MAINTENANCE	0	$	$

c. Partial Service: Regular Time Maintenance

PACKAGE 1: TERMINAL DEVICES EXCEPT HIGH SPEED WALKS			
Device	**# of Units**	**Monthly All Inclusive Cost per Unit**	**Annual All Inclusive Cost per Unit**
TRACTION PASSENGER ELEVATOR	0	$	$
TRACTION FREIGHT ELEVATOR	0	$	$
HYDRAULIC PASSENGER ELEVATOR	1	$	$
HYDRAULIC FREIGHT ELEVATOR	1	$	$
ESCALATOR TO 7000MM RISE	0	$	$
ESCALATOR OVER 7000MM RISE	0	$	$
PALLET STYLE MOVING WALK TO 30m	5	$	$
PALLET STYLE MOVING WALK OVER 30m	0	$	$
BELT STYLE MOVING WALK	0	$	$
BAGGAGE / MATERIAL LIFT	0	$	$
KONE MRL (eff. 6/1/16)	0	$	$
Total Portfolio	7		
LIFTNET MAINTENANCE	7	$	$

Additional Work

The GTAA at its sole and absolute discretion on an as and when requested basis during the period of the Contract may request the Contractor to perform additional work not included in the Scope of Work (Annex "A"). Such work will be reimbursed at the all-inclusive hourly rates (see TA5 (1)) detailed below. The GTAA does not guarantee any minimum or maximum under this category.

	*All inclusive Regular Time Hourly Rate	**All inclusive Premium Time Hourly Rate(Time and Half)	***All inclusive Premium Time Hourly Rate (Double Time)	****All Inclusive Overtime Rate Hourly Rate
Adjuster/Foreman	$	$	$	$
Licensed Mechanic	$	$	$	$
Helper	$	$	$	$

Material Cost above Invoice Cost %_____

***The bidder must provide the hours considered regular hours and after hours.**

****Premium time and a half applies to maintenance work.**

*****Premium double time applies to repair work or other work.**

******Overtime Rate applies to work not covered under the Contract and performed after regular hours.**

NOTE: In quoting Over Time and Premium Time rates, the bidder is expected to adjust indirect costs to reflect the fact that some indirect costs are based on worked hours, not paid dollars.

Year 2: April 1, 2017 – March 31, 2018

Unit Prices

The Tenderer offers to perform the work for the Unit Prices (including all labour, materials, products, equipment, services and overhead, profit, disbursements and related charges) described in the following tables. Unit Prices listed are firm during the applicable period of the Contract.

These Unit Prices will be used for adjusting the Contract Price where changes are required in the Work forming a part of the Contract, and where quantities may be adjusted during the term of this Contract.

The following table is the Unit Price Arrangement for the purpose of additions or deletions to Work performed under a Lump Sum Arrangement including changes in the inventory of elevating devices or where elevating devices are removed from service.

Unit Pricing

a. **Full Service: Regular Time Maintenance**

PACKAGE 1: TERMINAL DEVICES EXCEPT HIGH SPEED WALKS			
Device	**# of Units**	**Monthly All Inclusive Cost per Unit**	**Annual All Inclusive Cost per Unit**
TRACTION PASSENGER ELEVATOR	35	$	$
TRACTION FREIGHT ELEVATOR	6	$	$
HYDRAULIC PASSENGER ELEVATOR	66	$	$
HYDRAULIC FREIGHT ELEVATOR	2	$	$
ESCALATOR TO 7000MM RISE	92	$	$
ESCALATOR OVER 7000MM RISE	3	$	$

PALLET STYLE MOVING WALK TO 30m	17	$	$
PALLET STYLE MOVING WALK OVER 30m	25	$	$
BELT STYLE MOVING WALK	6	$	$
BAGGAGE / MATERIAL LIFT	6	$	$
KONE MRL (eff. 6/1/16)	1	$	$
Total Portfolio	259		
LIFTNET MAINTENANCE	268	$	$

PACKAGE 2: GTAA OUTSIDE BUILDINGS			
Device	**# of Units**	**Monthly All Inclusive Cost per Unit**	**Annual All Inclusive Cost per Unit**
HYDRAULIC PASSENGER ELEVATOR	13	$	$
ACCESSIBILITY LIFT	1	$	$
DUMBWAITER	1	$	$
STAIR LIFT	1	$	$
Portfolio Total Units	16		
LIFTNET MAINTENANCE	1	$	$

PACKAGE 3: HIGH SPEED WALKS			
Device	**# of Units**	**Monthly All Inclusive Cost per Unit**	**Annual All Inclusive Cost per Unit**
HIGH SPEED WALKS	2	$	$
LIFTNET MAINTENANCE	2	$	$

b. Full Service: Over time Maintenance

PACKAGE 1: TERMINAL DEVICES EXCEPT HIGH SPEED WALKS			
Device	**# of Units**	**Monthly All Inclusive Cost per Unit**	**Annual All Inclusive Cost per Unit**
TRACTION PASSENGER ELEVATOR	2	$	$
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HYDRAULIC PASSENGER ELEVATOR	36	$	$
HYDRAULIC FREIGHT ELEVATOR	0	$	$
ESCALATOR TO 7000MM RISE	22	$	$
ESCALATOR OVER 7000MM RISE	9	$	$
PALLET STYLE MOVING WALK TO 30m	0	$	$
PALLET STYLE MOVING WALK OVER 30m	10	$	$
BELT STYLE MOVING WALK	0	$	$
BAGGAGE / MATERIAL LIFT	0	$	$
KONE MRL (eff. 6/1/16)	0	$	$
Total Portfolio	82		
LIFTNET MAINTENANCE	0	$	$

c. Partial Service: Regular Time Maintenance

PACKAGE 1: TERMINAL DEVICES EXCEPT HIGH SPEED WALKS			
Device	**# of Units**	**Monthly All Inclusive Cost per Unit**	**Annual All Inclusive Cost per Unit**
TRACTION PASSENGER ELEVATOR	0	$	$
TRACTION FREIGHT ELEVATOR	0	$	$
HYDRAULIC PASSENGER ELEVATOR	1	$	$
HYDRAULIC FREIGHT ELEVATOR	1	$	$
ESCALATOR TO 7000MM RISE	0	$	$
ESCALATOR OVER 7000MM RISE	0	$	$
PALLET STYLE MOVING WALK TO 30m	5	$	$
PALLET STYLE MOVING WALK OVER 30m	0	$	$
BELT STYLE MOVING WALK	0	$	$
BAGGAGE / MATERIAL LIFT	0	$	$
KONE MRL (eff. 6/1/16)	0	$	$
Total Portfolio	7		
LIFTNET MAINTENANCE	7	$	$

Additional Work

The GTAA at its sole and absolute discretion on an as and when requested basis during the period of the Contract may request the Contractor to perform additional work not included in the Scope of Work (Annex "A"). Such work will be reimbursed at the all-inclusive hourly rates (see TA5 (1)) detailed below. The GTAA does not guarantee any minimum or maximum under this category.

	*All inclusive Regular Time Hourly Rate	**All inclusive Premium Time Hourly Rate Time and Half	***All inclusive Premium Time Hourly Rate Double Time	****All inclusive Overtime Rate Hourly Rate
Adjuster/Foreman	$	$	$	$
Licensed Mechanic	$	$	$	$
Helper	$	$	$	$

Material Cost above Invoice Cost %_____

*The bidder must provide the hours considered regular hours and after hours.

**Premium time and a half applies to maintenance work

***Premium double time applies to repair work or other work

****Overtime Rate applies to work not covered under the Contract and performed after regular hours

NOTE: In quoting Over Time and Premium Time rates the bidder is expected to adjust indirect costs to reflect the fact that some indirect costs are based on worked hours, not paid dollars.

2. Year 3: April 1, 2018 – March 31, 2019

Unit Prices

The Tenderer offers to perform the work for the Unit Prices (including all labour, materials, products, equipment, services and overhead, profit, disbursements and related charges) described in the following tables. Unit Prices listed are firm during the applicable period of the Contract.

These Unit Prices will be used for adjusting the Contract Price where changes are required in the Work forming a part of the Contract, and where quantities may be adjusted during the term of this Contract.

The following table is the Unit Price Arrangement for the purpose of additions or deletions to Work performed under a Lump Sum Arrangement including changes in the inventory of elevating devices or where elevating devices are removed from service.

Unit Pricing

a. **Full Service: Regular Time Maintenance**

PACKAGE 1: TERMINAL DEVICES EXCEPT HIGH SPEED WALKS			
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TRACTION FREIGHT ELEVATOR	6	$	$
HYDRAULIC PASSENGER ELEVATOR	66	$	$
HYDRAULIC FREIGHT ELEVATOR	2	$	$

ESCALATOR TO 7000MM RISE	92	$	$
ESCALATOR OVER 7000MM RISE	3	$	$
PALLET STYLE MOVING WALK TO 30m	17	$	$
PALLET STYLE MOVING WALK OVER 30m	25	$	$
BELT STYLE MOVING WALK	6	$	$
BAGGAGE / MATERIAL LIFT	6	$	$
KONE MRL (eff. 6/1/16)	1	$	$
Total Portfolio	259		
LIFTNET MAINTENANCE	268	$	$

PACKAGE 2: GTAA OUTSIDE BUILDINGS			
Device	**# of Units**	**Monthly All Inclusive Cost per Unit**	**Annual All Inclusive Cost per Unit**
HYDRAULIC PASSENGER ELEVATOR	13	$	$
ACCESSIBILITY LIFT	1	$	$
DUMBWAITER	1	$	$
STAIR LIFT	1	$	$
Portfolio Total Units	16		
LIFTNET MAINTENANCE	1	$	$

PACKAGE 3: HIGH SPEED WALKS			
Device	**# of Units**	**Monthly All Inclusive Cost per Unit**	**Annual All Inclusive Cost per Unit**

HIGH SPEED WALKS	2	$	$
LIFTNET MAINTENANCE	2	$	$

b. Full Service: Over time Maintenance

PACKAGE 1: TERMINAL DEVICES EXCEPT HIGH SPEED WALKS			
Device	**# of Units**	**Monthly All Inclusive Cost per Unit**	**Annual All Inclusive Cost per Unit**
TRACTION PASSENGER ELEVATOR	2	$	$
TRACTION FREIGHT ELEVATOR	3	$	$
HYDRAULIC PASSENGER ELEVATOR	36	$	$
HYDRAULIC FREIGHT ELEVATOR	0	$	$
ESCALATOR TO 7000MM RISE	22	$	$
ESCALATOR OVER 7000MM RISE	9	$	$
PALLET STYLE MOVING WALK TO 30m	0	$	$
PALLET STYLE MOVING WALK OVER 30m	10	$	$
BELT STYLE MOVING WALK	0	$	$
BAGGAGE / MATERIAL LIFT	0	$	$
KONE MRL (eff. 6/1/16)	0	$	$
Total Portfolio	82		
LIFTNET MAINTENANCE	0	$	$

c. **Partial Service: Regular Time Maintenance**

PACKAGE 1: TERMINAL DEVICES EXCEPT HIGH SPEED WALKS			
Device	**# of Units**	**Monthly All Inclusive Cost per Unit**	**Annual All Inclusive Cost per Unit**
TRACTION PASSENGER ELEVATOR	0	$	$
TRACTION FREIGHT ELEVATOR	0	$	$
HYDRAULIC PASSENGER ELEVATOR	1	$	$
HYDRAULIC FREIGHT ELEVATOR	1	$	$
ESCALATOR TO 7000MM RISE	0	$	$
ESCALATOR OVER 7000MM RISE	0	$	$
PALLET STYLE MOVING WALK TO 30m	5	$	$
PALLET STYLE MOVING WALK OVER 30m	0	$	$
BELT STYLE MOVING WALK	0	$	$
BAGGAGE / MATERIAL LIFT	0	$	$
KONE MRL (eff. 6/1/16)	0	$	$
Total Portfolio	7		
LIFTNET MAINTENANCE	7	$	$

Additional Work

The GTAA at its sole and absolute discretion on an as and when requested basis during the period of the Contract may request the Contractor to perform additional work not included in the Scope of Work (Annex "A"). Such work will be reimbursed at the all-inclusive hourly rates (see TA5 (1)) detailed below. The GTAA does not guarantee any minimum or maximum under this category.

	*All inclusive Regular Time Hourly Rate	**All inclusive Premium Time Hourly Rate Time and Half	***All inclusive Premium Time Hourly Rate Double Time	****All Inclusive Overtime Rate Hourly Rate
Adjuster/Foreman	$	$	$	$
Licensed Mechanic	$	$	$	$
Helper	$	$	$	$

Material Cost above Invoice Cost %_____

***The bidder must provide the hours considered regular hours and after hours.**

****Premium time and a half applies to maintenance work.**

*****Premium double time applies to repair work or other work.**

******Overtime Rate applies to work not covered under the Contract and performed after regular hours.**

NOTE: In quoting Over Time and Premium Time rates the bidder is expected to adjust indirect costs to reflect the fact that some indirect costs are based on worked hours, not paid dollars.

3. Year 4: April 1, 2019 – March 31, 2020

Unit Prices

The Tenderer offers to perform the work for the Unit Prices (including all labour, materials, products, equipment, services and overhead, profit, disbursements and related charges) described in the following tables. Unit Prices listed are firm during the applicable period of the Contract.

These Unit Prices will be used for adjusting the Contract Price where changes are required in the Work forming a part of the Contract, and where quantities may be adjusted during the term of this Contract.

The following table is the Unit Price Arrangement for the purpose of additions or deletions to Work performed under a Lump Sum Arrangement including changes in the inventory of elevating devices or where elevating devices are removed from service.

Unit Pricing

a. **Full Service: Regular Time Maintenance**

PACKAGE 1: TERMINAL DEVICES EXCEPT HIGH SPEED WALKS			
Device	**# of Units**	**Monthly All Inclusive Cost per Unit**	**Annual All Inclusive Cost per Unit**
TRACTION PASSENGER ELEVATOR	35	$	$
TRACTION FREIGHT ELEVATOR	6	$	$
HYDRAULIC PASSENGER ELEVATOR	66	$	$
HYDRAULIC FREIGHT ELEVATOR	2	$	$
ESCALATOR TO 7000MM RISE	92	$	$

ESCALATOR OVER 7000MM RISE	3	$	$
PALLET STYLE MOVING WALK TO 30m	17	$	$
PALLET STYLE MOVING WALK OVER 30m	25	$	$
BELT STYLE MOVING WALK	6	$	$
BAGGAGE / MATERIAL LIFT	6	$	$
KONE MRL (eff. 6/1/16)	1	$	$
Total Portfolio	259		
LIFTNET MAINTENANCE	268	$	$

PACKAGE 2: GTAA OUTSIDE BUILDINGS			
Device	**# of Units**	**Monthly All Inclusive Cost per Unit**	**Annual All Inclusive Cost per Unit**
HYDRAULIC PASSENGER ELEVATOR	13	$	$
ACCESSIBILITY LIFT	1	$	$
DUMBWAITER	1	$	$
STAIR LIFT	1	$	$
Portfolio Total Units	16		
LIFTNET MAINTENANCE	1	$	$

PACKAGE 3: HIGH SPEED WALKS			
Device	**# of Units**	**Monthly All Inclusive Cost per Unit**	**Annual All Inclusive Cost per Unit**
HIGH SPEED WALKS	2	$	$
LIFTNET	2	$	$

MAINTENANCE			

b. Full Service: Over time Maintenance

PACKAGE 1: TERMINAL DEVICES EXCEPT HIGH SPEED WALKS			
Device	**# of Units**	**Monthly All Inclusive Cost per Unit**	**Annual All Inclusive Cost per Unit**
TRACTION PASSENGER ELEVATOR	2	$	$
TRACTION FREIGHT ELEVATOR	3	$	$
HYDRAULIC PASSENGER ELEVATOR	36	$	$
HYDRAULIC FREIGHT ELEVATOR	0	$	$
ESCALATOR TO 7000MM RISE	22	$	$
ESCALATOR OVER 7000MM RISE	9	$	$
PALLET STYLE MOVING WALK TO 30m	0	$	$
PALLET STYLE MOVING WALK OVER 30m	10	$	$
BELT STYLE MOVING WALK	0	$	$
BAGGAGE / MATERIAL LIFT	0	$	$
KONE MRL (eff. 6/1/16)	0	$	$
Total Portfolio	82		
LIFTNET MAINTENANCE	0	$	$

c. **Partial Service: Regular Time Maintenance**

PACKAGE 1: TERMINAL DEVICES EXCEPT HIGH SPEED WALKS			
Device	**# of Units**	**Monthly All Inclusive Cost per Unit**	**Annual All Inclusive Cost per Unit**
TRACTION PASSENGER ELEVATOR	0	$	$
TRACTION FREIGHT ELEVATOR	0	$	$
HYDRAULIC PASSENGER ELEVATOR	1	$	$
HYDRAULIC FREIGHT ELEVATOR	1	$	$
ESCALATOR TO 7000MM RISE	0	$	$
ESCALATOR OVER 7000MM RISE	0	$	$
PALLET STYLE MOVING WALK TO 30m	5	$	$
PALLET STYLE MOVING WALK OVER 30m	0	$	$
BELT STYLE MOVING WALK	0	$	$
BAGGAGE / MATERIAL LIFT	0	$	$
KONE MRL (eff. 6/1/16)	0	$	$
Total Portfolio	7		
LIFTNET MAINTENANCE	7	$	$

Additional Work

The GTAA at its sole and absolute discretion on an as and when requested basis during the period of the Contract may request the Contractor to perform additional work not included in the Scope of Work (Annex "A"). Such work will be reimbursed at the all-inclusive hourly rates (see TA5 (1)) detailed below. The GTAA does not guarantee any minimum or maximum under this category.

	*All Inclusive Regular Time Hourly Rate	**All Inclusive Premium Time Hourly Rate Time and Half	***All Inclusive Premium Time Hourly Rate Double Time	****All Inclusive Overtime Rate Hourly Rate
Adjuster/Foreman	$	$	$	$
Licensed Mechanic	$	$	$	$
Helper	$	$	$	$

Material Cost above Invoice Cost %_____

*The bidder must provide the hours considered regular hours and after hours.

**Premium time and a half applies to maintenance work.

***Premium double time applies to repair work or other work.

****Overtime Rate applies to work not covered under the Contract and performed after regular hours.

NOTE: In quoting Over Time and Premium Time rates the bidder is expected to adjust indirect costs to reflect the fact that some indirect costs are based on worked hours, not paid dollars.

4. Year 5: April 1, 2020 – March 31, 2021

Unit Prices

The Tenderer offers to perform the work for the Unit Prices (including all labour, materials, products, equipment, services and overhead, profit, disbursements and related charges) described in the following tables. Unit Prices listed are firm during the applicable period of the Contract.

These Unit Prices will be used for adjusting the Contract Price where changes are required in the Work forming a part of the Contract, and where quantities may be adjusted during the term of this Contract.

The following table is the Unit Price Arrangement for the purpose of additions or deletions to Work performed under a Lump Sum Arrangement including changes in the inventory of elevating devices or where elevating devices are removed from service.

Unit Pricing

a. **Full Service: Regular Time Maintenance**

PACKAGE 1: TERMINAL DEVICES EXCEPT HIGH SPEED WALKS			
Device	**# of Units**	**Monthly All Inclusive Cost per Unit**	**Annual All Inclusive Cost per Unit**
TRACTION PASSENGER ELEVATOR	35	$	$
TRACTION FREIGHT ELEVATOR	6	$	$
HYDRAULIC PASSENGER ELEVATOR	66	$	$
HYDRAULIC FREIGHT ELEVATOR	2	$	$
ESCALATOR TO	92	$	$

7000MM RISE			
ESCALATOR OVER 7000MM RISE	3	$	$
PALLET STYLE MOVING WALK TO 30m	17	$	$
PALLET STYLE MOVING WALK OVER 30m	25	$	$
BELT STYLE MOVING WALK	6	$	$
BAGGAGE / MATERIAL LIFT	6	$	$
KONE MRL (eff. 6/1/16)	1	$	$
Total Portfolio	259		
LIFTNET MAINTENANCE	268	$	$

PACKAGE 2: GTAA OUTSIDE BUILDINGS			
Device	**# of Units**	**Monthly All Inclusive Cost per Unit**	**Annual All Inclusive Cost per Unit**
HYDRAULIC PASSENGER ELEVATOR	13	$	$
ACCESSIBILITY LIFT	1	$	$
DUMBWAITER	1	$	$
STAIR LIFT	1	$	$
Portfolio Total Units	16		
LIFTNET MAINTENANCE	1	$	$

PACKAGE 3: HIGH SPEED WALKS			
Device	**# of Units**	**Monthly All Inclusive Cost per Unit**	**Annual All Inclusive Cost per Unit**
HIGH SPEED WALKS	2	$	$

LIFTNET MAINTENANCE	2	$	$

b. Full Service: Over time Maintenance

PACKAGE 1: TERMINAL DEVICES EXCEPT HIGH SPEED WALKS			
Device	**# of Units**	**Monthly All Inclusive Cost per Unit**	**Annual All Inclusive Cost per Unit**
TRACTION PASSENGER ELEVATOR	2	$	$
TRACTION FREIGHT ELEVATOR	3	$	$
HYDRAULIC PASSENGER ELEVATOR	36	$	$
HYDRAULIC FREIGHT ELEVATOR	0	$	$
ESCALATOR TO 7000MM RISE	22	$	$
ESCALATOR OVER 7000MM RISE	9	$	$
PALLET STYLE MOVING WALK TO 30m	0	$	$
PALLET STYLE MOVING WALK OVER 30m	10	$	$
BELT STYLE MOVING WALK	0	$	$
BAGGAGE / MATERIAL LIFT	0	$	$
KONE MRL (eff. 6/1/16)	0	$	$
Total Portfolio	82		
LIFTNET MAINTENANCE	0	$	$

c. **Partial Service: Regular Time Maintenance**

PACKAGE 1: TERMINAL DEVICES EXCEPT HIGH SPEED WALKS			
Device	**# of Units**	**Monthly All Inclusive Cost per Unit**	**Annual All Inclusive Cost per Unit**
TRACTION PASSENGER ELEVATOR	0	$	$
TRACTION FREIGHT ELEVATOR	0	$	$
HYDRAULIC PASSENGER ELEVATOR	1	$	$
HYDRAULIC FREIGHT ELEVATOR	1	$	$
ESCALATOR TO 7000MM RISE	0	$	$
ESCALATOR OVER 7000MM RISE	0	$	$
PALLET STYLE MOVING WALK TO 30m	5	$	$
PALLET STYLE MOVING WALK OVER 30m	0	$	$
BELT STYLE MOVING WALK	0	$	$
BAGGAGE / MATERIAL LIFT	0	$	$
KONE MRL (eff. 6/1/16)	0	$	$
Total Portfolio	7		
LIFTNET MAINTENANCE	7	$	$

Additional Work

The GTAA at its sole and absolute discretion on an as and when requested basis during the period of the Contract may request the Contractor to perform additional work not included in the Scope of Work (Annex "A"). Such work will be reimbursed at the all-inclusive hourly rates (see TA5 (1)) detailed below. The GTAA does not guarantee any minimum or maximum under this category.

	*All inclusive Regular Time Hourly Rate	**All inclusive Premium Time Hourly Rate Time and Half	***All inclusive Premium Time Hourly Rate Double Time	****All inclusive Overtime Rate Hourly Rate
Adjuster/Foreman	$	$	$	$
Licensed Mechanic	$	$	$	$
Helper	$	$	$	$

Material Cost above Invoice Cost %_____

***The bidder must provide the hours considered regular hours and after hours.**

****Premium time and a half applies to maintenance work.**

*****Premium double time applies to repair work or other work.**

******Overtime Rate applies to work not covered under the Contract and performed after regular hours.**

NOTE: In quoting Over Time and Premium Time rates the bidder is expected to adjust indirect costs to reflect the fact that some indirect costs are based on worked hours, not paid dollars.

5.1 The tenderer agrees that prices tendered in this Article TA5 include, without limitation, customs tariffs and duties, taxes, royalties, handling, transportation, overhead, profit and all other charges, costs, excluding the Harmonized Sales Taxes (HST).

5.2 The tenderer acknowledges and agrees that its tender shall remain firm and irrevocable and open for acceptance by the GTAA at any time, (following the Closing Time) for a period of forty-five (45) days, or such longer period as the GTAA and the tenderer may agree.

TA6 CONTRACT PERIOD

The tenderer shall provide the Work stated herein for the period commencing April 1, 2016 and ending March 31, 2021 subject to earlier termination as provided in Annex "C".

TA7 The tenderer shall be paid for Work completed to the GTAA's satisfaction in accordance with the rates quoted in TA5.

TA8 The tenderer acknowledges that the payment procedures under the Contract documents include compliance with the holdback and other requirements of the Construction Lien Act (Ontario) (if applicable).

TA9 If the tenderer is a consortium, joint venture or partnership comprised of more than one person or entity, then each of the persons or entities shall be bound jointly and severally to fulfill the tenderer's obligations under the Contract.

Annex A: Scope of Work

Maintenance and Repair Services of Elevators, Escalators, and Moving Walks

GTAA

1 Scope of Work

1.1 Intent

The intent of the Maintenance Contract is to provide comprehensive maintenance services (preventative maintenance, corrective and demand repairs and emergency response) to the GTAA's elevating devices in a timely cost effective, efficient and environmentally safe manner, in accordance with the terms and conditions of the Contract, so as to:

- Provide trouble-free service in order to prolong equipment life, to continually provide performance quality as per original equipment manufacturers (OEM) installation.
- Keep the equipment in substantially new condition and maintain its performance in accordance with operating parameters and design features of the original installation specifications of the equipment.
- Provide high level of uptime service availability to Toronto Pearson passengers and employees.

Under this Scope of Work, the Contractor shall perform all inclusive, planned and non-scheduled maintenance, and CAT 1 and CAT 5 testing, responding to and performing emergency work, and carrying out repairs and/or replacing components, equipment, tools and parts to all elevators, escalators moving walks and other types of devices described, collectively as "elevating devices", at the Airport as set out in the GTAA's inventory of elevating devices in Appendix A, which the GTAA may change from time to time.

In performing the Scope of Work the Contractor shall provide all labor, supervision, materials parts, supplies, tools, Contractor's Equipment, diagnostic equipment, vehicles, cleaning agents, and all other materials necessary for the due execution of the Work described in this Scope of Work including in Annexes A, A1, A2, A3 and A4 in the following buildings:

- Terminal 1
- Terminal 1 Parking Garage
- Infield Terminal (IFT)
- Terminal 3 (including Terminal 3 Pier A)
- Terminal 3 Parking Garage
- Automated People Mover (APM) stations (Terminal 1, Terminal 3 and Viscount Road)

- Value Park Garage (6B)
- GTAA administration building
- Cargo 2 building
- Cargo 3 building
- Central De-icing Facility
- FESTI building
- Peel Police building
- Transport Canada building
- Airfield Maintenance Facility.

The GTAA's current inventory of the elevating devices, covered by this Scope of Work, is attached as Appendix A and subject to change from time-to-time-. In case GTAA adds or deletes elevating devices, the Contract price shall be adjusted based on the unit costs set out in the Contract and Pricing Table.

The Contractor shall be an expert in the Work, as defined in this Scope of Work, and shall perform the Work applying best industry practices and effective and safe methods of work. The GTAA relies on the expertise of the Contractor to perform the Work. The GTAA is looking for the Contractor to provide information /recommendation on best practices and opportunities for efficiencies and increased value.

The Contractor shall Contract not subcontract any of the Work without prior written approval of the GTAA. All conditions and procedures applicable to the Contractor shall also apply to sub-trade personnel.

2 Contractor's Work Compliance

The Contractor shall perform the Scope of Work in strict compliance, and adhere to the Contract and the following:

1. CSA B44-2013 (latest edition) Safety Code for elevating devices – CAN CSA B355 – 2009 (R2013) Lifts for Persons with Physical Disabilities.
2. Any and all manufacturer's operations and maintenance guidelines in provided maintenance manuals.
3. Current Ontario TSSA regulatory items and directors orders if agreed by GTAA.
4. Reliably and in a safe manner to maintain service to tenants and occupants of the Airport, the public, and the GTAA and in strict accordance with all guidelines, codes and Applicable Laws.
5. GTAA Standard Operating Procedures, as attached.

6. Using trade's personnel licensed in accordance with this Scope of Work, to operate and maintain elevating devices. Contractor's schedule shall include work to be performed seven (7) days per week, including weekends and statutory holidays.
7. Some Scope of Work in highly utilized areas shall be required during off hours and/or on weekends to minimize impact on Airport operations (see Appendix A – GTAA's Inventory of Elevating Devices).The Contractor shall be available on a twenty-four (24) hours a day, seven (7) days per week, year round basis to perform the Work.
8. The Contractor shall develop and implement a staffing plan to meet the performance benchmark, as defined in this Scope of Work. Any changes to this plan, must be communicated, reviewed and approved in advance by the GTAA in writing.

3 Airport Operational and Maintenance Coverage

3.1 Operational Coverage Hours

1. With regard to Annex A.1 and A.3, the Contractor shall provide on-site personnel for operational coverage between the hours of 0600 hours-2400 hours, 7 days a week, 365 days a year to satisfy performance requirements, respond to emergencies, incidents, accidents, technical failures, all mechanic required restarts requests for escalators, moving walks and elevators.
2. With regard to Annex A.2, the Contractor is not required to have on-site operational coverage.
3. The Contractor's Mechanics providing Airport operational coverage for in Annexes A.1 and A.3 may be used for maintenance giving priority to operational coverage including calls, restarts and emergencies.

3.2 Maintenance Coverage Hours

1. The Contractor shall perform Scope of Work in the Airport in highly utilized terminal areas during non-operational hours and/or on weekends to minimize impact on Airport operations. Based on Airport impact, the GTAA has classified all Elevating Devices into three (3) groups (as per the Inventory of Units attached to this Scope of Work):
   - Critical Elevating Devices
   - Impacting Customer Experience Elevating Devices
   - Regular Elevating Devices.

Each of these groups has different requirements for the time of the day when the Contractor shall perform scheduled maintenance, such as:

- All Scheduled Maintenance including annual tasks for Critical Elevating Devices shall be performed only during 1800 hours and 0530 hours (refer to Appendix A: Elevating Devices Classification).
- Scheduled Maintenance for Impacting Customer Experience Elevating Devices can be performed during the hours of 0600 hours -1800 hours. The Contractor shall coordinate and receive approval from the GTAA in advance for any pro-longed shutdowns such as annuals, CAT1, CAT5 tests or similar work.
- Scheduled maintenance for Regular Elevating Devices can be performed during the hours of 0600 hours to 1800 hours coordinating the Work with GTAA Representative.

Completing regulatory CAT (Category) tests and clean downs for escalators and moving walks:

- The Contractor shall make every effort to minimize disruption of the Airport operation when scheduling CAT testing and clean downs for escalator and walk preventative maintenance tests.
- CAT1 maintenance for Critical Escalators and Moving Walk shall be done in one continuous shutdown cycle (refer to the Elevating Devices Classification document for critical list of units). This maintenance Work shall not be interrupted when started and shall continue until it is fully complete without deferring to next day.
- The Contractor shall schedule maintenance of the escalators and elevators, which service passenger boarding areas (gates) (Critical Elevating Devices and Impacting Customer Experience elevating devices) during the time when no flight activity is scheduled. All maintenance for the elevating devices servicing gates shall be coordinated with GTAA IOCC and RMU both in advance and at the time of the work.

4 Daily Operational Support and Signage

1. Upon arrival and departure from the Airport, the Contractor shall ensure that its personnel must check in and check out with the IOCC (416-7766-3055).
2. The Contractor shall comply with the Contractual response times. If the unit must be taken out of service, the Contractor shall erect GTAA approved signs and safety barricades at each point of access to the unit (ends of the escalator or moving walk, and outside landing of each floor served by the elevator). As part of RFP proposal the Contractor shall demonstrate what type of "out of service "signs will be used.

3. When responding to calls dispatched by the IOCC, the Contractor shall, upon arrival at the unit, advise the IOCC via radio or phone (6-3055).
4. The Contractor shall display small, light, and portable contingency signage to direct users to the next available unit in service. The signage shall be mounted on or near the barricades. The signs shall be legible, professionally made and be installed during each outage.
5. The Contractor shall supply and erect GTAA approved warning signs and barricades around all Work areas. It is the Contractor's sole responsibility to properly identify any and all situations where any danger exists and erect sufficient and appropriate signs. The Contractor shall also erect signs to direct passengers and employees to alternate units in service. No damaged, broken or not legible signs shall be used. All public signs shall be in two official language English and French.
6. The Contractor shall, before removing any elevating device from service for Work, notify the IOCC of the unit number and the duration it will be out of service. Upon completion of the Work the Contractor shall notify IOCC that the elevating device is back in service. For scheduled shutdowns, the Contractor shall follow the GTAA Shutdown Procedure.
7. In order to minimize impact to passenger flow and prolonged inconveniences, no more than two (2) adjacent units or units in the same area shall be taken out of service for maintenance concurrently. Where a unit is out of service and maintenance is scheduled on an adjacent unit, the out of service until must first be repaired and placed in public service before continuing with scheduled maintenance work. Where scheduled maintenance work schedule is affected, arrangement must be made with IOCC to reschedule the work at an agreeable time.
8. During on-site Operational Coverage, the Contractor will respond, complete all restarts and/or determine if further corrective work is required, at no additional cost to the GTAA, regardless of the reason for the unit stoppage.
9. The Contractor shall promptly respond to all calls from the IOCC (as detailed in the Performance Benchmark in this Scope of Work), at no additional cost to the GTAA.
10. The Contractor shall cooperate with the GTAA to mitigate interference or inconvenience to Airport Operations for the tenants, the public, and the GTAA.
11. The Contractor's Representative shall attend daily maintenance & operational briefings at the times and places directed by the GTAA Representative. Meetings are held to review performance, Scope of Work, invoices, coordination of Work with the Airport, projects and additional work and/ or discuss other items of mutual interest.

12. The Contractor shall provide notice to the IOCC and the GTAA Representative, reporting any elevating device that is expected to exceed 12 hours out of service. The report shall identify the reason(s) the unit is out of service, corrective action(s) being taken and expected return to service date and time. If the unit's downtime exceeds 12 hours the Contractor shall report it to IOCC to provide a status on the unit and estimated date and time to be back in service.

5 Regulatory Inspections and Compliance Verification by Third Party Inspection

GTAA uses a third-party Inspection Company contracted to continuously verify compliance of the Toronto Pearson elevators, escalators and moving walks with all applicable codes and standards. There are two (2) types of inspections conducted by the GTAA's Inspection Contractor on all elevating devices per year.

1. Regulatory Inspection is performed once per year for each elevating device to maintain compliance to the applicable codes
2. Operational Inspection is performed once per year to comply with GTAA customer service requirements, operational needs and public safety
3. The Contractor shall accommodate and coordinate with the GTAA's designated Inspection Company access to the elevating devices to perform regulatory inspections.
4. The Contractor shall communicate maintenance schedule for all CAT1 and CAT5 tests on a monthly basis with the GTAA and GTAA's designated Inspection Company. The GTAA's designated Inspection Company will perform the regulatory inspection at the same time as the Contractor performs the CAT1 and CAT 5 maintenance and testing. The Contractor shall coordinate and provide access for GTAA's designated Inspection CompanyInspection Company to inspect the units during CAT1 and CAT5 testing.
5. The Contractor shall comply with all directives provided by the GTAA's designated elevator Inspection Company within the specified due dates and provide supporting documentation to confirm compliance. The Contractor shall not be compensated for complying with directives that relate to work, the Contractor is required to perform under this Scope of Work and Contract.
6. While completing the Category 1 (CAT1) on escalators and moving walks, the Contractor shall identify all regulatory and non-regulatory issues with the units and complete repairs wherever possible. In cases where the Contractor is unable to rectify any issues during CAT1 maintenance, the Contractor shall schedule the corrective work within 2 weeks. For all corrective Work, the Contractor shall open a work order in EAM. GTAA reserves the right to audit the completion and accuracy of the corrective work logged in EAM at any time.

7. The Contractor shall comply with all directives provided to the GTAA by the GTAA's designated elevator inspector and provide documentation to confirm compliance and that any issues and/or work have been completed.

5.1 Elevating Devices Whiteboard (EDW)

The Elevating Devices Whiteboard (see EDW) is a custom application developed and administered by the GTAA. This application is used to track and manage all inspections, deficiencies, and corrective maintenance, as identified by the GTAA designated Inspection Company, for all GTAA owned elevators, escalators, and moving walks.

1. The Contractor shall use the EDW (see the EDW manual attached to this Scope of Work) to update on a weekly basis, and input its compliance with all directives, which are logged by the GTAA's designated Inspection Company.
2. The Elevating Devices Whiteboard is interactive / web based application and will utilize email messaging to notify all stakeholders such as the GTAA designated inspection-company and the Contractor about the open, closed and complete directives.
3. The Contractor shall provide email addresses to the GTAA of the designated personnel who will use the EDW application.
4. The GTAA will provide access to the EDW and training for the Contractor's designated personnel.
5. The GTAA reserves the right to replace the EDW with another application based on the regulatory requirements and airport needs. In case GTAA replaces the EDW with EAM the Contractor will be provided with access to the EAM system and necessary training and documentation.

6 GTAA Maintenance Control Program (MCP)

The Contractor shall include in its tender, a detailed description of the unit specific MCP program will be used to maintain the GTAA elevators, escalators and moving walks.

The Contractor's MCP shall demonstrate and include:

1. Compliance to clause 8.6 of the B44 2013 Code (the "Code") for Elevating Devices.
2. Compliance with manufacturer's recommended maintenance requirements for each device.
3. Defined maintenance and test procedures for special or unique components and devices not covered by generic procedures.
4. A maintenance logbook detailing:

- List of unit specific routine maintenance procedures and tasks.
- Planned frequency of performance for each task.
- Category 1 inspections and tests.
- Category 5 inspections and tests.
- Recommended repairs section.
- Completed repairs section.
- Record of Firefighter's Emergency Operation annual testing.
- Oil level record keeping for hydraulic elevators.
- All non-applicable tasks in generic logbooks must be neatly and clearly crossed out and initialed at start of the maintenance program.
- All regulatory log books and maintenance records have to be stored at the Airport in designated locations approved by the GTAA. All signatures and records must be performed by authorized Contractor's personnel and be clear and legible. All signatures must have a legend at the end of the log with printed names.

5. As part of the Contractor's proposed MCP, the Contractor shall demonstrate how the MCP will prolong the service life of the GTAA's elevating devices.
6. The GTAA reserves the right to require the Contractor to use an electronic logbook system using electronic devices (tablets), which will be provided by the GTAA.

7 GTAA Specific Routine Maintenance Requirements

1. All elevating devices shall be maintained on a monthly basis, as a minimum, unless otherwise specified by the GTAA.
2. Minimum routine monthly, bi-monthly or quarterly maintenance for elevators, which the Contractor shall perform includes all Code mandated and the following:
   a. Riding each device to check for smooth operation with no undue noises, vibration, scrapping, banging or jerkiness.
   b. Verify adequate lighting in the car.
   c. Checking cab-leveling accuracy and correction, if higher or lower than +/- 7mm.
   d. Test reports for lighting levels shall to be provided to the GTAA annually.
   e. Checking door operation including functionality of door protection operation, door open and door close buttons, nudging operation; condition of belts,

door rollers, gibbs and tracks. Correct any deficiencies or non-compliance found.

f. Verify in-car emergency communications and alarm bell operation.

g. Verify operation of emergency lighting.

h. The Contractor shall replace all burnt out lamps and ballasts in elevator cars, hoist ways, pits and escalator machine spaces.

i. Verify operation of all operating fixtures and lamps. All replacements of failed lamps need to be with LED energy efficiency type lamps (where applicable).

j. Inspect pit for accumulation of debris, oil leaks, water accumulation. Verify operation of pit lights and stop switch. Check oil capture bucket on hydraulic elevators and empty if more than 1/3 full.

k. Inspect car top for accumulation of debris, oil or other obstructions. Check for damaged, loose or non-functioning car top equipment and correct any issues found.

l. Inspect the hoist way for accumulation of debris, dust and dirt. Check lubrication of guiderails and condition of guide inserts.

m. Inspect traction hoist machine, brake and sheaves for abnormal noises, vibration and leaks. Check machine oil level and grease fittings as required. Clean up any oil spills. Check lubrication of hoist ropes.

n. Inspect DC motors and generators. Clean brush gear and replace worn brushes. Lubricate bearings as required.

o. On hydraulic machines check oil levels and report unexplained loss of oil inspect motor drive belts if applicable; inspect machine for leaks; clean oil drip pans and correct any issues found.

p. Inspect controllers for signs of damage, worn or burnt contactors, wiring and fuses. Confirm absence of temporary jumpers. Clean and vacuum as required.

q. Inspect over-speed governor for proper operation. Inspect governor bearings to ensure sheave runs true.

r. Clean and tidy-up machine room.

s. Dispose of all worn and replaced parts. All materials properly stored. Wiring Diagrams and MCP manuals tidy and in place. No oily waste left behind. Guarding in place and all cabinet doors secured.

t. Complete MCP inspection logbook.

3. Minimum monthly routine maintenance for escalators and moving walks, which the Contractor shall perform includes all Code mandated requirements and the following:

a. Check exterior safety devices such as wedge guards; intersect guards, anti-slide devices and exterior barricades to ensure they are in place as applicable and in good condition.

b. Inspect exterior decking for damage and alignment.

c. Inspect entry and exit ends for obstructions that may inhibit traffic flow. Check for loose or damaged landing plates. Shim or adjust landing plates if required. Report damaged landing plates that cannot be corrected in a routine visit.

d. Verify signage is in place and in good condition.

e. Verify operation of comb and demarcation lights.

f. Ride each device and observe normal operation. Check for smooth, vibration free, ride from both the steps/pallets and the handrail throughout the travel. Investigate and correct abnormal noises, bumps and vibrations.

g. Verify handrail tension. Confirm handrails run at substantially the same speed as the steps.

h. Check for proper meshing of pallets and combs.

i. Inspect skirt panels for alignment, damage and missing screws. Check for damage to skirt brushes.

j. Inspect steps through 2 complete rotations for damage, missing demarcations, alignment, dirt, debris and oily substances. Clean and repair as required.

k. Verify proper operation of the start/stop switches at each end of the unit. Observe the stopping distance complies with unit specifications. Verify stop switch cover alarm.

l. Check step to skirt clearance with gauge at several locations in the travel for code compliance.

m. Replace worn or damaged comb plate segments with broken teeth. Replace colored comb plate segments with 2/3 paint worn off.

n. Conduct external inspection of the handrails for cracks, wear, over-heating, spalling and pinch hazards. Report damaged handrails for repair or replacement.

o. With both ends properly barricaded, open pit end. Verify operation of stop switch. Remove accumulated debris and dirt. Visually inspect tension carriage guides and safety switches. Inspect and clean handrail entry guards. Visually inspect the step chain. Lubricate if auto-lubricators not provided.

p. With both ends properly barricaded, open the upper ends machine space. Verify operation of the stops switch. Remove accumulated debris and dirt.

Visually inspect the drive chain for proper tension. Manually operate the broken drive chain switch. Lubricate if required.

q. Inspect controllers for signs of damage, worn or burnt contactors, wiring and fuses. Confirm absence of temporary jumpers. Clean and vacuum as required.

r. Inspect drive machine and gearbox. Check chain drive pinions for adequate lubrication. Check oil level in gearbox for proper oil level. Clean any oil leaks.

s. Check main service brake and emergency brake for proper operation.

t. CNIM units – remove main service brake cover and clean all brake components. Verify brake torque.

u. Return unit to normal service and observe operation for a minimum of 2 rotations.

v. Complete MCP inspection logbook.1

4. The Contractor shall perform the following specific tasks for CNIM escalators and walks:

- Monthly gearbox oil checks and re-fill if necessary
- Monthly chain lubrication
- Monthly operational motor breaks checks and cleaning.

8 Contractor's Performance Objectives and Performance Measurements

The Contractor shall include in its tender the following:

1. A plan on how the Contractor will accomplish and meet the established performance benchmark, as detailed in this Scope of Work.
2. Provide details on how the data which will be used for performance benchmark calculation will be tracked, collected and calculated.

The performance benchmark is based on location of the elevating devices with higher-performance requirements applicable to the units located in the Terminals, Parking Garages and APM stations.

8.1 Using Contractor's Data

1. The Contractor shall include in its tender, details on how accurate and timely logging, tracking and measuring of the Performance benchmark will be ensured. The Contractor shall demonstrate a process how GTAA can access the logged data either in excel or other standard raw format. GTAA, at sole its discretion, may choose the Contractor's process or system for logging, tracking and measuring of the Performance Benchmarks.

2. In case GTAA choses to use the Contractor's method of gathering, logging, tracking and reporting of the performance benchmarks, the Contractor shall provide all necessary back up data for calculations including all assumptions and exclusions or inclusions applied.
3. If the GTAA determines the tracking and measurements proposed are not accurate, the GTAA reserves the right to use other measurement methods.
4. The Contractor shall provide a sample of the reports and demonstrate how the data will be gathered, logged, tracked, measured and provided to GTAA on regular basis.

8.2 Benchmarks' Definitions and Calculations

All calculations are based on a 24 hour operating day.

8.2.1 Service Availability (SA) Calculation

- SA elevators = NUS x TOT – TOS / NUS x TOT
- SA escalators = NUS x TOT – TOS / NUS x TOT
- SA moving walks = NUS x TOT – TOS / NUS x TOT
- SA express walks = NUS x TOT – TOS / NUS x TOT
- NUS - Number of Units (elevating devices) in public service
- TOT - Total Operating Time. For monthly calculations the total number of hours per month shall be used,
- **Note: Operating hours for conventional people moving devices based on operation 24 hours per day. The operating hours for express walks are based on 18 operating hours per day.**
- TOS - Total Out of Service time. Total hours out of service for a calculated period. TOS includes all downtime regardless of the cause such as downtime controllable and non-controllable including downtime due to maintenance, repairs, unit internal component failures, passenger interaction, damage etc.

8.2.2 System Availability (SS) Calculation

- SS elevators = NUS x TOT –TOSS / NUS x TOT
- SS escalators = NUS x TOT – TOSS / NUS x TOT
- SS moving walks = NUS x TOT –TOSS / NUS x TOT
- SS express walks = NUS x TOT – TOSS / NUS x TOT
- NUS - Number of Units (elevating devices) in public service

- TOT - Total Operating Time. For monthly calculations the total number of hours per month shall be used
- TOSS - Total out of Service System hours. Total hours out of service for calculated period. TOSS includes all downtime only incurred due to unit internal component failure of the elevating devices and downtime required to repair of the failure. All other downtime related to maintenance, repairs, passenger interaction or damage should be excluded from calculation.

8.2.3 Deductions for Availability Non Performance and Payment Factor

The Contractor acknowledges and agrees that, without prejudice to any other right or remedy which the GTAA may have; a payment factor shall be applied to decrease or maintain (but in no event increase) the monthly Contract price.

The applicable payment factor shall be determined based upon the average Availability in the applicable calendar month and in the immediately two (2) previous months, as applicable. Such Average Availability is calculated as follows:

- Average Availability Elevators (AAel) = (SS Elevators Month 1 + SS Elevators Availability Month 2 + SS Elevators Availability Month 3) / 3
- Average Availability Escalators (AAes) = (SS Escalators Month 1 + SS Escalators Availability Month 2 + SS Escalators Availability Month 3) / 3
- Average Availability Moving Walks (AAmw) = (SS Moving Walks Month 1 + SS Moving Walks Availability Month 2 + SS Moving Walks Availability Month 3) / 3
- Average Availability Express Walks (AAew) = (SS Express Walks Month 1 + SS Express Walks Month 2 + SS Express Walks) / 3

The Payment Factor shall be determined as follows:

Average Availability (Conventional Units)	Payment Factor (Conventional Units)
≥ 98%	100%
< 98%	AA el ÷ 98% AA mw ÷ 98% AA es ÷ 98%
Express Walks	**Payment Factor (Express Walks)**
≥ 95%	100%
< 95%	AAew ÷ 95%

8.2.3.1 Example and Clarification of the Payment Factor Calculation

Payment factor calculated by dividing the achieved Average System Availability calculate for 3 months (as explained above) by the Performance Benchmark System availability defined in Annex A.1, A.2 and A.3.

Example:

a. Average Availability Elevators (AA) for 3 months equals 99.5%
b. Average Availability Escalators (AA) for 3 months equals 96%
c. Average Availability Moving Walks (AA) for 3 months equals 98%
d. Payment factor for Elevators = 99.5 / 98 = 1
e. Payment factor for Escalators = 96 / 98 = 0.9795
f. Payment factor for Moving Walks = 98 / 98 = 1

When Average Availability (AA) for elevators, escalators and moving walks achieve 98% and above, the payment factor is one (1). In this case, the Contractor is entitled to the full monthly payment:

a. Monthly Payment Elevators = Contractual monthly payment x Payment Factor = $100,000 x 1 = $100,000 – full payment.
b. Monthly Payment Escalators = Contractual monthly payment x Payment Factor = $100,000 x 0.9795 = $97,950 – reduced payment.
c. Monthly Payment Moving Walks = Contractual monthly payment x Payment Factor = $100,000 x 1 = $100,000 – full payment.

8.2.4 Grace Period

For the first three (3) months of the term of the Contract, the Contractor shall calculate the Availability and provide to the GTAA as per the requirements of this Contract. In case of lower than 98% availability attainment the Contractor shall review the equipment of concern and provide a proposal or plan how the identified concerns can be rectified to achieve a minimum Contractual Availability of 98%. The proposal shall be provided to GTAA by June 30th, 2016. The Payment Factor will not be applied in the first three (3) months of the Contract.

The 3 months grace period is not applicable to the Express Walks.

8.2.5 Callback Rate

Callback rates are defined as the annual number of service calls per unit for elevators, escalators and moving walks out of service due to device malfunction/system related failure. It does not include calls for damage, misuse, vandalism, non-equipment related faults (i.e. power failures from power grid) and restart calls due to e-stop and comb plate for escalators or moving walks.

8.2.6 *Maintenance Performance*

Maintenance performance is a performance benchmark, established by the GTAA, for the completion of regulatory maintenance and the MCP, as per schedule.

Maintenance performance will be measured based on completion of maintenance, as per EAM reports, and sign-off by mechanics, for individual tasks in the regulatory log books.

100% attainment of completion of scheduled maintenance is achieved when all scheduled work orders for measured period closed in EAM and all tasks are signed off by mechanics in regulatory logs.

8.2.7 *Maintenance Performance – Completion of Category 1 tests*

Completion of the scheduled maintenance for Category 1 tests has its individual performance benchmark and will be tracked in Maximo as follows:

100% attainment is achieved when Category 1 maintenance work orders completed as per scheduled maintenance plan in EAM system / RFP Proposal (refer to paragraph 23)

8.2.8 *Restart Calls for Escalators and Moving Walks*

Response time to Emergency calls will be measured by the GTAA's IOCC through its Perspective system reports. The response time for the escalator and walk restart calls is measured monthly and will be averaged for the period of 3 months (current month and two previous months).

The total time of all restart calls for 3 months divided by the total number of restart calls for 3 months shall be less or equal the maximum response time of the applicable performance benchmark (as per the applicable Annexes A.1, A.2, and A.3).

Dispatched calls to, and updates from the Contractor, shall be logged and tracked by the GTAA/IOCC within the Perspective System. It is Contractor's responsibility to ensure that Contractor's staff adheres to the communication protocol with the GTAA/IOCC to provide timely and accurate updates when responding to the calls. In particular, the Contractor's staff shall communicate the following to the GTAA/IOCC:

Update IOCC with arrival time to the unit (on scene)

Update IOCC with restarting time of the unit (unit is returned to public service)

At the end of each month, the GTAA will generate a summary report from the Perspective System for all restart calls and actual response time, in order to measure performance against the established benchmarks *(as per the applicable Annexes A.1, A.2, and A.3)*.

8.2.9 *Response Time to Emergency Calls (entrapments, incidents and Accidents)*

Response time to Emergency calls will be measure by IOCC through Perspective system reports. The reports will be run monthly and the attained response time measured against the benchmark.

It is Contractor's responsibility to ensure that the Contractor's staff adheres to the communication protocol for providing timely and accurate updates to IOCC when responding to the emergency calls.

In particular, the Contractor's staff shall advise IOCC the following:

Update IOCC with arrival time to the unit

Update IOCC with restarting time of the unit

8.2.10 *Liftnet Communication*

The Contractor shall rectify all basic Liftnet communication faults within 24 hours. A monthly report will be generated from Perspective and/or Liftnet to review the Liftnet communication failures. The attained performance of the Liftnet communication will be compared against the established benchmark (*(as per Annexes A.1, A.2 and A.3)*.

100% attainment is achieved when Liftnet communication faults resolved within 24 hours.

The benchmark is applied to the faults directly related to the Liftnet software and hardware and its interfaces with elevating devices controllers. The benchmark will not be applied for any communication faults which are beyond the reasonable control of the Contractor such as communication faults due to GTAA's network and GTAA server and computer hardware.

Basic Liftnet communication problem is considered a fault, which can be resolved by the Contractor through a reset of the Liftnet hardware or software or by minor troubleshooting requiring validation of the Liftnet communication parameters or replacing Liftnet communication hardware.

8.2.11 *Overdue Directives*

1. Directives are code non-compliances identified by the GTAA's third-party inspector Contract(refer to item 5 in this Scope of Work):

100% attainment is achieved when there are no directives with "Overdue" status on a monthly basis.

2. The GTAA's designated Inspection Company will log the directives with "open" status allocating a grace period for addressing the directives. The grace period for "Open" directives is based on criticality of the individual directive and normally ranges from 30 to 90 days. In case the directive is not rectified by the Contractor

within the grace period, it moves to "Overdue" status with applicable deductions for non-performance and the directive must be addressed immediately, by the Contractor.

3. The Contractor shall provide GTAA with a detailed Maintenance Work Plan. The Maintenance Work Plan shall include but not limited to the following:
   - How the Contractor proposes to fulfill the obligations of the Contract and manage the Scope of Work.
   - On annual basis by November 1, the Contractor shall supply a detailed Maintenance Schedule. The Contractor's Maintenance Schedule will be reviewed by GTAA and current Maintenance Plan in MAXIMO will be updated. The Contractor's Maintenance Schedule shall include details how maintenance of the critical and impact customer experience elevators, escalators and walk will be completed to minimize impact on Airport operations and in accordance with the Scope of Work and time for the maintenance. All revisions and changes to the Maintenance Schedule shall be communicated to the GTAA for approval in advance throughout the term of Contract.
   - Annual Staffing / Shift Schedule with regular updates.
   - Strategy for covering of supervisory employees in case of vacations, sick leaves and any time they are away from site longer than 1 day.
   - Complete with a comprehensive breakdown of the provision of resources, trade employees, the Contractor's Equipment and Materials used employee availability.
   - Where and in what locations the Work will be performed on daily basis (including planned maintenance schedules for all elevating devices covered by this Scope of Work as listed in the current GTAA inventory of elevating devices provided with this Scope of Work). This detailed Maintenance Work Plan shall be included in the proposal submitted to the GTAA.
4. The Contractor shall perform all Work including planned and non-scheduled maintenance as required in conformance with, all Applicable Laws, this Contract, the Contractor's Maintenance Plan, and manufacturer operation and maintenance manuals.

8.3 Service Conditions

1. The Contractor shall perform all Work and any additional Work to the satisfaction of the GTAA during the term of the Contract. The GTAA will have the right to conduct an inspection and/or an audit of the Work, equipment and /or review the Contractor's operating or maintenance methods at any time during the term of the Contract without prior notice to the Contractor.

2. The GTAA, at its sole discretion, may provide (but not obligated) a written report of the inspection or an audit, and any deficiencies noted to the Contractor. The Contractor shall respond in writing and indicate the corrective action(s) it will take to remedy any noted deficiencies within two (2) working days of receipt of the report.
3. The Contractor shall maintain the units in accordance with the GTAA approved Maintenance Plan and Maintenance Schedule.
4. The Contractor shall ensure all materials are GTAA approved for use and environmentally compliant where applicable.
5. The Contractor shall use GTAA approved barricades as identified in their Safety Plan.
6. The Contractor shall make use of the GTAA approved signage indicating duration of work and closest alternative devices to be used. The Contactor shall submit a sample of "Out of Service" signs for elevators and escalators to be used on site as part of its tender response.
7. The Contractor shall ensure that all operating and maintenance manuals (O&M manuals) wiring diagrams, drawings and any other documentation as it relates to the Work is kept up to date during the course of the Contract.
8. The Contractor shall clean up all debris, remnants, material, dust, dirt or other by-products resulting from the Work performed in all areas of Work activity prior to leaving the property each and every day.
9. The Contractor shall ensure that all steps or pallets for moving walks and escalators are removed, cleaned, inspected and properly identified during annual preventative maintenance (see procedure Adding or Removing People Moving Devices (non-APM) from Public Service (short term or maintenance-related work) attached to this Scope of Work.
10. The Contractor shall be solely responsibility for loss to the Contractor's equipment, parts, and materials.
11. The Contractor shall ensure that any warranties are obtained in the name of the GTAA, as appropriate. All Warranties shall be provided to GTAA in writing.
12. The Contractor shall ensure that all GTAA's elevating devices and all other utilized materials are maintained in good working condition at all times.

8.4 Machine Room and Pits Housekeeping

The Contractor shall carry out regular and orderly housekeeping/cleaning of its work area including maintenance space, shops, offices, storage space, work rooms, equipment and equipment rooms and tools, instruments, and furniture

The Contractor shall keep oils, lubricants and clean rags in approved storage containers and keep all spare parts on metal shelves or in metal cabinets. All containers shall be labeled with the current contents, and such labels shall conform to all Laws including, without limitation, the WHMIS requirements of the *Occupational Health and Safety Act* (Ontario) and the requirements of the *Transportation of Dangerous Goods Act*

1. The Contractor shall provide the following services, in the area of elevator machine-room housekeeping:
   - All elevator machine rooms shall be maintained in a clean and tidy manner.
   - Waste shall be placed in approved containers or removed from site daily. Oily waste shall not be mixed with regular waste.
   - Within 12 months of awarding the Contract the Contractor shall clean and paint floor in each elevator machine room.
   - The Contractor is solely responsible for all waste (including hazardous waste), garbage and any used parts removed
   - The Contractor shall not use machine rooms for storage of any parts other than those parts required for regular routine maintenance unless approved by the GTAA.
   - Old and worn parts are to be removed from all machine rooms
2. Contractor shall perform 10 random oil lab tests each year of the Contract. The tests shall be completed on hydraulic oil elevators with high usage or as directed by GTAA. The lab reports must be provided to GTAA within a maximum of two (2) weeks after tests completed. The Contractor shall evaluate the lab oil reports and take corrective actions if necessary.

8.5 Elevator Cathodic Protection Systems

1. The Contractor shall be responsible for maintenance and repairs of the cathodic protection systems installed at the following elevators: hydraulic elevator at GTAA Administration building – ADM-ASPO.
2. The Contractor shall include the cost of an annual inspection and check of the cathodic protection system by an approved provider and submit a report to GTAA within 2 weeks after inspection.

8.6 Machine Room and Elevator Car Top Guarding

1. The Contractor shall maintain, repair and replace all machine room guarding and elevator car top guarding installed in GTAA's machine rooms and elevator cabs.
2. The Contractor shall perform safety check of all interlocks for the collapsible car top guarding minimum once per year or as required by applicable codes for elevator H23 / H24 (Terminal 3, Pyramid elevators).

8.7 Partial Maintenance Service

1. From time to time, GTAA will remove elevating devices from regular service but may keep units ready to be returned to public use on short notice, which are known as the Partial Maintenance Service units (as identified in the Inventory of Units attached to this Scope of Work. Designated Partial Maintenance Service units will not be part of the regular MCP maintenance program. In its place, the Contractor shall perform a basic quarterly service to 'exercise' the unit and ensure the unit can be placed back in service when required (see Appendix A for complete list of units). The contract price for Partial Maintenance Service units will be adjusted in accordance with the unit pricing.
2. The Contractor shall perform partial Maintenance Service for elevators including the following:
   - Run elevators manually to every floor a minimum of 10 times.
   - Verify leveling operation.
   - Verify smooth floor to floor operation with no noise or vibration.
   - Verify door operation and satisfactory operation of door protection.
   - Check oil level on hydraulic machines.
   - Inspect pit for debris, oil or water.
   - Inspect car top for abnormal conditions.
   - Disable unit from unauthorized operation.
   - Complete Partial Maintenance Service inspection logbook.
3. The Contractor shall perform partial Maintenance Service for escalators and moving walks including the following:
   - Visual inspection of external devices including wedge guards, intersect guards, anti-slide devices, decking, balustrades and barricades.
   - Visual inspection of steps/pallets, skirt panels, combs, landing plates and handrails.
   - Start-up the unit and run for a minimum of ½ an hour.
   - Verify lubrication of the step chain and drive chains.
   - Verify operation the starting and stopping devices at both ends of the unit.
   - Disable unit for unauthorized operation.
   - Complete Partial Service inspection logbook.
4. Prior to returning a Partial Maintenance Service unit to normal public use, the elevating device will be thoroughly inspected and all CAT 1 or outstanding CAT 5

tests completed by the Contractor. The unit will be inspected by the third-party inspection service before being certified for return to service.

The GTAA may elect to reduce the scope of the service from full to partial service for units temporarily removed from public service, or to suspend service completely for units removed from service for longer periods of time. In these cases, the GTAA will review the costs on a case-by-case basis.

8.8 Cleaning of the Terminal 1 Rainbow Glass Elevators (FDP04 and FDP10)

1. The Contractor shall arrange all necessary labor, tools and materials to clean glass elevators as follows:
   - Exterior glass shall be cleaned and washed with liquid agents.
   - Top glass shall be cleaned and washed with liquid agents.
   - All dust shall be vacuumed on top of elevator, electrical components, and travelling cables.
   - The pit shall be cleaned and washed and vacuumed.
2. Cleaning date and time of the elevators shall be coordinated and approved by the GTAA.

8.9 Contractor's Continuous Improvement

1. The Contractor shall implement a continuous improvement philosophy to seek root causes of problems, recommend improvements in quality, efficiency and effectiveness in maintenance and operations of all elevating devices.
2. Within first six (6) months of the commencement date of the Contract, the Contractor shall provide a plan demonstrating continual improvement in respect to:
   - elevators, escalators, walks availability
   - elevators, escalators, walks reliability
   - achievement of consistent maintenance attainment
   - quality and completeness of performed work
   - completeness and accuracy in regulatory documentation and reports provided to the GTAA
   - reduction of energy costs;
3. On an annual basis (minimum), the Contract and GTAA will meet to discuss continual improvement opportunities and implementation plans acceptable to GTAA and the Contractor.

4. The Contractor shall do a minimum three (3) Root Cause Analysis (RCAs) per month on maintenance and operational issues or as directed by the GTAA. The triggers for an RCA are as follows, but not limited to:
   - Unit technical brake down causing downtime over 72 hours.
   - Re-occurring technical breakdowns and/or entrapments.
   - Incidents involving public or worker safety.

8.10 Changes to the Contract Scope

The GTAA may, at any time, add or delete elevating devices using unit pricing set out in the Contract. Subsequently, the billing amount will be adjusted based on the quantity and type of added or removed elevating devices.

8.11 Alterations of the Elevating Devices

1. The Contractor shall submit minor A and minor B alteration notifications to the GTAA on the forms provided. Minor A and minor B alterations are as defined under TSSA Director's Order 251-11. These submissions are not to be sent to TSSA and no fees are applicable.
2. The process for change management is outlined in the Contract including GTAA SOP G02 FM-0094 Change Management for Elevating Devices (attached to this Scope of Work).

8.12 Waste Disposal

1. The Contractor shall ensure proper storage, handling, and disposal of waste and contaminates, whatever the source, or hazardous waste if and when it is involved in the Work in accordance with WHMIS standards, Applicable Laws including the Transportation of Dangerous Goods Act, and the Occupational Health and Safety Act.
2. The Contractor, at its expense, shall safely dispose of all waste, including hazardous, material in compliance with Applicable Laws.

8.13 Support and Coordination with Other Terminal Activities

1. The Contractor shall, at no additional cost, assist with all annual testing of fire alarm initiating devices in machine spaces, pits, and shafts of all elevating devices (1 test per unit per year). This scope includes elevating devices in IFT as well (total 18 units).
2. The Contractor shall, at no additional cost, assist with testing of Firefighters Emergency Operation and complete all regulatory paper work for the FEO tests, Submit the test results to GTAA within 2 weeks from completion of the tests.

3. The Contractor shall, at no additional costs, assist with annual planned power shutdowns. There are approximately 25 power shutdowns annually. The work is usually conducted outside of regular hours with 5 hours per test on average. During the on-site hours the Contractor shall, at no additional costs, respond to IOCC requests to restart any elevating devices regardless of the cause.
4. The Contractor shall, at no additional cost, coordinate escalator and moving walk CAT1 inspection and testing with elevating devices Inspection Company (one for each unit per year).

8.14 Demand Based Maintenance

1. Minimum once per year, or as directed by the GTAA, the Contractor shall evaluate the usage of people moving devices using traffic analysis available through Liftnet or other means available to the Contractor.
2. The Contractor can use its own traffic analysis and/or the GTAA Liftnet traffic analysis to perform the evaluation.
3. Upon completion of the annual analysis the Contractor shall provide recommendations for changes to the scope and frequencies of the maintenance tasks based on the higher or lower usage of elevating devices equipment.
4. Based on the results of the annual analysis of elevating devices equipment the Contractor may recommend additional capital overhauls and upgrades to the GTAA elevators, escalators and walk.

8.15 BAE Belted Walks

Repair and/or replacement of moving belts are not included within this Scope of Work.

9 Parts and Materials

9.1 Contractor's Spare Parts

1. The Contractor shall procure and maintain, on GTAA property, appropriate inventory levels of its own spare parts based on the elevating device manufacturer's original recommendations and on the industry's historical usage for all components of the elevating devices. All inventory items must be stored safely and in an organized manner.
2. The Contractor shall provide and maintain the required spare parts inventory onsite to ensure continuous service of all elevating devices meeting performance benchmark and that no unit is to be out of service due to lack of spare for parts longer than 24 hours.

3. The Contractor shall procure the parts for all makes and models of the elevating device under this Scope of Work.
4. The Contractor is responsible for preparing and issuing purchase orders and paying invoices for replacement inventory. The Contractor shall provide employees for receiving and restocking inventory, if the Contractor believes that changes are needed.
5. As part of the Contractor's response to the RFP, the Contractor shall describe its approach and plan in managing spare parts. The Contractor shall describe what resources are available and will be used to source and procure spare parts or replacement parts in case parts discontinued.

9.2 Replacement Parts

6. The Contractor shall use only Original Equipment Manufacturer (OEM) parts where applicable or an exact equivalent and shall maintain sufficient quantities of basic repair and replacement materials necessary to perform the kinds of repairs specified by the Contract at all times. Any replacement parts or materials used by the Contractor must be equal to or better than the ones replaced, when they were newly installed. Any and all warranties for any parts must be obtained in the name of the GTAA.

9.3 Spare Lending Parts

9.3.1 GTAA owned critical spare parts for Conventional Elevating Devices

In addition to the Contractor's spare parts inventory, the GTAA maintains its own critical spare parts inventory for all elevating devices.

The Contractor shall manage the GTAA critical spare parts inventory as follows:

a. The Contractor shall replenish/maintain GTAA-owned spare parts.
b. The Contractor shall procure and maintain inventory levels of GTAA owned spare parts inventory.
c. The Contractor will remove parts from inventory as required for maintenance purposes and will be responsible for promptly reporting such part usage to the GTAA using a standard format acceptable to both parties.
d. The Contractor will be responsible for preparing and issuing purchase orders and paying invoices for replacement inventory. The Contractor shall issue a purchase order to replace used GTAA-owned spare parts within 5 business days.
e. The Contractor shall provide personnel for receiving and restocking inventory. If the Contractor believes that changes are needed, it will advise the GTAA in writing of recommended revisions in current inventory levels and parts. Without

limiting the generality of the foregoing, the Contractor shall maintain the GTAA owned inventory.

f. The intent of the GTAA-owned spare parts inventory is that the GTAA will continue updating and adding parts deemed critical to avoid prolonged downtime and to maintain availability of the units.

g. The GTAA may audit the GTAA spare-parts inventory at any time.

9.3.2 Contractor's spare parts on site

The Contractor shall provide in its tender, a plan for it to manage, stock and replenish Contractor's spare parts to meet performance benchmark.

9.4 GTAA Materials and Equipment

For the Term of the Contract, no materials, tools or equipment belonging to the GTAA shall be removed from the premises of the GTAA without the prior written consent of the GTAA.

9.5 Using Parts from Out of Service GTAA Elevating Devices

The Contractor shall not remove, dismantle or take off site any GTAA parts, elevating devices, materials and property or the Contractor will be deemed to be in breach of the Contract.

25 Annex A.1: Maintenance and Repair of Terminal Conventional Elevators, Escalators and Moving Walks

25.1 Performance Benchmarks for Terminal Conventional Elevators, Escalators and Moving Walks

Performance Benchmark	Measurement	Data Source / Reporting System
System Availability – Terminal elevators (includes baggage lifts)	98%	Contractor / Liftnet
System Availability – Terminal escalators	98%	Contractor / Liftnet
System Availability – Terminal moving walks	98%	Contractor / Liftnet
Callback Rate * Elevators Escalators / Moving Walks	 3.0 callback/unit/year 2.0 callback/unit/year	 Contractor / IOCC Records Contractor / IOCC Records
Maintenance Performance – attainment of the regulatory maintenance PM – Preventative Maintenance	100%	AMMS/MAXIMO
Maintenance Performance – attainment of the regulatory maintenance CAT1 – Performance against the Maintenance Plan	100%	AMMS/MAXIMO
Maximum response time to arrive on scene for regular (non-emergency) restart calls for escalators and walks during on-site hours averaged for the period of 3 months. The compliance with the 30 min response time will be measured through Airport Communication Centre Perspective System. It is the Contractor's responsibility to follow communication protocol with IOCC with updates.	30min	Contractor / Perspective - IOCC
Maximum response time to arrive on scene for emergency calls during on-site hours averaged for the period of 3 months	15 min	Contractor / Perspective - IOCC
Maximum response time to arrive on scene for emergency calls after hours	60 min	Perspective

Liftnet communication – no communication faults over 24 hours	24hrs	Liftnet
Timely completion of Open directives prior Overdue status.	100%	Elevator Inspection Board / Maximo

*** Callback rates are defined as annual number of service calls per unit for devices out of service due to device malfunction. Does not include calls for damage, misuse, vandalism, non-equipment related faults or re-starts on escalators or moving walks.**

25.2 LiftNet Monitoring

1. LiftNet is an interactive real-time monitoring system developed by Integrated Display System Inc. (IDS) to monitor and manage the Airport's elevators, escalators and moving walk equipment at the following facilities:.
   - Terminal 1
   - Terminal 1 Parking Garage
   - Terminal 1 APM station
   - Terminal 3
   - Terminal 3 Pier A
   - Terminal 3 Parking Garage
   - Terminal 3 APM station
   - Viscount APM station
   - Viscount Garage.
2. The LiftNet monitoring system is connected to each elevator controller in the elevator machine rooms, and to the individual controllers located in the pits in the case of escalators and moving walks. The LiftNet monitoring system transmits alarm detection conditions and equipment malfunctions to the servers and computer workstations. Equipment performance statistical data shall be continuously captured and stored in LiftNet servers and computer workstations memory.
3. Except as provided in paragraph 5 below, the Contractor shall maintain, repair, troubleshoot and test the LiftNet monitoring system and those related control components directly connected from the monitored elevators, escalators and walks to the applicable LiftNet interface devices, servers and computer workstations. The Contractor shall be responsible for maintenance of the LiftNet which shall continuously remotely monitor key functions for all of the Airport's elevator, escalator and moving walk equipment identified by the T1 LiftNet Inventory and T3 LiftNet Inventory (as attached to this Scope of Work).

4. The Contractor shall maintain, repair, replace and troubleshoot all LiftNet hardware per the LiftNet inventory including CTM interface boards, B&B Vlinx and Moxa devices, LiftNet LNP cards UPS units and back up batteries.
5. The LiftNet computer workstations and server hardware (2 servers) is excluded from the Contract, as the computer and server hardware is maintained by GTAA IT&T.
6. The Contractor shall maintain, update, troubleshoot and repair all LiftNet software and firmware including LiftNet application (at minimum revision 16), CTM interface board firmware and B&B Vlinx and Moxa firmware.
7. The Contractor shall include in its tender a maintenance plan for LiftNet system based on the manufacturer's recommendations, site conditions and the usage of the system.
8. The Contractor shall be responsible for all maintenance, repairs and troubleshooting of the following LiftNet cabling and terminations:
   - All daisy chain wiring and terminations to the LiftNet interface cards in the escalator and walk pits for CNIM equipment.
   - All serial interface connections between LiftNet interface cards and CNIM PLCs in the pits.
   - All serial and Ethernet connections from the wall jacks to B&B VLINX and Moxa devices in elevator machine rooms.
   - All daisy chain terminations of the serial communication for the CNIM equipment in the telecommunication rooms.
   - All hardwired connections and terminations from the Thyssen escalator and walk controllers to LiftNet interface boards located in the pits.
   - All LiftNet cabling which uses the Ethernet Airport's Campus Area Network between the telecommunication rooms and the main communication room (MCR1) is excluded from the maintenance Contract.
   - All LiftNet daisy chain cabling between the telecommunication rooms and individual escalator and moving walk pits.
9. The Contractor shall provide, maintain and repair, at its sole costs (including any and all maintenance and replacement costs), a paging / email system for use with the LiftNet monitoring system. The paging system shall be capable of receiving full text messages of pre-defined LiftNet elevator, escalator or walk faults or conditions. The Paging System (a mobile device with text capabilities shall be provided by the Contractor) shall receive a text message indicating that a fault has occurred and correctly identify the equipment at fault by unit designation/ID within 5 minutes of the LiftNet system detecting the fault or failure.

APPENDIX A2

GTAA Testing, Commissioning, Acceptance, and Turnover Standard

GTAA Testing, Commissioning, Acceptance and Turnover Standard

Airport Planning and Technical Services

Creation Date: April 28th, 2014

Version: 1.8

Document Control

Version History

Version	Date	Changes	Stakeholder	Documentation
1.8	2014-12-11	• Recovered James Persaud's minor changes and updated version	R. Riseborough	A. Schwartz
1.7	2014-08-27	• Added CMMS and EAM to definitions • Changed section 2.5.4.5 to read: The contractor must provide updated asset data, as per the GTAA's standards outlined in "Guide for Contractors to Provide Data for Assets Requiring Maintenances" (available through the GTAA Project Manager). This includes the removal of all assets from service, as part of the project. These changes must be in place prior to Turnover, so the preventive maintenance program can be developed and initiated.	R. Riseborough	A. Schwartz
1.6	2014-06-02	• Added an extra field to sample forms, as per stakeholders • Added links in Standard to sample forms	M. Boyle R. Riseborough	A. Schwartz
1.5	2014-05-01	• Incorporated D. Kerrigan and Shaila D'Souza's edits, where applicable	M. Riseborough D. Kerrigan	A. Schwartz
1.5	2014-04-30	• Final cleanup and sanity check	M. Riseborough D. Kerrigan	A. Schwartz
1.5	2014-04-28	• Final technical input	M. Riseborough D. Kerrigan	Group update
1.4	2014-04-21	• Significant rewrite	M. Riseborough D. Kerrigan	M Boyle
1.4	2014-04-14	• Significant rewrite	M. Riseborough D. Kerrigan	M Boyle

1.3	2014-04-07	• Created T/C/A/T diagrams and added to beginning of relevant sections • Created high-level diagram & added to 1st section of document • Resequencing of sections	M. Riseborough D. Kerrigan	A. Schwartz
1.3	2014-04-04	Finalized changes and diagrams for working copy Ann to complete the following: • create Triangle diagram and add to document • finalize review changes from meeting • Marcus and Ann to meet 2014-04-11 to finalize draft and send to team for final review and sign off	M. Riseborough D. Kerrigan	A. Schwartz
1.2	2014-03-26	Realign content and edit document for review by the team	M. Riseborough D. Kerrigan	A. Schwartz
1.1	2014-01-23	Consolidated 19 chapters into one Document template for first draft review	M. Riseborough D. Kerrigan	A. Schwartz
1.1	2014-02-17	Reordered information in more logical order	M. Riseborough	A. Schwartz
1.1	2014-02-18	Deleted redundant information (not complete) Uploaded for Mike's review	M. Riseborough	A. Schwartz
1.1	2014-02-21	Mike completed a final draft review. Ann to do a final edit prior to Mike sending to team to sign off	M. Riseborough	A. Schwartz
1.1	2014-02-25	Final draft edit and reformat and sent to Mike for stakeholder review	M. Riseborough	A. Schwartz

Reference Documents

Title	Date	Description/Comments
Air Handling Unit.pdf	2014-06-02	Sample Form
Cables Low Voltage.pdf	2014-06-02	Sample Form
Heat Pump.pdf	2014-06-02	Sample Form
Pump.pdf	2014-06-02	Sample Form
Radiant Panel.pdf	2014-06-02	Sample Form
Switchgear Switchboard Assemblies.pdf	2014-06-02	Sample Form
Three Phase Dry-Filled Transformers.pdf	2014-06-02	Sample Form

Table of Contents

1 Overview

This standard summarizes the Testing, Commissioning, Acceptance and Turnover (TCAT) process for mechanical, electrical (including related software systems), site services, and architectural systems; for new building construction, and renovations and/or modifications to existing buildings or systems.

The TCAT process is intended to follow the standards in the CSA 320-11 Building Commissioning Standard. Consultants and Contractors are responsible for following this standard and the commissioning requirements as set out in CSA 320-11. All requests for clarification of specific information in this standard will be directed to the Associate Director Technical Performance, or in his/her absence, the Greater Toronto Airports Authority (GTAA) Project Manager. All GTAA projects, large or small, must go through the TCAT process before they are turned over to the GTAA.

After the substantial performance of large scale projects and, prior to opening, the facility will be maintained through normal operating processes, either directly by the GTAA or through a third party contractor. The predictive, preventative and corrective maintenance will be performed as though the facility was fully functional. Work orders will be issued though a Computerized Maintenance Management System (CMMS) and assigned accordingly. This process will help refine the frequency, task content and task times associated with each function, and provide valuable orientation and familiarization training for maintenance management and trades staff.

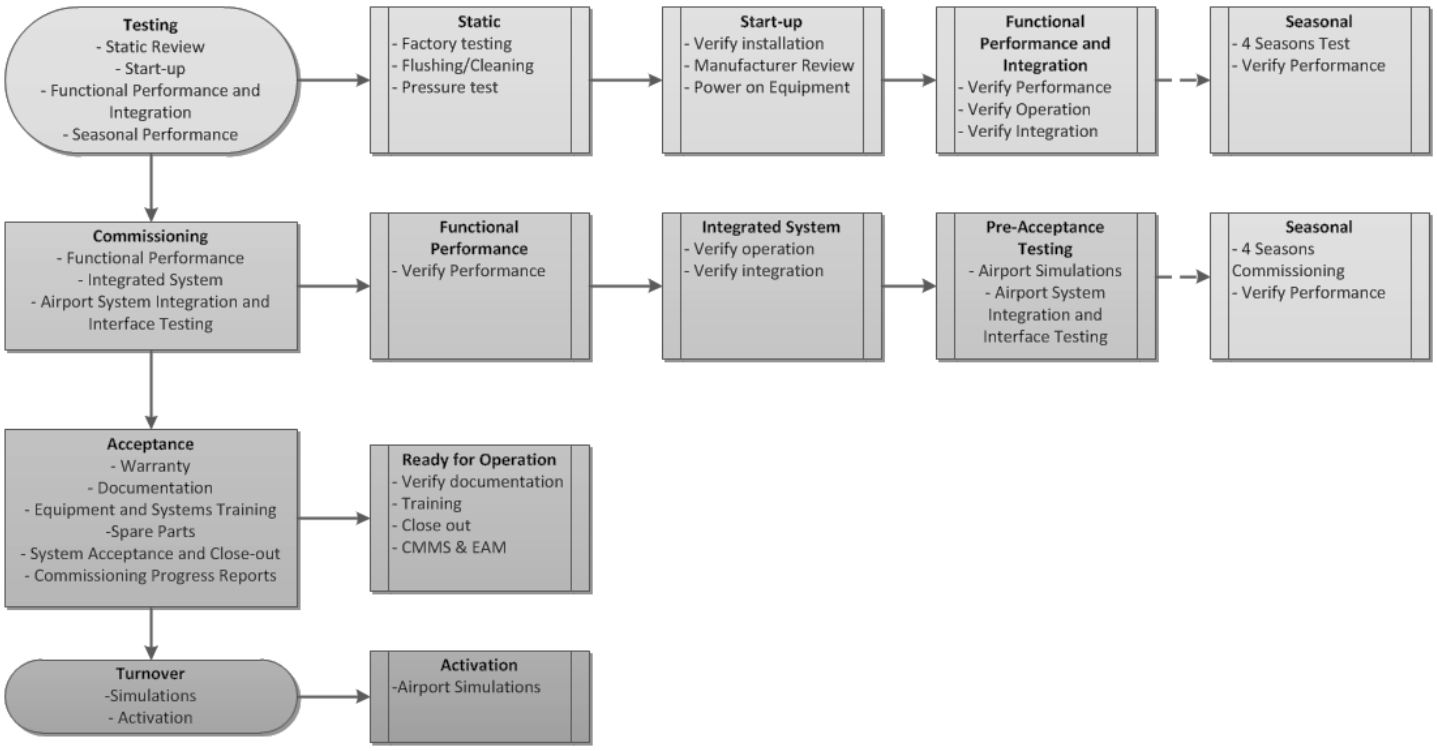
The TCAT process is an essential tool for the development of staff. The commissioning team will ensure the training and involvement of the GTAA staff will be sufficient for the GTAA staff to operate and maintain the systems that are being handed over to the GTAA. This includes answering questions from staff, resolving issues identified and updating systems during the TCAT process.

The designated APTS Manager and Project Manager will define the level of compliance required for each project. The GTAA, consultants and contractors must be familiar with the TCAT process outlined in this document.

Note: This TCAT standard is a subset of the overall Quality Assurance Program that is expected of any project from the first stages until final handover.

Refer to the contract documents for details on the equipment and systems testing and commissioning requirements, roles and responsibilities of each member of the commissioning team and the deliverables for the project. The flowchart, below, identifies the TCAT process and deliverables for each stage of the TCAT process.

Summary of Testing, Commissioning, Acceptance and Turnover



1.1 Objectives

The objectives of the TCAT process are to verify the following:

a. The GTAA's Owner's Project Requirements (OPR) PR (i.e. the purpose) for the facility has been documented and utilized in the development of the Basis of Design (BOD).

b. The installation meets the requirements of the contract documents.

c. The equipment and system performance meets the requirements of the contract documents, the OPR and the BOD.

d. The newly installed systems are integrated with the existing systems.

e. The energy target objectives meet the requirements of the contract documents.

f. The operational project turnover, as defined in the contract documents and the TCAT Standard, has been completed.

g. Operation and maintenance data for the equipment and systems are provided for inclusion in the CMMS.

h. The documentation delivered to GTAA meets the requirements of the contract documents and the operational requirements.

i. The operation and maintenance training meets the requirements of the contract documents and the operational requirements.

j. Seasonal testing and correction of all deficiencies and warranty issues.

1.2 Benefits

The TCAT process provides several benefits, incl

- Coordination of the design and construction teams to bring the building systems to completion successfully.
- Ensuring integration of the new and existing systems.
- Introduction and overview of the system for familiarization of operations and maintenance staff.
- Making necessary technical information available to make operating staff capable of operating, troubleshooting and maintaining the building systems.
- The additional control of the documentation flow will ensure that essential documentation is delivered to the GTAA when it required.
- Reduction of the number of deficiencies and warranty repairs.
- Reducing the number of complaints and problems during the first year of operation and ongoing operation.
- Ensuring all relevant information is contained within the GTAA's Computerized Maintenance Management System (CMMS) prior to initiation of maintenance activities which will ensure a complete maintenance history of the asset(s).

It is the responsibility of the consultants and contractors to ensure that these benefits are realized.

1.3 The TCAT Team

The TCAT team is assembled at the beginning of a project to maintain oversight of the TCAT process for a project from beginning to end. The TCAT team may consist of the following people:

- GTAA APTS Manager
- GTAA Project Manager
- Commissioning Authority
- Prime Consultant (architect or engineer)
- Construction Manager or General Contractors.

The GTAA Project Manager will co-ordinate the responsibilities of the TCAT team, who will, in turn, provide the following services:

1. Assist the Commissioning Authority (if in place) to coordinate the project commissioning requirements with the contract documents.
2. Prepare the contract documents detailing the project requirements.
3. Assist the GTAA to develop the Owner's Project Requirements
4. Provide input on the preparation of the commissioning plan by the Commissioning Authority based on the OPR, BOD and the design documents requirements.
5. Verify that the mechanical, electrical, site services and architectural systems and their installation meet the contract document requirements.
6. Verify that the contractors have complete A2-12 , start up, functional performance and systems integration tests.

7. Provide the test requirements in the contract documents on the mechanical, electrical, site services and architectural systems to verify that they achieve the basis of design performance.
8. Participate in the final performance and systems integration testing of the mechanical, electrical, site services and architectural systems, to be conducted by the contractors.
9. Verify that the contractors have provided the training specified in the contract documents.
10. Verify that the as-built documentation meets the requirements of the contract documents.
11. Verify that operation and maintenance data for the equipment and systems are provided.
12. Co-ordinate with the Commissioning Authority, the construction manager or the general contractor and the contractors.
13. Verify that seasonal testing is completed and all warranty and deficiencies items are corrected.
14. Provide an overall assessment report associated with acceptability of installation and performance of equipment.

1.4 The Commissioning Authority

This section describes the function and responsibility of the Commissioning Authority. The APTS Manager and the project manager will determine, at the beginning of the project, if a Commissioning Authority is required.

1. When required, the Commissioning Authority will be hired directly by the GTAA and report to the GTAA.
2. The GTAA project manager will determine for each project the scope of work for the commissioning authority and at what point in the project the commissioning authority is brought into the project.
3. The Commissioning Authority will provide the following services:
    - Assist the GTAA to develop the Owner's Project Requirements.
    - Assist the consultants to coordinate the project commissioning requirements with the contract documents.
    - Assist the consultants to prepare the commissioning specifications detailing the project commissioning requirements.
    - Prepare the commissioning plan based on the OPR, BOD and the design documents requirements.
    - Perform reviews on the design documents using the OPR and BOD and provide feedback to the consultants.
    - Assist the consultants to verify that the mechanical and electrical systems and their installation meet the contract document requirements.
    - Assist the consultants to verify that the contractors have completed all static, start up, performance verification and system integration tests.
    - Provide independent performance verification and systems integration tests on the mechanical and electrical systems to verify that they achieve the basis of design performance.
    - Participate in the final performance verific A2-13 systems integration testing of the mechanical and electrical systems, to be conducted by the contractors.

- Verify that the contractors have provided the training specified in the contract documents.
- Assist the consultants to verify that the as-built documentation meets the requirements of the contract documents.
- The Commissioning Authority will co-ordinate with the consultant and contractor, including:
    - Verify that operation and maintenance data for the equipment and systems are provided.
    - Verify that seasonal testing is completed and all warranty and deficiencies items are corrected.
- Provide an overall assessment report associated with acceptability of installation and performance of equipment.

1.5 Definitions

Words and terms used in this manual, not included in the list of definitions, will have the meaning that is commonly assigned to them in the context in which they are used. This excludes specialized use of terms by the various trades and professions to which the terminology applies, in which case common industry use shall prevail.

1.5.1 Primary Definitions

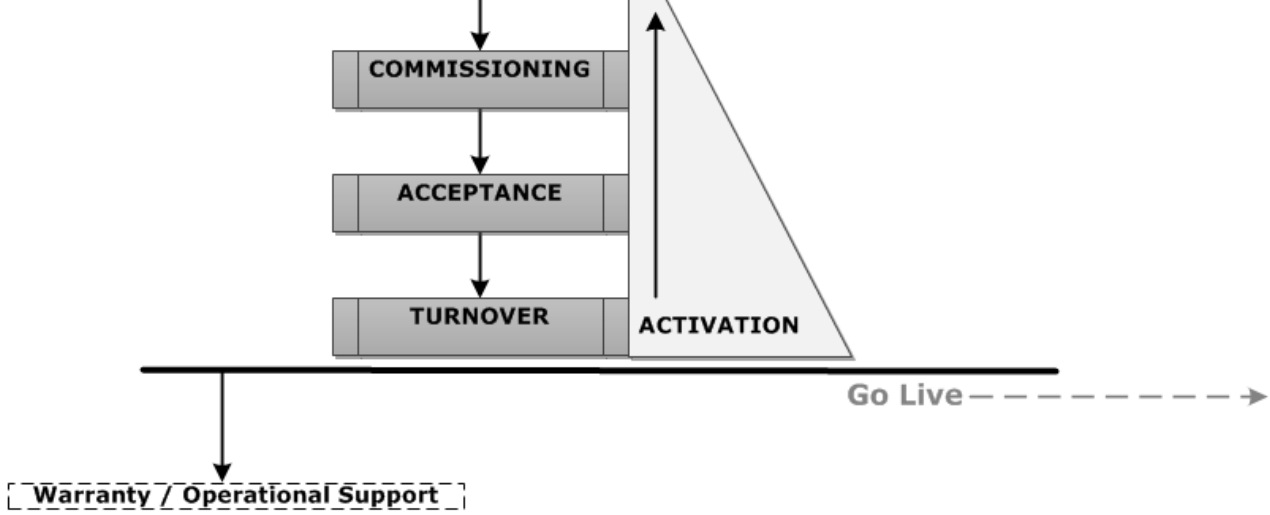
The following words or terms in this manual have the following meaning. See the diagram below for a summary of how they inter-relate.

A. Testing: This stage includes testing components and individual systems against a set of design criteria.

B. Commissioning: This stage includes the systematic verification, documentation, and training, as applied to all activities during the design, construction, static verification, start-up, functional performance testing and integration testing of equipment and systems in a facility to ensure that the facility operates in conformity with the owner's project requirements and the basis of design in accordance with the contract documents.

C. Acceptance: The purpose of this stage is for the Project Manager to verify the deliverables from the vendor based on the project requirements. This process is mostly related to substantial performance.

D. Turnover: The purpose of this stage is for the project team to hand the deliverables over the operations and maintenance groups and for the facility to be operationalized. This includes validating the facility/system is fit for its intended purpose and all deliverables such as drawings, manuals, tools and training have been made available to stakeholders. Though preparation for activation occurs in all steps of the TCAT process the active part of it is during Turnover.



1.5.2 Additional Definitions

Activation – Activation is defined as the transition process from the construction of the new facility to full operation. While the proper operation of the physical asset is assured by the successful implementation of the design, construction and commissioning of the facility for its intended use, it is vitally important that all stakeholders involved in the terminal are properly oriented and trained to operate the new facility seamlessly and continuously. Activation addresses this facet of the development.

Basis of Design (BOD): This is a document, prepared by the consultants, that records the rationale, concepts, calculations, decisions, product selections, schemes and systems complete with narrative describing the design approach to achieving the Owner Project Requirements and to satisfy applicable regulatory requirements, standards and guidelines.

Building Management System (BMS): The BMS is a computerized system, which controls and monitors the various building systems. Several workstations are connected to the GTAA (airport wide) LAN. These workstations allow operators access to the BMS database. Note that the BMS is a term that is used to refer to any combination of Building Management System, Building Automation System, or Facility Monitoring System, jointly referred to as the BMS.

Close out Procedures: The close out procedures will be defined in the contract document. They will define the contractor's requirements to achieve substantial performance, total performance, and the contractor's requirements during the warranty period.

Commissioning Authority: An individual or company identified by an owner to lead the TCAT team in the implementation of the commissioning process (for more information, see section 1.4 The Commissioning Authority).

Commissioning Specifications: This is a document, prepared by the consultants, that describes the project commissioning requirements and details the roles and responsibilities of the TCAT team members in the execution of the commissioning process.

Commissioning Team: The commissioning team is part of the Contractor's team and shall be responsible for ensuring that all building systems work with one another to produce an integrated facility that functions as per the contract documents. For more information refer to section 1.3.

Commissioning Plan: This is a document which describes the commissioning process to be created and implemented by the commissioning team. A project commissioning plan shall be prepared and shall include:

- Objectives
- Team roles and responsibilities

- Commissioning process
- Schedule
- Static verification
- Start-up
- Functional performance testing (including post-occupancy, seasonal, and deferred testing)
- Training
- Documentation
- Final acceptance.

CMMS: Computerized Maintenance Management System

Construction Stage: the construction process from contract award to substantial performance and total performance.

Consultant: the person/company that is responsible for the design of the work being done, including the preparation of the contract documents. The consultant shall participate in the TCAT process as required to ensure that the Owner's Business Requirements are met.

Contractor: the person/company that is responsible for implementing the contract documents, including the appropriate stages of the TCAT process.

Design Stage: The process of the design of the building and its systems, from identifying the OPR for the building to preparing the design to meet these requirements and preparing the contract documents for construction.

EAM: Enterprise Asset Management

Functional Performance Testing: The objective of Functional Performance Testing is to ensure all mechanical/electrical assemblies and components perform in accordance with the design intent. Tests should be selected during the design stage and be appropriate to the operational requirements. Functional Performance Testing shall include, as a minimum, the following: a full range of tests under actual load, conducted to verify that specific systems, subsystems, components, and interfaces between systems conform to a given criteria. These tests are typically used to verify that a sequence of operation is correctly implemented and that the design intent has been met. They are typically performed after equipment is placed in full operation.

Includes: Any use of the terms includes, including, include, etc. shall be interpreted to have the meaning "includes, but not limited to".

Independent Performance Testing and Operational Testing: The GTAA may determine a need to conduct these tests independent of the project team using either GTAA or a 3rd party commissioning consultant resource to verify that the installation and the systems comply with the GTAA Project Requirements and that the design meets current operational requirements.

Integration/Interface Tests: The process of ensuring that the systems and sub-systems components through their respective interfaces are linked together and to any supervisory system in such a way as to achieve a facility/system that functions and operates as intended design.

Integrated System Testing: When functional testing of individual systems has been completed, Integrated System Testing will commence. This includes data transfer verification from system to system to confirm proper reaction and functionality. It also includes testing of multiple integrated systems performance to verify proper functional interface between systems. Typical Integrated Systems Testing includes all regular, failure mode and contingency operations, verifying that systems respond properly to partial system loss, loss of utility, transfer to emergency power sources, re-transfer from emergency power source to normal utility source; interface between HVAC controls and fire alarm systems for equipment shutdown, interface between fire alarm system and elevator control systems, interface between fire alarm system and security access to control access to spaces during fire alarm conditions and other similar tests as determined for each specific project, etc.

Operating and Maintenance Manuals (O&M): This is a document provided by the contractor that provides the operation and maintenance requirements and associated data for safe and efficient operation of specific pieces of equipment and systems.

Owner's Project Requirements: This is a document, provided to the prime consultant, which describes the GTAA project requirements for the building and desired methods to meet those requirements. These will range from architectural, structural, mechanical, electrical and operational requirements. A dynamic document that provides the explanation of the ideas, concepts, and criteria that are considered to be very important to the owner. The OPR should cite specific measurable goals for the owner's objective to the greatest extent possible.

Post Construction Stage: the contractor's responsibility for the warranty period, starting from the date identified in the contract documents to the end of the warranty period.

Seasonal Performance Testing: The deferred testing that the contractor will conduct over the four seasons after substantial performance to verify that the installation and the systems meet the consultant's basis of design under varying load conditions.

Start-up: Progressive start-up of equipment and systems, beginning at the power source and moving outward systematically. The purpose of the tests are to ensure that all equipment and systems are ready for operation and functional performance testing. Prior to start-up the following shall be completed, witnessed and documented:

- Safety tests
- Inspection and acceptance by authorized safety authority
- Emergency power tests
- Firefighters' operation tests.

Static Testing: All tests required to be completed to ensure that the equipment is ready and safe to be energized, prior to start-up.

Subject Matter Expert (SME): is an individual who is an expert in a particular subject field, building system or process.

Substantial Performance: The criteria for achieving substantial performance shall be defined in the contract documents for the project.

Systems Operating Manual: This manual is provided by the consultants and describes, in lay terms, the operating intent of each system, including design performance and operational data. It is to include diagrams

for that illustrate the sequence of operation for each system and interaction between individual systems. An operational manual details modes of operation and includes associated diagrams that illustrate the sequence of operation for each system and interaction between individual systems. This is verified by the commissioning team during the TCAT process.

Testing Commissioning Acceptance Turnover (TCAT): Testing, Commissioning of systems, Acceptance and Turnover (TCAT) of a facility system or component. The process utilized by the GTAA to ensure the equipment and systems are ready for activation and use for the purpose intended [see Definitions a – d].

Total Performance: The criteria for achieving total performance shall be defined in the contract documents for the project.

2 Testing, Commissioning, Acceptance and Turnover (TCAT)

This section provides a general summary of the TCAT process. The TCAT process describes the responsibilities of the design, construction and GTAA teams during all stages of a project. The Testing, Commissioning, Acceptance and Turnover process ensures the OPR, BOD and contract requirements are achieved and the facility can be used for its intended purpose. The consultants and contractors will facilitate and support the GTAA and/or commissioning authority to participate or observe in all stages of the TCAT process.

2.1 General Requirements

The following are common requirements for all stages of the TCAT process:

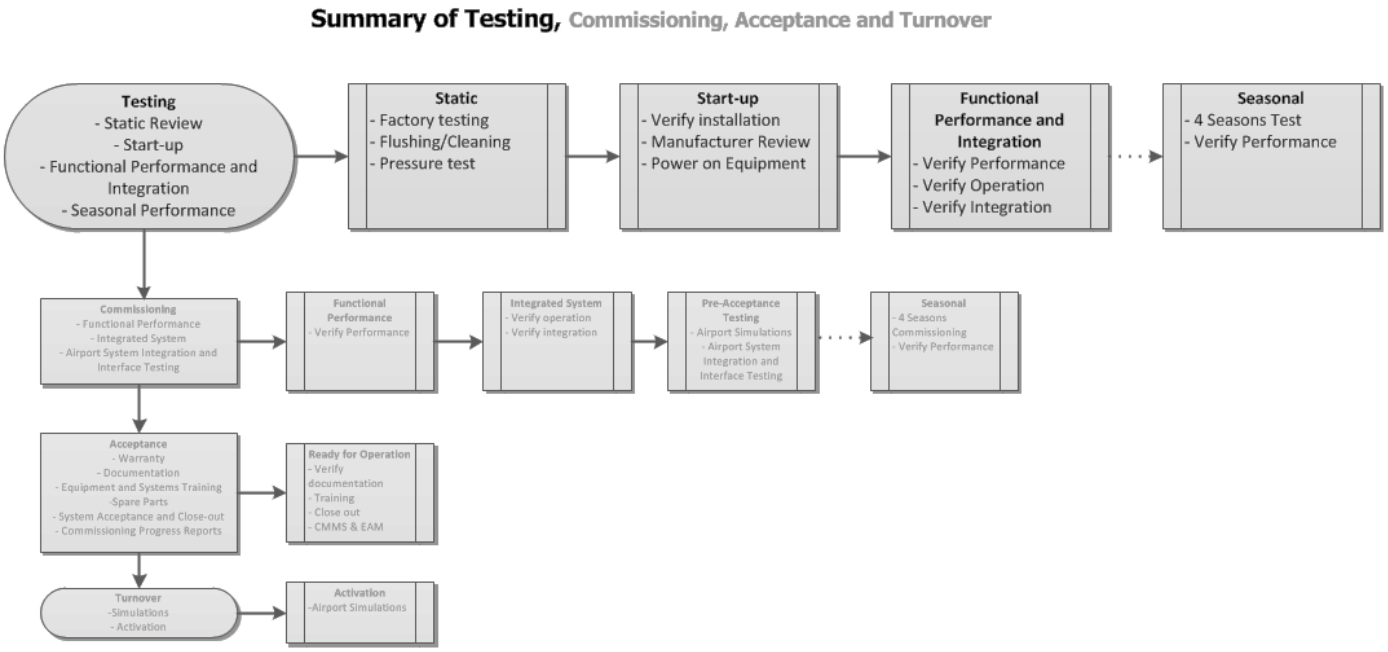
1. The current status and results of the TCAT process will be documented at the construction meetings by the commissioning team and the contractor will update the TCAT activities in the construction schedule in advance of each meeting.
2. Completion of the associated TCAT forms by the commissioning team. The completed forms will be forwarded to the consultants and commissioning authority for review against requirements in general and the Basis of Design specifically.
3. The commissioning team will provide a report, identifying compliance or non-compliance to the basis of design and contract documents at the end of each state and sub-stage.
4. The consultant will issue a compliance or non-compliance letter to the GTAA project manager, detailing any issues that may remain at the Testing, Commissioning and Acceptance phases.
5. The commissioning authority will issue a report to the GTAA project manager, detailing any issues that may remain at the Testing, Commissioning and Acceptance phases.
6. The BMS will be programmed with historic trend logs for a minimum of 3 months. The Commissioning Authority will review these logs to evaluate the performance of the mechanical system.

2.2 Systems

1. The TCAT forms and tests will include the following systems:
    a. Boilers.
    b. Chillers.
    c. Cooling Towers.
    d. Air handling units.
    e. Variable speed drives.
    f. Building Management System.
    g. Central Utility Plant Management and Control System.
    h. Computerized Maintenance Management System.
    i. Baggage systems.
    j. Bridges.
    k. Emergency power.

l. Lighting system.
m. Fire alarm system.
n. Smoke venting and smoke control.
o. Fire Protection.
p. Communication system.
q. IT systems.
r. Security system.
s. Airport Traffic Information System.
t. Apron Fuel Shutdown System.
u. Lighting Management System.
v. Lightning Prediction System.
w. Power Management and Control System.
x. Ramp Services Management System.
y. Vertical and Horizontal Transportation System.

2.3 Testing



Testing incorporates the various methods the contractor will use to verify that components of a specific system are correctly installed and functioning, and that they work in concert with each other to form the specific system (e.g. all electrical, mechanical and fire alarm components within a system).

The Testing Phases includes the following:

a. Static Testing.

b. Start-up Testing.

c. Functional Performance and Integration Testing.

d. Seasonal Performance Testing.

For all stages of testing, the contractor shall prepare a construction schedule, which includes all testing specified or required by the contract documents. The contractor shall provide confirmation of the tests dates, with a minimum of 48 hours' notice.

2.3.1 Static Testing

Responsibilities are as follows:

- GTAA Stakeholders – Optional Attendance
- GTAA Project Manager – Optional Attendance
- Commissioning Authority – Optional Attendance
- Consultant – Optional Attendance
- Contractor - Responsible

The requirements for static testing will be identified in the specifications. They will include the following:

a. Factory acceptance tests.
b. General Site Services.
c. Electrical Cable testing.
d. Switchboard testing.
e. Cable and equipment conductivity tests.
f. Communications Cable testing.
g. Mechanical Drainage testing.
h. Plumbing testing.
i. Piping testing.
j. Duct pressure testing.
k. Flushing/cleaning piping systems, chemical water treatment, domestic water sanitization and water sample testing, inspection by authorities having jurisdiction.
l. Verification of documentation.

2.3.2 Start-up Testing

Responsibilities include:

- GTAA Stakeholders – Optional Attendance
- GTAA Project Manager – Optional Attendance
- Commissioning Authority – Optional Attendance
- Consultant – Optional Attendance
- Contractor – Responsible.

Start-up Testing consists of the following:

1. The Start-up tests will be performed when there is permanent power in the building, or a temporary power source that is acceptable to the GTAA.
2. The contractors will progressively energize the equipment and systems, beginning at the power source and moving outward systematically. Tests include: power phasing, switchgear, protective devices, calibrations, alignments and motor rotations.
3. A systematic start-up of each component of the system until the entire system is operating. Each component is checked and all deficiencies rectified prior to starting the next component.
4. The contractors and equipment manufacturers will verify the installation of the equipment meets the manufacturers and specification requirements and conducts the start-up process.
5. The contractors will conduct the start-up tests and complete the associated test form. The completed forms and tests results will be forwarded to the consultant and Commissioning Authority for review.
6. Observe initial systems operation and visual inspections after operation.
7. Temperature measurements for hydronic and air systems.

8. Voltage measurements.
9. Operation of safety controls and interlocks.

2.3.3 Functional Performance and Integration Testing

Responsibilities include:

- GTAA Stakeholders – Optional Attendance
- GTAA Project Manager – Optional Attendance
- Commissioning Authority – Partial Attendance
- Consultant – Optional Attendance
- Contractor – Responsible.

Functional Performance and Integration testing includes:

1. The purpose of Functional Performance Testing is to verify that the basis of design for the building systems have been achieved in all areas of the building, including as much as possible due to the time of the year of the testing, the operation during different seasonal modes.
2. The systems functional performance and integration testing will be conducted when the static testing and start-up is completed. These tests will be designed to verify the basis of design of the mechanical and electrical systems have been met at all levels of the system.
3. The integrated system tests will be conducted when all mechanical and electrical equipment is operating and when all relevant system testing has been completed.
4. The systems are started and tests are performed through a full range of operating conditions through simulations and monitoring of equipment functions. Corrective actions are recorded and applied.
5. "End to End" tests which tests all functionality from the device level up to, and including the Building Management/Monitoring and Automation systems (BMS). These are performed or repeated at this level, as necessary, to ensure that all functionality is working between the device and the BMS.
6. All failure modes and contingency modes that are applicable to the functional performance testing, including testing of all alarms.
7. The contractors will issue a document to the consultant and commissioning authority that the systems are ready for commissioning.
8. The Commissioning Authority will review the results of the testing with the consultants. The consultants will confirm whether all the results meet the basis of design performance and issue a report to the GTAA project manager.
9. The tests that the mechanical contractor will have completed include:
    - Pressure testing of all piping and ductwork
    - Start-up of all equipment and systems
    - Point to point verification of all controls points
    - Balancing of the air and hydronic.
10. The Air and Hydronic Balancing Contractor will co-ordinate with the BMS Contractor to verify operation of equipment and instrumentation calibration.

11. The mechanical consultant and the Commissioning Authority will witness the final performance demonstration of these systems.
12. The electrical contractor and the electrical testing contractor will have completed the following tests at this stage:
    - Cable testing
    - Switchboard and transformer testing
    - Ground fault protection testing
    - Co-ordination study
    - Voltage measurements.
13. Thermographic testing of the electrical distribution system of 460 Volts and above.
14. Load measurements at all electrical distribution panels and review the results with the consultants.
15. Harmonics readings and review the results with the consultants and Commissioning Authority.
16. The electrical contractor will have completed testing on the diesel generator, automatic transfer switching and the UPS. The mechanical contractor will have completed testing on the oil delivery system.
17. The electrical contractor will conduct a four hour test to verify the system's ability to provide the basis of design performance.
18. The electrical contractor will have completed the testing on the lighting system.
19. The electrical consultant and the Commissioning Authority will witness a final performance test of the operation of the computerized lighting control system and lighting level measurements for each zone of the facility.
20. The electrical contractor and the fire alarm contractor will complete all the required testing and conduct their final verifications. The Fire Department and the code consultant will then attend and witness the testing and demonstration of the fire alarm system and its sub-systems. The sub-systems will include the following:
    - Voice communication system
    - Electro-magnetic locking devices
    - Elevators, escalators and moving walkways
    - Emergency lighting system
    - Sprinkler systems
    - Fire pumps
    - Fire hydrants
    - Fire suppression systems for exhaust hoods
    - Standpipe systems.
21. The electrical consultant and the Commissioning Authority will witness the final performance demonstration of the fire alarm system and its interface with the mechanical systems.

22. The electrical contractor and the security system contractor will have completed testing and verification of the security system.
23. The electrical consultant and the Commissioning Authority will witness the final performance demonstration of the security system and its interface with other systems.
24. The electrical contractor and the associated systems manufacturer will have completed testing and verification of the systems.
25. The electrical consultant and the Commissioning Authority will witness the final performance demonstration of these systems.
26. The contractor and manufacturer will have completed the specified tests and code tests appropriate for any elevator, escalator or moving walk. The consultant, authority having jurisdiction and the Commissioning Authority will witness the final performance demonstration of these systems.
27. The contractor and manufacturer will have completed appropriate tests for any dock leveler. The consultants and the Commissioning Authority will witness the final performance demonstration for any dock leveler.
28. The contractor and manufacturer will have completed the specified tests for door hardware. When the door hardware is utilized by the security and/or the final alarm system the contractor will have tested the door hardware with these systems.
29. The consultants will witness the final performance demonstration of door hardware not associated with the security and/or the fire alarm system.
30. Other items architectural covered by the architectural section of the specifications to also be tested as required.

2.3.4 Seasonal Performance Testing

Responsibilities include:

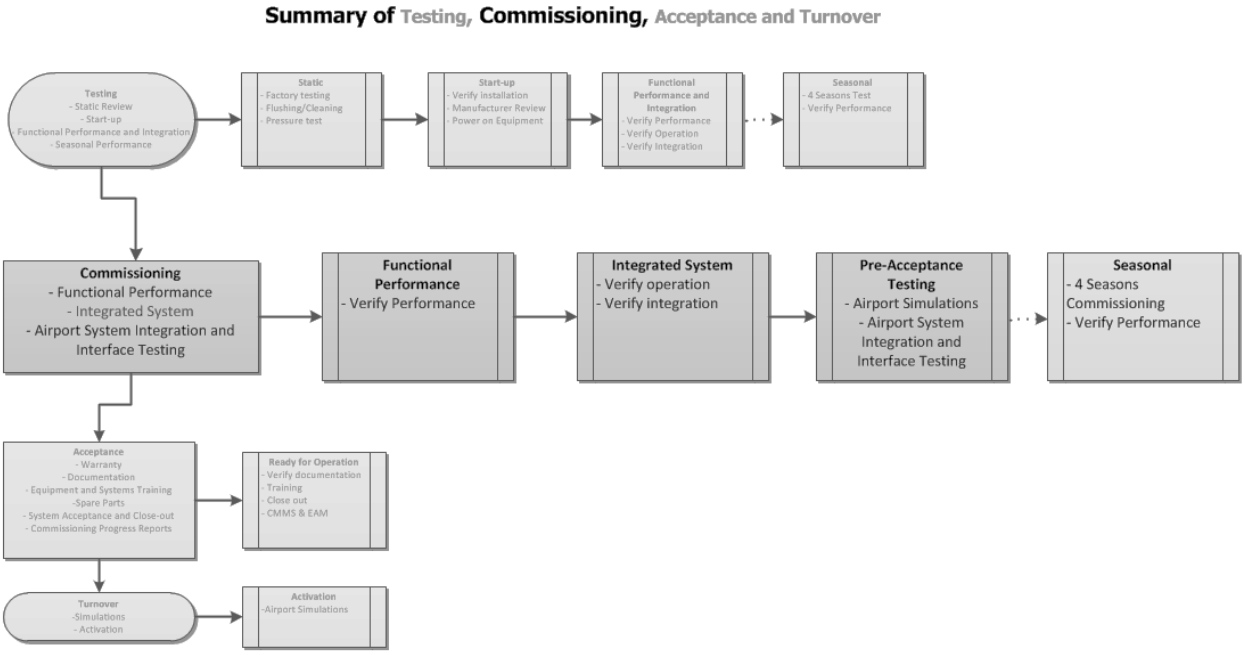
- GTAA Stakeholders – Optional Attendance
- GTAA Project Manager – Optional Attendance
- Commissioning Authority – Attendance
- Consultant – Optional Attendance
- Contractor – Responsible.

Seasonal Performance testing includes:

1. The contractors, consultants and Commissioning Authority will conduct seasonal performance tests so as to allow testing for all 4 full seasons. The intention is to validate operations with full operational loads during extreme conditions as well as shoulder seasons where systems are in transition.
2. The seasonal performance tests will be a continuation of the performance tests conducted prior to substantial completion.
3. The tests will be designed to verify the operation of the mechanical system throughout the four seasons with a building load.

4. The test results will be documented and compared to the basis of design and contract documents requirements. The Commissioning Authority will issue a letter of acceptance.
5. The electrical system does not require systems seasonal performance testing. A power system load balance and harmonics test may be necessary if the building occupancy increases during the first year of operation.
6. The consultants will witness the emergency power start-up tests, once during the warranty period and verify the results with the performance requirements.
7. The consultants will review the results of the seasonal performance testing to verify that the basis of design has been achieved.

2.4 Commissioning



2.4.1 Functional Performance Commissioning

Responsibilities include:

- GTAA Stakeholders – Optional Attendance
- GTAA Project Manager – Optional Attendance
- Commissioning Authority – Attendance
- Consultant – Attendance
- Contractor - Responsible

Functional Performance Commissioning testing includes:

1. When the commissioning team has received notice that the contractors have completed testing, the facility is clean and ready for continuous operation, they will begin the commissioning process. The GTAA will assign, where possible, operational staff to participate in the commissioning process. The BMS will also be used to verify that the basis of design performance is provided at all stages of the mechanical system and in every room of the building. The tests will be based on loads that are available at the time of testing.
2. The functional performance test will commence starting at the equipment and then to the systems.
3. Final performance testing of the mechanical systems. These will include chillers, boilers, air handlers, BMS, pumps, air and water distribution, supplemental cooling, fire protection and plumbing systems.

4. Final performance testing of the electrical systems. These will include switchboards, electrical distribution, ground fault protection, emergency generators, automatic transfer switches, voltage and harmonics measurements, the lighting system, the fire alarm system and the security system.
5. The commissioning team will provide a report, identifying compliance or non-compliance to the basis of design.
6. The commissioning team will verify whether the operational requirements have been provided.
7. The commissioning team will verify the air and Hydronic Balancing.
8. The commissioning team will witness the final performance testing of the various mechanical and electrical systems.

2.4.2 Integrated System Commissioning

Responsibilities include:

- GTAA Stakeholders – Optional Attendance
- GTAA Project Manager – Optional Attendance
- Commissioning Authority – Attendance
- Consultant – Attendance
- Contractor – Responsible.

Integrated System commissioning includes:

1. When every individual system has been commissioned and verified, the systems integration commissioning will begin. The primary purpose is to ensure that all systems integrate with all other systems such that overall system provides the desired functionality.
2. These tests will be set up to demonstrate that all systems operate in concert. For example, when the fire alarm system is activated all associated systems that receive this data will be activated and verified.
3. These tests will verify that data from and to the individual systems has been successfully transferred from and to the BMS.
4. The information displayed at the BMS will be verified.
5. The systems to be integrated will be defined in the individual contracts and may include the following:
    - Airport Traffic Information Management System
    - Apron Fuel Shutdown System
    - Baggage Handling Computer System
    - HVAC Systems
    - Central Utility Plant Management and Control System
    - BMS
    - Fire Alarm System
    - Fire Protection

- Smoke Control and Smoke Venting
- Lighting Management System
- Lighting Prediction System
- Power Management and Control System
- Ramp Services Management System
- Vertical and Horizontal Transportation Management System
- Security System
- IT System
- Architectural Systems.

2.4.3 Pre-Acceptance Commissioning (GTAA)

Responsibilities include:

- GTAA Stakeholders – Partial Attendance
- GTAA Project Manager – Attendance
- Commissioning Authority – Partial Attendance
- Consultant – Partial Attendance
- Contractor – Responsible.

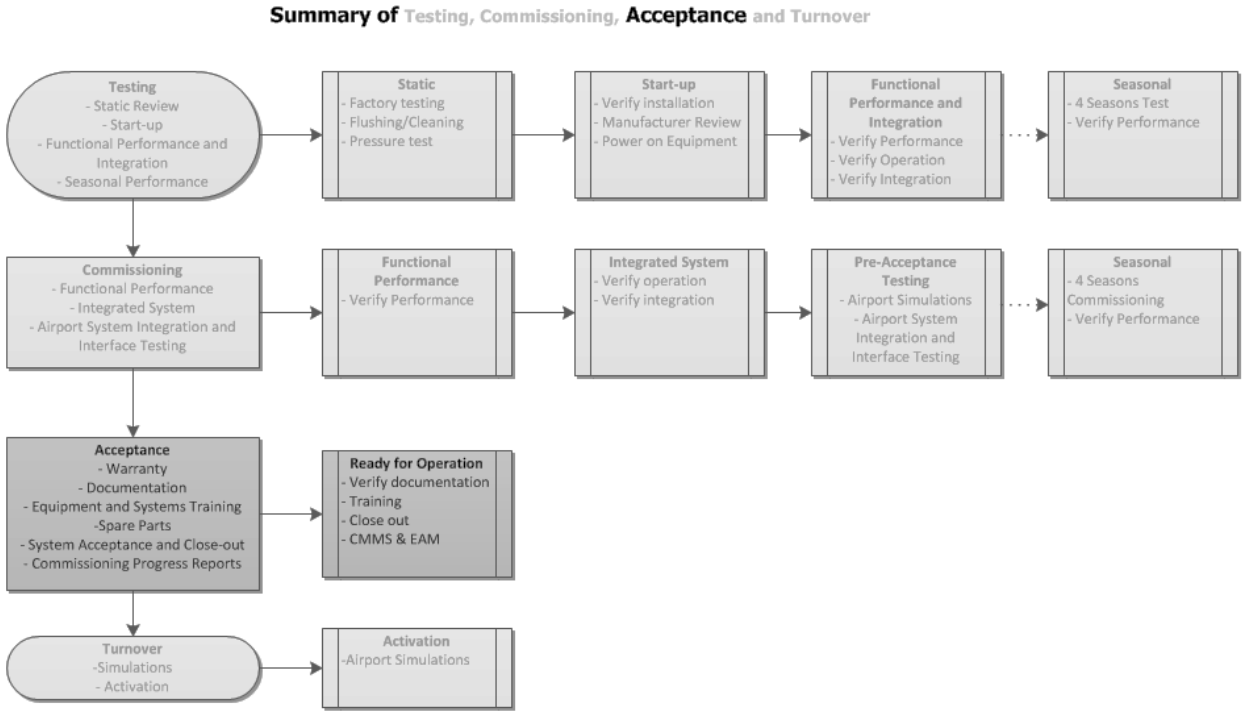
Pre-Acceptance testing includes:

1. Life safety commissioning to ensure that they are ready for the AHJ.
2. Security commissioning to ensure that systems are ready for operational requirements.
3. Elevating device (Elevators, Escalators, Moving Walkways) commissioning.
4. Aircraft fit checks.
5. Emergency and UPS power systems.

2.4.4 Seasonal Performance Commissioning

Refer to section 2.3.4 Seasonal Performance Testing

2.5 Acceptance



The requirements for acceptance will be detailed in the contract documents. The Commissioning Team will co-ordinate with the consultants to verify that the contractor has completed its requirements to achieve substantial and/or total performance.

2.5.1 Verify Documentation

As a minimum, the documentation required for each project is the operation and maintenance manuals, training documents, and as-built drawings. This documentation must be created in an acceptable format, be received in a timely manner, and maintain a high- degree of accuracy and quality of content. These documents provide the foundation of knowledge required to manage the facility. Documentation shall include:

- Commissioning Reports
- Commissioning Issues Tracking Report
- Seasonal Performance Testing Report
- As-Built Record Drawings
- Operating and Maintenance Manuals
- Systems Operating Manual (prepared by the consultants)
- Systems and Equipment Training
- Spare Parts
- Warranty Documentation.
- Close-Out Procedures

- Airport Simulations.

2.5.2 Testing and Commissioning Report(s) (T&C Report)

1. Further requirements for T&C Report may be identified in the GTAA Construction Code and the contract documents.
2. The T&C Report is the responsibility of the contractor and their commissioning team. This report is a condition of substantial performance.
3. The commissioning team will prepare the final T&C Report which will identify that the testing and commissioning stages have been completed successfully and whether the results meets the basis of design. The report will include copies of all test and commission results.
4. The T&C Report will identify any outstanding deficiencies and how they affect the performance of the building.
5. The TCAT team will provide input to the consultants and contractors to establish the data required to prepare this documentation.
6. The contractors reports shall include:
   - Testing schedule
   - Completed test forms
   - Completed equipment start-up forms including maintenance information for each piece of equipment.
7. The commissioning team reports shall include:
   - Comments and recommendations of testing schedule.
   - Comments and recommendations of testing forms received.
   - Comments and recommendations of systems performance test results.
   - Comments and recommendations of integrated systems test results.
   - Deficiency list completion.
   - Confirmation of training schedule.
   - Issues tracking report.
8. The consultants reports shall include:
   - Conformation that testing results received meets the basis of design.
   - Confirmation that commissioning test results received meets the basis of design.
   - Confirmation that shop drawings and as-built drawings meets the specification requirements.
   - Issuing of deficiency lists and confirmation that they have been completed.
   - Confirmation that the turn over procedure has been completed.

2.5.3 As-Built (Record) Drawings

1. Further requirements for as-built drawings may be identified in the GTAA Construction Code and the contract documents. The methodology for quality control during the preparation of these documents must be followed.

2. The red-line drawings are the responsibility of the contractor. They shall be provided at least 30 business days in advance of substantial performance and are a condition of substantial performance.
3. The as-built drawings are the responsibility of the consultant. They are based on the red-line drawings and must be provided, and approved by the GTAA and the consultant, prior to substantial performance.
4. A final update of the red-line drawings and as-built drawings may be required as a result of changes made during final deficiency clean-up. If so the update of the as-built drawings would be a condition of total performance.
5. The TCAT team will provide input to the consultants and contractors to establish the data required to prepare this documentation.

2.5.4 Operation and Maintenance Manuals (O&M Manuals)

1. Further requirements for O&M Manuals may be identified in the GTAA Construction Code and the contract documents. The methodology for quality control during the preparation of these documents must be followed.
2. The O&M Manuals are the responsibility of the contractor. A working draft shall be provided at least 20 business days in advance of training, or at least 30 business days in advance of substantial performance, whichever comes earlier. Final draft version of the O&M Manuals, approved by the GTAA, is a condition of substantial performance.
3. A final update of the O&M manuals may be required as a result of changes made during final deficiency clean-up. If so the update of the O&M manuals would be a condition of total performance.
4. The TCAT team will provide input to the consultants and contractors to establish the data required to prepare this documentation.
5. The contractor must provide updated asset data, as per the GTAA's standards outlined in "Guide for Contractors to Provide Data for Assets Requiring Maintenances" (available through the GTAA Project Manager). This includes information on the removal of all assets from service, as part of the project. These changes must be in place prior to Turnover, so the preventive maintenance program can be developed and initiated.

2.5.5 Systems Operating Manual

1. See Appendix C for more detail on the Systems Operating Manual (SOM).
2. The SOM is a reference source for operations staff, which describes the design parameters and operating performance of the systems.
3. Further requirements for SOM may be identified in the GTAA Construction Code and the contract documents. The methodology for quality control during the preparation of these documents must be followed.
4. The SOM is the responsibility of the consultants with input from the commissioning authority and contractor. A working draft shall be provided at least 20 business days in advance of training, or at least 30 business days in advance of substantial performance, whichever comes earlier.

5. A final update of the SOM may be required as a result of changes made during final deficiency clean-up. If so the update of the SOM is to be provided prior to total performance.
6. The TCAT team will provide input to the consultants and contractors to establish the data required to prepare this documentation.

2.5.6 Systems and Equipment Training

1. Training shall be provided for all new technology, systems, operational methods or maintenance methods.
2. Further requirements for training may be identified in the contract documents.
3. The contractor will develop a training schedule in co-operation with the GTAA APTS Manager, Project Manager and Commissioning Authority. The dates and duration for each day, and required attendees, will be confirmed with the GTAA. The schedule will include for multiple classes to suit operator shift requirements.
4. The schedule will be orderly in that mechanical, electrical and general disciplines are not scheduled on the same days.
5. The contractor will develop a course agenda which will be reviewed by the TCAT team for acceptability. The trade contractor or manufacturer will ensure all training is of acceptable quality and content and that it meets the owner's requirements. The contractors and manufacturers will follow the approved agenda.
6. A typical agenda shall include:
    a. Introduction to the manufacturer or contractor.
    b. A list of contacts and phone numbers etc., will be provided.
    c. Hand out material will be provided
    d. The design of the equipment or system will be reviewed.
    e. The operation of the equipment or system will be reviewed.
    f. The maintenance requirements of the equipment or system will be reviewed.
    g. The emergency procedures will be reviewed.
    h. The operating and maintenance manual will be reviewed.
7. The contractor will ensure that each trainer has provided an agenda and has experience with the training process.
8. The trainer for each session will be experienced with the operating and maintenance procedures for this particular equipment or system and have the necessary presentation skills to perform the training effectively.
9. Sufficient hand-out material will be provided by the contractor such that all participants will have training materials.
10. The trainer will prepare an attendance list for each training session. A copy of these lists will be forwarded to the GTAA Project Manager.

11. Training will be a condition of substantial performance, and total performance, depending on the timing of the training requirements as specified by the GTAA.
12. The contractor will provide electronic training material which duplicates the scope of each training session.

2.5.7 Spare Parts

1. The consultants will verify that the spare parts turned-over by the Contractors are in accordance with the contract documents.
2. Spare parts handover are a condition of substantial performance.

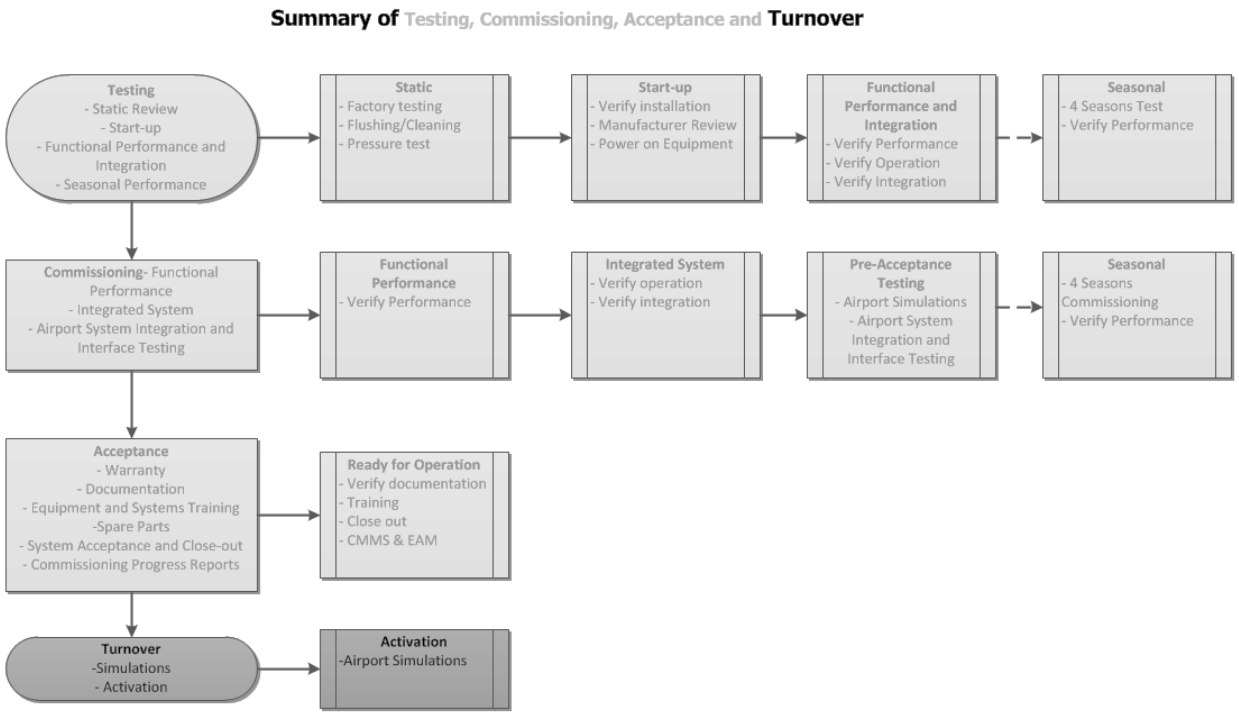
2.5.8 Warranty

1. The GTAA will report warranty issues to the Contractor or directly to the installation contractor or manufacturer who will conduct repairs and retest the associated equipment and system if required. (See Appendix B)
2. Just prior to the end of the warranty period the contractors, consultants and the commissioning team will meet at the facility to review and provide recommendations on:
   - Outstanding deficiencies
   - Warranty issues
   - Operating issues
   - Maintenance issues
   - System performance issues.

2.5.9 Acceptance

1. Acceptance procedures are outlined in the contract documents.
2. The commissioning authority will provide recommendation to the GTAA Project Manager for acceptance.
3. The consultant shall provide recommendation to the GTAA Project Manager for acceptance.
4. The GTAA Project Manager will seek approval from the GTAA stakeholders prior to acceptance.
5. The GTAA Project Manager will accept the system/facility on behalf of the GTAA.

2.6 Turnover



The purpose of the turnover phase is to ensure that the system or facility is fit for the purpose intended, including the operational requirements.

For simpler systems this may be as simple as a sign off process between the GTAA Project Manager and the business stakeholders. For more complex system there may be an entire activation process.

Responsibilities include:

- GTAA Stakeholders – Responsible
- GTAA Project Manager – Support
- Commissioning Authority – Advisory
- Consultant – Advisory
- Contractor – Support.

2.6.1 Activation

The activation of a facility is a process that follows the project from its inception through completion to opening day. The objective of the process is to deliver a fully functional facility, compliant with all of the terms and conditions of the contract documents including codes standards and requirements to obtain occupancy and the airport license.

The activation process also establishes the facility meets the current operational needs. All staff must be fully trained and intimately familiar with operating and maintaining the facility. All operating and technical documentation must be accurate and effectively stored to allow easy access.

As part of the activation process simulation of actual airport requirements may be required.

2.6.2 Simulations (GTAA)

The GTAA may perform Airport Simulations to verify all operational and maintenance procedures are adequate and that the facility and equipment meet the operational requirements. During this period the equipment will be operated on a continuous basis to resolve operational difficulties and to refine operating and maintenance activities. Various real life scenarios will be enacted using volunteers as mock passengers to demonstrate functional responses to the facilities, and systems.

2.6.3 Simulation Tests

As part of the Simulations all or part of the commissioning tests may be enacted including:

- Security and Life Safety
- Passenger access to and from the Airport,
- Processing of passengers through the terminal facilities including baggage, Customs, Immigration controls and security requirements.
- Efficiency of directional signage and graphics including ATIMS, FIDS, BIDS.
- All Airfield systems including apron equipment, Passenger boarding Bridges, 400 Hz power, point of use water, guidance systems and emergency response.

2.6.4 Simulation Training

Simulation provides the opportunity for extensive orientation and training of staff that will operate the facility. Response to emergency and other situations will be analyzed and improved. Although the training program is a continuous process throughout construction this stage of the training is paramount to success.

2.6.5 Airport Simulations

When the systems have been accepted the GTAA will conduct Airport Trials and Simulations. The commissioning team may be requested to assist with this process. The Project Manager will determine the level of involvement of the Commissioning Team.

2.6.6 Independent Testing

Simulations provide an ideal opportunity to fine tune the systems and to performance test all of the systems under load.

The commissioning team will performance test selected components and systems during this stage to ensure effective and reliable operation beginning opening day.

2.6.7 Acceptance

As part of the activation process the business owner will identify, to the GTAA Project Manager, deficiencies, warranty issues or requested changes to the system or facility. The GTAA Project Manager will act on these as appropriate.

Once all items have been rectified or resolved the business owner will accept the system from the GTAA Project Manager.

2.6.8 Go-Live

Once all systems have been accepted and all documentation is in place, the system or facility will be able to "Go-Live".

A TCAT Test Forms

This section describes the requirements for test forms to be produced and to be utilized as record documentation of the TCAT process. Where required the documentation is to be compliant with all applicable Provincial and Federal Regulations e.g. the Federal Halocarbon Regulations (FHR).

1. Some sample test forms are attached for reference. All forms are to be submitted to the GTAA for approval before being used.
2. The static and start up test forms are to be completed by the contractor. A copy is to be forwarded to the construction manager or general contractor on a monthly basis in electronic form. The originals are to remain in a hard covered binder, which will be turned over to GTAA at substantial performance. A complete set of completed test forms are to be turned over to the GTAA in electronic form prior to substantial performance and total completion.
3. Testing shall be done “end to end” in that all tests shall include operation of the end device (field device or logical trigger) and shall include tracking for correct response at the Building Management/Automation Systems.
4. The contractors will enter the test results on the forms. If the tests do not achieve the results required by the specifications or regulations the contractors will correct the problem and repeat the test.
5. The contractors and equipment manufacturers will conduct the contractor’s performance tests. They will complete the forms provided by the manufacturers, which verifies the installation and operation of the system.
6. The tests will be witnessed either by the appropriate GTAA representative, the consultant, and or Commissioning Authority and the construction manager or general contractor.
7. The contractor and the witnessing body will sign the test forms.
8. The functional performance and integration test shall commence once all static and start-up testing has been completed and the system operation has been confirmed by the contractor.
9. The commissioning authority with input from the commissioning team shall develop the performance test procedure for all equipment and systems to be tested.
10. The commissioning authority with input from the commissioning team shall develop an integration test matrix listing all the systems to be tested and expected results during the integration test.
11. The commissioning authority shall direct the commissioning team and contractor in the implementation of the integration test and document the test results.
12. Responsibilities:
    - GTAA Stakeholders – None
    - GTAA Project Manager – Advisory
    - Commissioning Authority – Review
    - Consultant – Review
    - Contractor – Responsible.

A.1 Test Form Categories

1. Test forms are to be created for each stage of testing including:
    - Static tests
    - Start-up tests
    - Functional Performance and Integration tests
    - Seasonal Performance, tests Airport Integrated Interface System tests.

A.1.1 Mechanical Test Forms

1. Mechanical test forms and tests will include the following tests:
    - Drainage tests
    - Domestic piping pressure tests
    - Duct leakage pressure tests
    - CHW piping pressure tests
    - HW piping pressure tests
    - Air and hydronic flow tests
    - System temperature tests
    - Sprinkler piping pressure tests
    - Halocarbon refrigerant system leak test
    - Vertical Sortation Unit Inspection.

A.1.2 Electrical Test Forms

1. Electrical test forms and tests will include the following tests:
    - Cable testing
    - Electrical distribution testing
    - Co-ordination study
    - Electrical Field Devices Inspection.

A.2 Static Tests

1. Static test forms and tests will include:
    - Completion of piping fittings and field installed devices
    - Piping and ductwork pressure leak test
    - Cable testing
    - Shipping bolts removed
    - Vibration isolators unrestrained

- Equipment identification completed
- Thermal insulation completed
- Conduit and cable fire-stopping completed
- Grounding completed.

A.3 Start-up Tests

1. Start-up test forms and tests will include:
    - Correct motor rotation
    - Check for excessive vibration
    - Inspection for gland and seal leaks
    - Pump, fan and equipment startup
    - Check breaker size and whether it trips
    - Check motor overload size and whether it trips.

A.4 Functional Performance and Integration Tests

1. The functional performance and integration test is performed with the system in full operation. The system is exercised through all possible scenarios.
2. The functional performance and integration test forms will be prepared by the Commissioning Authority with input from the commissioning team. The functional performance and integration tests will be conducted by the Commissioning Authority with assistance from the contractors.

B Hydronic and Air Balancing

This section includes the requirements for hydronic and air balancing of the mechanical system. The requirements for air and Hydronic Balancing will be included in the specifications by the mechanical consultant and shall comply with the requirements of NEBB and /or AABC.

B.1 Typical Project Structure

1. The hydronic and air balancing contract will be tendered by the mechanical contractor. The balancing contractor will report to the mechanical contractor.
2. The balancing contractor is an integral part of the commissioning team and will co-ordinate with the Commissioning Authority.
3. The mechanical specifications identify the work that the mechanical contractor must complete prior to the balancing contractor starting their work.

B.2 System Balancing

B.2.1 Hydronic Systems Testing, Adjusting and Balancing

1. The balancing contractor will have reviewed the piping installation and provided reports regarding balancing valves and their locations. They will have received the shop drawings for the mechanical equipment to obtain the necessary data to balance the piping system, i.e. pump curves, equipment pressure drops, etc. The remaining data that they require will be documented in the construction drawings and specification.
2. The mechanical contractor will have flushed the piping systems and under the direction of the chemical treatment contractor, treated the water. Final samples will have been tested and the results reviewed by the consultant.
3. The balancing contractor will proceed to set balancing valves to the desired settings and verify hydronic flows throughout the systems.
4. Should the balancing contractor find major discrepancies with their measurements and the basis of design, they will immediately inform the consultant. The problem will be rectified as soon as possible.
5. The balancing contractor will, on a daily basis, provide deficiency reports to the contractor and the Commissioning Authority. It is important that these deficiencies are corrected immediately to maintain the construction schedule.
6. The balancing contractor will provide an interim balancing report within two working days of completion of a system. This report will be reviewed by the consultants and the Commissioning Authority. Any discrepancies with the results and the basis of design must be corrected immediately.
7. The final balancing report will be provided within two weeks of completion of balancing of all the hydronic systems.
8. The balancing procedures and data required to be entered into the report are documented in the specification.

B.2.2 Air Systems Testing, Adjusting and Balancing

1. The balancing contractor will have reviewed the ductwork installation and provided reports regarding balancing dampers and their locations. They will have received shop drawings for the mechanical equipment to obtain the necessary data to balance the ductwork systems, i.e. fan curves, equipment pressure drops, etc. The remaining data that they require will be documented in the construction drawings and specification.
2. The mechanical contractor will have pressure tested the ductwork and completed the equipment start up procedures.
3. The contractor will have cleaned the ductwork and facility so that it is ready for continual air handling unit operation.
4. The balancing contractor will proceed to balance the ductwork systems. The procedures are documented in the specifications.
5. Should the balancing contractor find major discrepancies with their measurements and the basis of design they will immediately inform the consultants. The problem must be rectified as soon as possible.
6. The balancing contractor will, on a daily basis, provide deficiency reports to the contractor and the Commissioning Authority. It is important that these deficiencies are corrected immediately to maintain the construction schedule.
7. The balancing contractor will provide an interim balancing report within two working days of completion of a system. This report will be reviewed by the consultant and the Commissioning Authority. Any discrepancies with the results and the basis of design will be corrected immediately.
8. The final balancing report will be provided within two weeks of completion of balancing of all the ductwork systems.
9. When balancing is complete the balancing contractor and the Commissioning Authority will conduct performance testing on the air handling unit.
10. The mechanical consultant will review the balancing report and compare the data to the basis of design and specification performance data.

B.2.3 Balancing Contractor & Controls Contractor Co-ordination

1. The controls contractor must be available when the balancing contractor is conducting their work. The co-ordination will be for all required functionality including:
    - Commanding control valves open and closed
    - Setting up mixing dampers
    - Setting up pressure and differential pressure controls
    - Setting up fan tracking controls
    - Setting up VAV box minimum and maximum set points
    - Setting up static pressure controls.

C Systems Operating Manuals (SOMs)

This section describes the requirements for the Systems Operating Manuals (SOM). The SOM is intended to provide an understanding of how a system is intended to function inclusive of the design assumptions. This will provide for design review ease and better understanding of how the system performs under different conditions.

C.1 Application

1. The consultants will provide construction, CAD (micro station format) drawings on a disk or on CD. The contractors will provide copies of the as-built shop drawings and equipment operating and maintenance manuals. The contractors will also provide information regarding equipment locations and schedules.
2. The SOM is to be used as a training tool and should be initially assembled early in the construction stage. It is recognized that the SOM will evolve as construction progresses. The SOM first draft will be available for review, by the GTAA, 20 business days prior to start of training. The second draft will be available 3 weeks after the commissioning authority completes the performance testing. The final document will be available after the seasonal performance testing has been completed.

C.2 SOM Structure

The Systems Operating Manual will be divided into volumes, with each volume sub-divided into chapters.

Volume Structure – Large Projects

The Volume structure for large projects will consist of the following:

- Volume 1 – Building Services (energy sources, plumbing and drainage, fire protection, building HVAC)
- Volume 2 – Electrical Systems (Emergency Power System, Lighting System, Fire Alarm System, Security System, Communications and Monitoring Systems)
- Volume 3 – Heating Systems
- Volume 4 – Chilled Water Systems
- Volume 5 – Controls Systems
- Volume 6 – Equipment Data Sheets / Commissioning Records
- Volume 7 – Preventative Maintenance Program.

Volume 7 does not form part of the Commissioning Program. Each Volume will consist of an individual binder, complete with spine and front covers graphics, to be approved by the GTAA Project Manager.

Volume Structure – Small Projects

Small Projects will follow the large project Volume structure, except that Volumes may be combined in one or more binders. Where multiple Volumes are provided in one binder, they will be separated with a labeled tabbed divider.

C.3 Chapter Structure – All Projects

1. Each Volume will be sub-divided into chapters, the number and title of which will depend on the requirements of each project. Example chapters may include:
    - Building exhaust systems
    - Air conditioning systems
    - Normal power distribution
    - Emergency power distribution.
2. Each chapter will include the following information, and be presented in a format acceptable to the GTAA, or will be completed on a form to be provided by the GTAA:
    - Table Data
    - General system description
    - Design Criteria
    - System Location
    - System Redundancy
    - Energy Source
    - Emergency Power Operation
    - Emergency Procedures
    - Operating Schedule
    - Drawing Reference (list of design drawings)
    - Operating and Maintenance Manual Reference
    - System Setpoint Parameters
    - BMS/Controls Sequence of Operation
    - Operating Instructions
    - Operator's Notes
    - Schematic diagram of system operation
    - Interface/interaction with other systems.

2.7 SOM Content

2.7.1 Table Data

Provide a summary table which includes the following information:

- System name
- Reference Number
- Abstract

- A list of major associated equipment and equipment ID's
- Location of Equipment.

2.7.2 General Description

- An expansion of the system abstract, the general description will provide a brief overview of the system.

2.7.3 Design Criteria

The basis of design data will be obtained from the construction documents, shop drawings and the equipment operating and maintenance manuals. The consultants will provide any data not identified in these documents.

2.7.4 System Location

1. The system location will identify the location of major equipment. A reproduction of the CAD drawings will also identify the location.
2. The areas in the building served by the system will be identified. In some cases it may be possible to add CAD drawings which have been color coded.

2.7.5 System Redundancy

Provide a description of redundancy levels provided by the equipment in the event of equipment failure.

2.7.6 Energy Source

The energy sources section will identify what energy sources service the equipment or system. For example:

- Air Handling Unit #1
- Heating water, converted to glycol
- Chilled water
- Steam for humidification
- 600V power from MCC #1
- 120V power from panel #001, circuit #02, circuit #04, circuit #06.

2.7.7 Emergency Power Operation

A description of all of the systems and/or parts which may operate on emergency power.

2.7.8 Emergency Procedures

- The emergency procedures will identify the recommended procedures which are contained in the main equipment manufacturers' documentation.

2.7.9 Operating Schedule

- Describe the operating schedules applicable to the system, including automatic time clock operation, and methods for manual or remote "after-hours" operation.

2.7.10 Drawing Reference

- Provide a reference list of As-Built drawings.

2.7.11 Operating and Maintenance Manuals Reference

- Provide a cross-reference listing for equipment maintenance manuals.

2.7.12 Setpoint Parameters

- The systems parameters section will identify the equipment and systems environmental setpoints, time of day schedules, alarm limits, current setpoints, time of delays, etc.

2.7.13 Sequence of Operation

- The system operation section will describe how the system has been set up to operate. This section will reference other documentation where more detail can be found.

2.7.14 Operating Instructions

- Provide descriptions of system start-up requirements. This will be modified by the building operators as required.

APPENDIX B

Network Rail – Example of Contract-Specific Requirements for the Design of Key Infrastructure

MODULE 1-1

CONTRACT SPECIFIC REQUIREMENTS

Contract Number	OP-146642		
Contract Name	CPS Western Capacity Improvement Program – Reading to Oxford		
Document Reference	CP6/RDG-OXF-CR-T 001		
Document Issue	Version 001	Document Date	24TH April 2015

Extracts from the above which specify the application of "whole life cost" approach to option selection

Whole Life Cost Strategy

The primary benefit of this project is to enhance the network to support economic growth through the provision of additional capacity to cater for increasing demand. This means it is appropriate to apply WLC methodology from the outset in line with the Network Rail WLC Manual.

In GRIP stages 1 and 2 WLC should be delivered by adopting business case methodology when generating options, allowing identification of options with positive business cases at the end of GRIP stage 2. Delivery of the different elements of business case methodology will be agreed between the sponsor and the Network Rail Economic Analysis team. Estimates developed throughout the GRIP process shall be developed in line with the Rail Method of Measurement (RMM).

It is expected that a generic model can be used for assessment of WLC, with outputs at each GRIP stage aligning with the process described in Section 7.2 of the WLC Manual. Options which provide partial delivery of the ITSS should be identified if they offer significant benefits in affordability. Infrastructure interventions which can be phased in line with increased train service requirements and other route enhancements (such as ETCS, HS2 and Digital Railway) over time will be preferred and the Whole Life Cost comparison of phased approaches (if available) with single, larger interventions should be made, including measurement against the following three criteria :

- Affordability

- Value for Money
- Feasibility

A Whole Life Cost study shall be undertaken in accordance with the Network Rail WLC Manual, which provides the methodology and tools relating to why, when and how to apply WLC analysis throughout the GRIP process.

Whole Life Cost Model

The Contractor shall produce capital cost estimates (at the appropriate level of detail) for each long-list and short-list option to enable comparison as part of the optioneering process. The Contractor shall also provide details on any routine maintenance works required throughout the life of the asset to enable the Asset Manager to assess likely costs as part of their option selection process.

Options which allow the phased delivery of outputs in line with increases in train service requirements (an expression of which is contained in the train service specification addendum) should be preferred. Where the delivery of infrastructure interventions over a shorter timeframe offers better value for money then this trade-off should be expressed as part of the Whole Life Cost analysis used to support option selection.

The [GRIP2] Options Feasibility report will present the final set of options that are deemed to meet the overarching requirements. Any derogations from the requirements shall be clearly articulated for each option. The report shall include drawings/sketches, computer generated 3D/4D models and the results of any initial investigations to effectively present and compare the relative Whole Life Costs, maintainability, safety, buildability benefits (in terms of risk minimization for cost, program and scope certainty), disadvantages, program risks, etc. associated with each option.

Critical success criteria for the stage are:

- Whole Life Cost analysis carried out: WLC model built taking account of economic benefits (led by the Sponsor in conjunction with Economic Analysis team), capital costs, renewals, operations, maintenance and end of life costs, particularly those factors that differ between the options. This shall be carried out in line with Network Rail's Whole Life Cost methodology

Reference

Office of Rail and Road, **http://orr.gov.uk/about-orr/who-we-work-with/industry-organisations/network-rail**)

APPENDIX C

TCO Tool – User's Manual

For questions or feedback please contact:

Laith Alfaqih
Tel: (205) 886-5211
E-mail: LALFAQIH@CH2M.COM

About TCO Tool

The Total Cost of Ownership (TCO) tool was developed as part of ACRP project 09-13 “Considering Life Cycle Costs in Airport Procurement”.

To learn more about the project, please visit the project’s webpage at:

http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3850

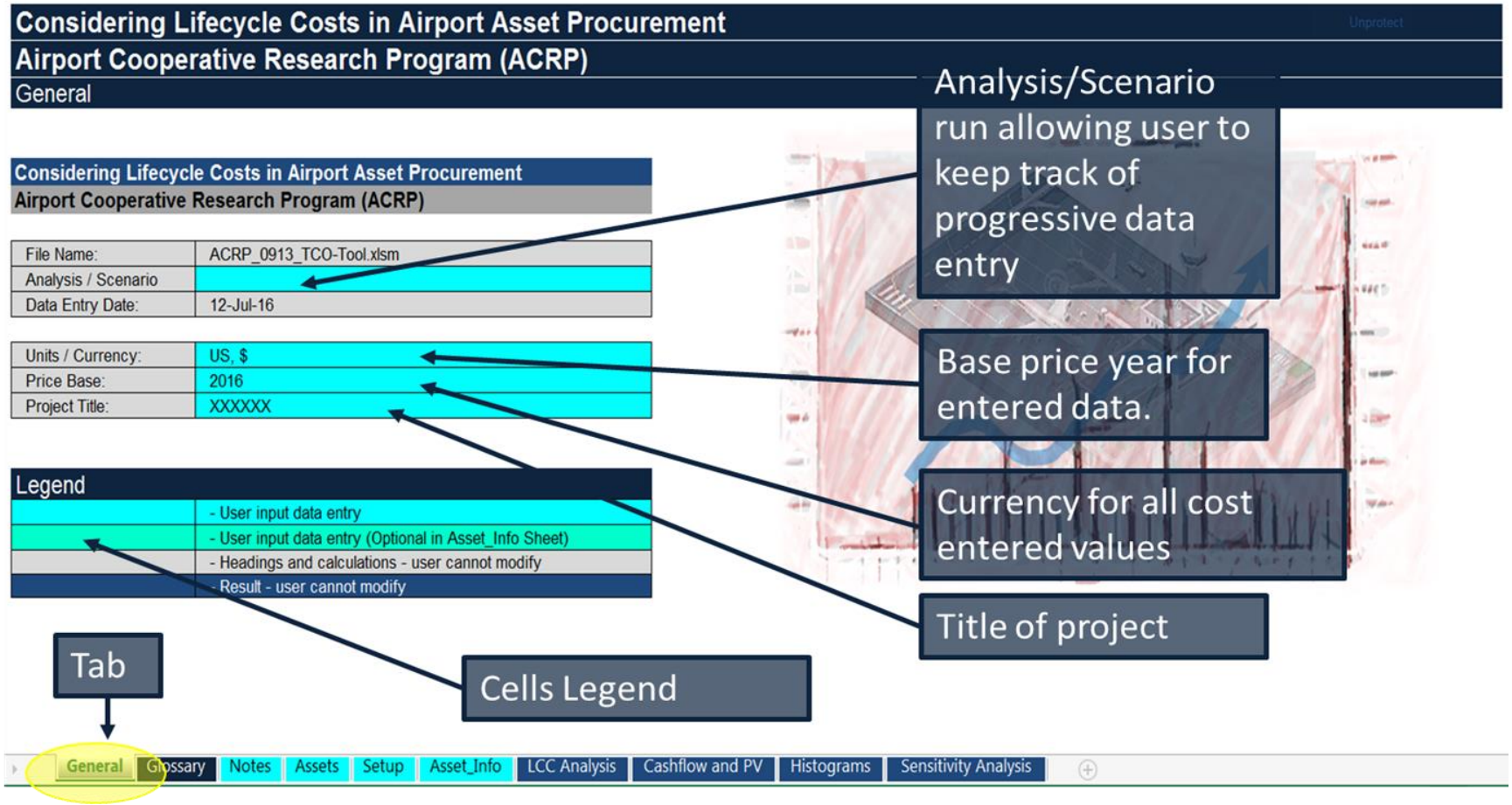
General Guidelines

- The TCO tool is Excel based. The user can save this file multiple times under different titles.
- **Cells colored light blue (all sheets) and light green (Asset Info sheet) will accept user input**. All other colors are intended for display and calculation and should remain unchanged.
- Not all user input cost related cells are required and will be assumed "0" if omitted
- Deleting or inserting rows / columns is not recommended to maintain integrity of calculations. Therefore, this excel file is locked to prevent these accidental changes.
- Screenshots in this manual are examples and for demonstrative purposes only

General Information

The General Information tabs are black

General Information



Glossary

- This sheet provides the definition of the terms used in the tool
- These definitions are also available as comments for terms in the “Asset_info” sheet

Considering Lifecycle Costs in Airport Asset Procurement
Airport Cooperative Research Program (ACRP)
Glossary

Term	Definition
Adj. Start Year	Indicates the commencement of the incurred costs. This is the calculated difference between the Expected Service Life of Asset and Age Adjustment.
Age Adjustment	The age of the existing asset. This is the calculated difference between the Installation Year of Asset and the Model Start Year. Redundant if a new asset.
Annual Insurance	An annual fee/premium paid to the insurance company or supplier to provide a guarantee of compensation for specified loss or damages on the asset during operation
Appraisal / Analysis Period	Period of time in years which the analysis covers
Asset Unit Cost (Equipment, Material, etc.)	Cost to acquire the asset (equipment, material, etc.) or the cost of the collective material to produce the asset.
Installation Year of Asset	This is the first installation of the asset. If this is greater than the Model Start Year it is assumed there is no existing asset in place
Business Case Development	Cost to produce the business case evaluation document to support the decision making process
Capital improvements	Cost to introduce enhancement to the facility as part of installing or upgrading the asset
Child / Element	The components that collectively make up the asset
Construction Index adjustment percentage	This is the % delta change when using cost indices for different estimating periods (i.e. quarters) to be applied to the unit cost rate of an element/sub-component.
Consulting Fees	Fees paid to consultants to study, analyse, plan, design, and produce any related documentation for the implementation of the asset
Corrective Maintenance	Cost to conduct corrective maintenance activities to the asset
Decommissioning Cost	Cost to remove the asset from active service
Design Cost	Cost to design the asset and produce any related documentation such as drawings, documentation, specifications, etc.
Discount Rate	The interest rate used to discount future cash flow to its present value
Disposal Fee of Old Equipment	The cost to get rid of the asset at a facility which might include in addition to the facility fee; 1.) State disposal and environmental protection fee, 2.) solid waste management district fees, and 3.) host community fees
Energy Consumption	The cost of consumed energy (electric, gas, etc.) to operate the asset
Expected Service Life New Asset	The frequency (in years) at which the work item (capital or O&M) is undertaken for the new asset. It should reflect monitored engineering experience.
Expected Service Life of Existing Asset	This is the expected service life or design life of the existing asset based on the manufacturers guarantee aligned to specific in-use conditions
Extended Warranties	Cost to extend the warranty after expiration (see warranty cost)

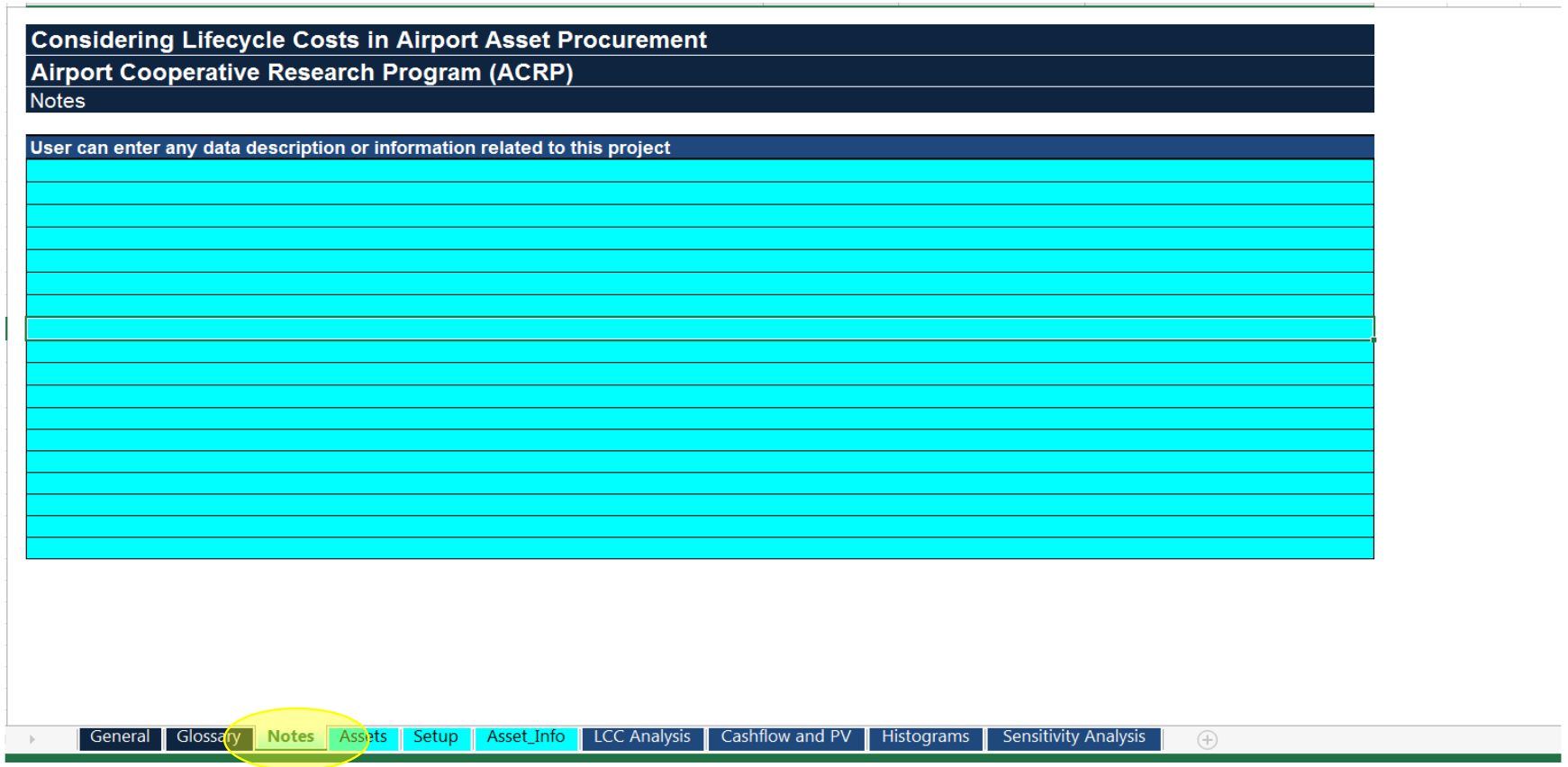
General | Glossary | Notes | Assets | Setup | Asset_Info | LCC Analysis | Cashflow and PV | Histograms | Sensitivity Analysis

Data

The Data input tabs are light blue

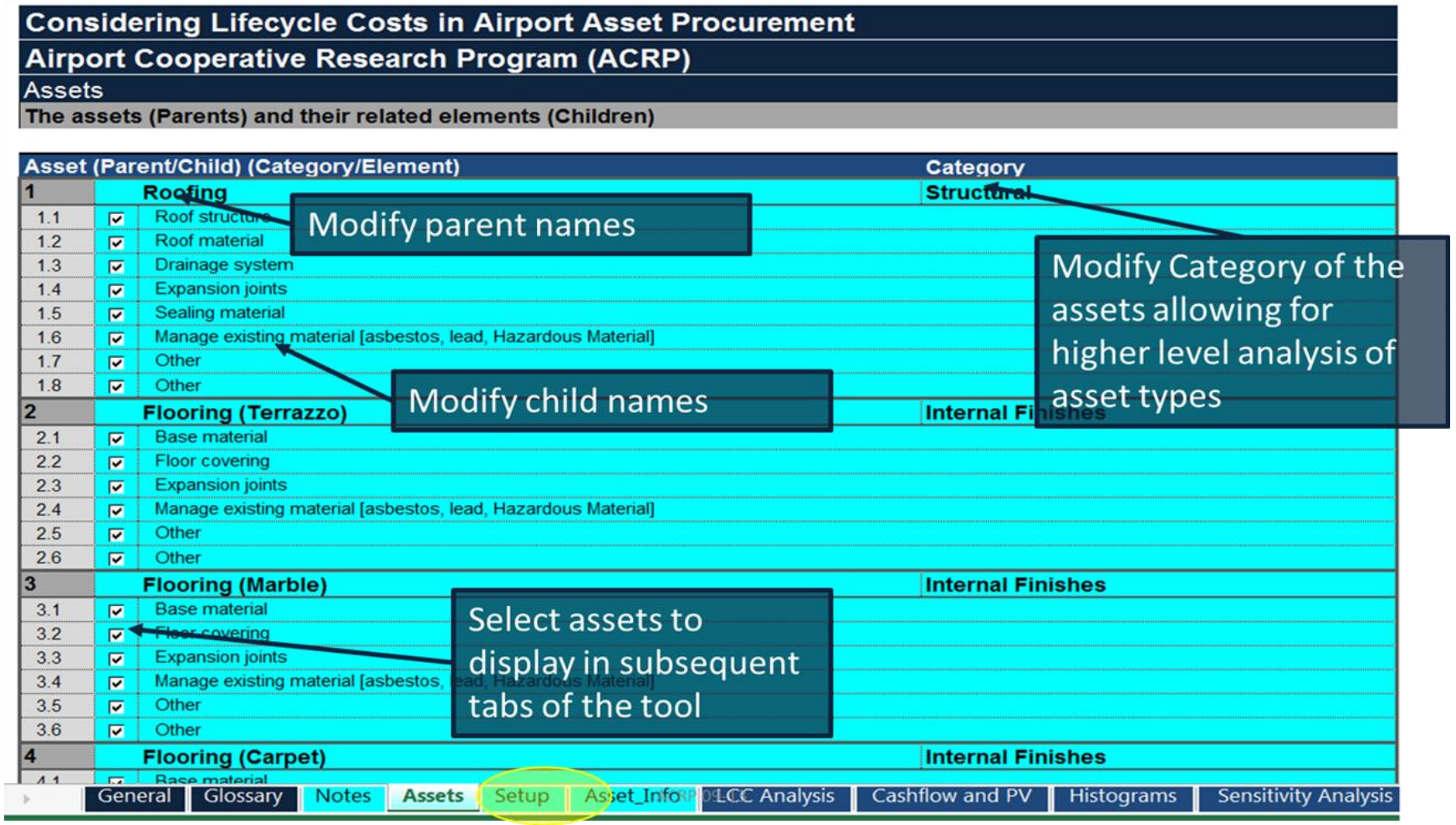
Notes

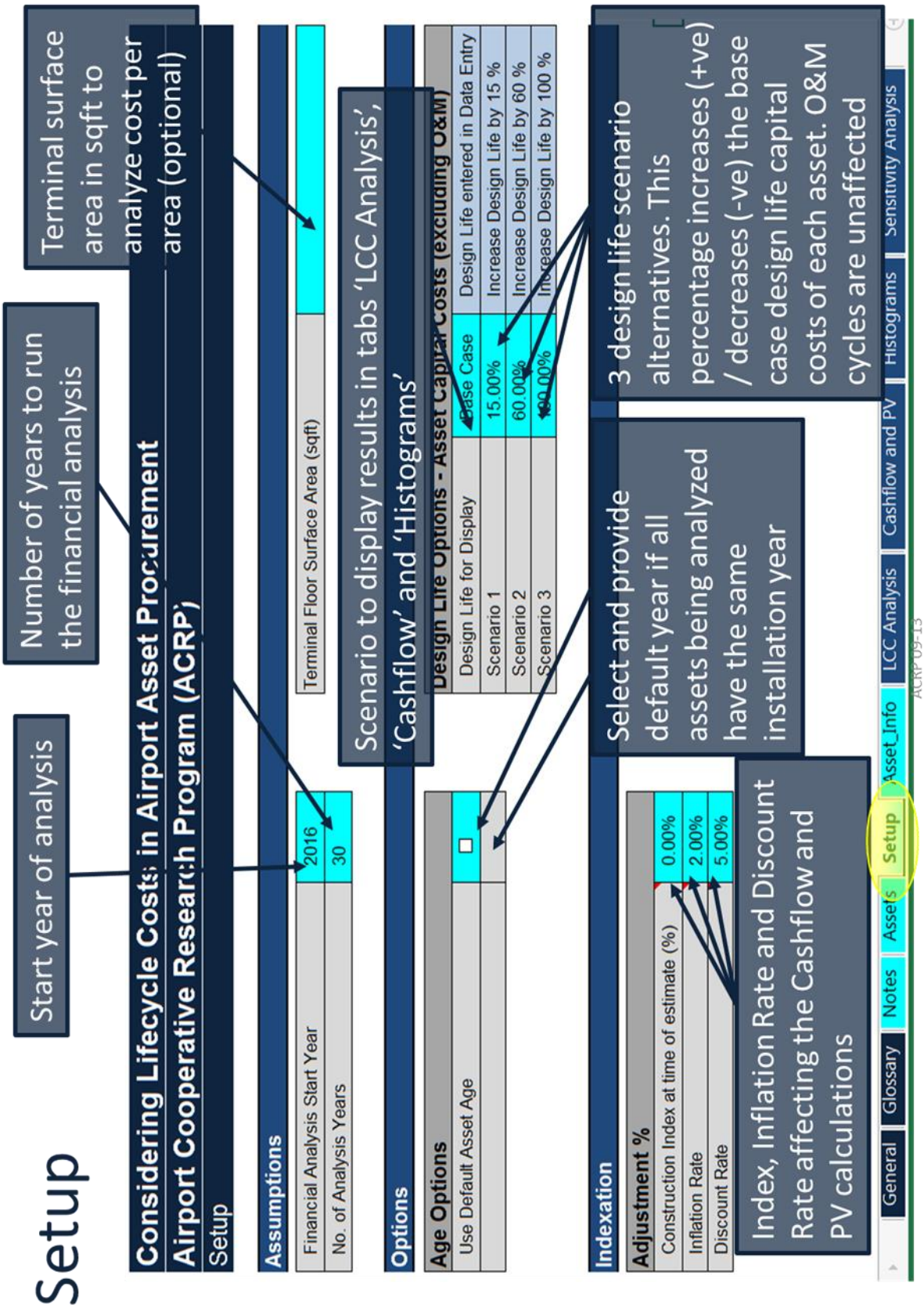
- This sheet can be used by the user to enter information or special notes about the project in this file



Assets

- This sheet includes the list of parent / child assets and their categories
- User can edit the assets and choose which ones to include in the analysis




Setup
Start year of analysis
Number of years to run the financial analysis
Terminal surface area in sqft to analyze cost per area (optional)
Considering Lifecycle Costs in Airport Asset Procurement
Airport Cooperative Research Program (ACRP)
Setup
Assumptions
Financial Analysis Start Year
2016
No. of Analysis Years
30
Terminal Floor Surface Area (sqft)
Scenario to display results in tabs 'LCC Analysis', 'Cashflow' and 'Histograms'
Options
Age Options
Use Default Asset Age
Design Life Options - Asset Capital Costs (excluding O&M)
Design Life for Display
Base Case
Design Life entered in Data Entry
Scenario 1
15.00%
Increase Design Life by 15 %
Scenario 2
60.00%
Increase Design Life by 60 %
Scenario 3
100.00%
Increase Design Life by 100 %
3 design life scenario alternatives. This percentage increases (+ve) / decreases (-ve) the base case design life capital costs of each asset. O&M cycles are unaffected
Select and provide default year if all assets being analyzed have the same installation year
Indexation
Adjustment %
Construction Index at time of estimate (%)
0.00%
Inflation Rate
2.00%
Discount Rate
5.00%
Index, Inflation Rate and Discount Rate affecting the Cashflow and PV calculations
General
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Setup
Asset_Info
LCC Analysis
Cashflow and PV
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Sensitivity Analysis
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Asset Info – Asset Properties

Name of asset from 'Assets' tab

Asset element component relating to capital cost or operation and maintenance

The existing asset's age at the start of the analysis

Adj. service life based on the design life option scenario (in 'Setup')

times the asset cost is repeated in analysis

Considering Lifecycle Costs in Airport Asset Procurement
Airport Cooperative Research Program (ACRP)
Asset_Info

			ASSET PROPERTIES			---	ASSET PROPERTIES				
Asset Element (Child)	Description	Replacement	Model Start Year	Installation Year of Asset	O&M Costs Incurred on	Age Adj.	Expd Service Life Existing Asset	Adj. Start Year	Expd Service Life New Asset	Service Life Applied for New Asset	Times Repeated
1-Roofing											
1.1-Roof structure	Asset Capital	Commencing yr 2 Repeating on yr 5 Cycle	2016	1996	No	20	21	2	5	5	6
	Asset O&M	Commencing yr 4 Repeating on yr 5 Cycle							2	2	15
1.2-Roof material	Asset Capital	Commencing yr 5 Repeating on yr 30 Cycle	2016	2020	Yes	0		5	30	30	1
	Asset O&M	Commencing yr 5 Repeating on yr 5 Cycle							5	5	6
1.3-Drainage System	Asset Capital	Commencing yr 1 Repeating on yr 10 Cycle	2016	2016	Yes	0		1	10	10	3
	Asset O&M	Commencing yr 1 Repeating on yr 1 Cycle							1	1	30
1.4-Expansion joints	Asset Capital	Commencing yr 1 Repeating on yr 0 Cycle	2016					1		0	
	Asset O&M	Commencing yr 1 Repeating on yr 0 Cycle								0	
1.5-Sealing material [Lead, Hazardous Material]	Asset Capital	Commencing yr 1 Repeating on yr 0 Cycle	2016					1		0	
	Asset O&M	Commencing yr 1 Repeating on									

Setup | Asset_Info | LCC Analysis | Cashflow and PV | Histograms | Sensitivity Analysis

ACRP 09-13

Summary of Life Cycle Cost (LCC)

From engineering judgement, manufacturers design life guide and/or published tech. data

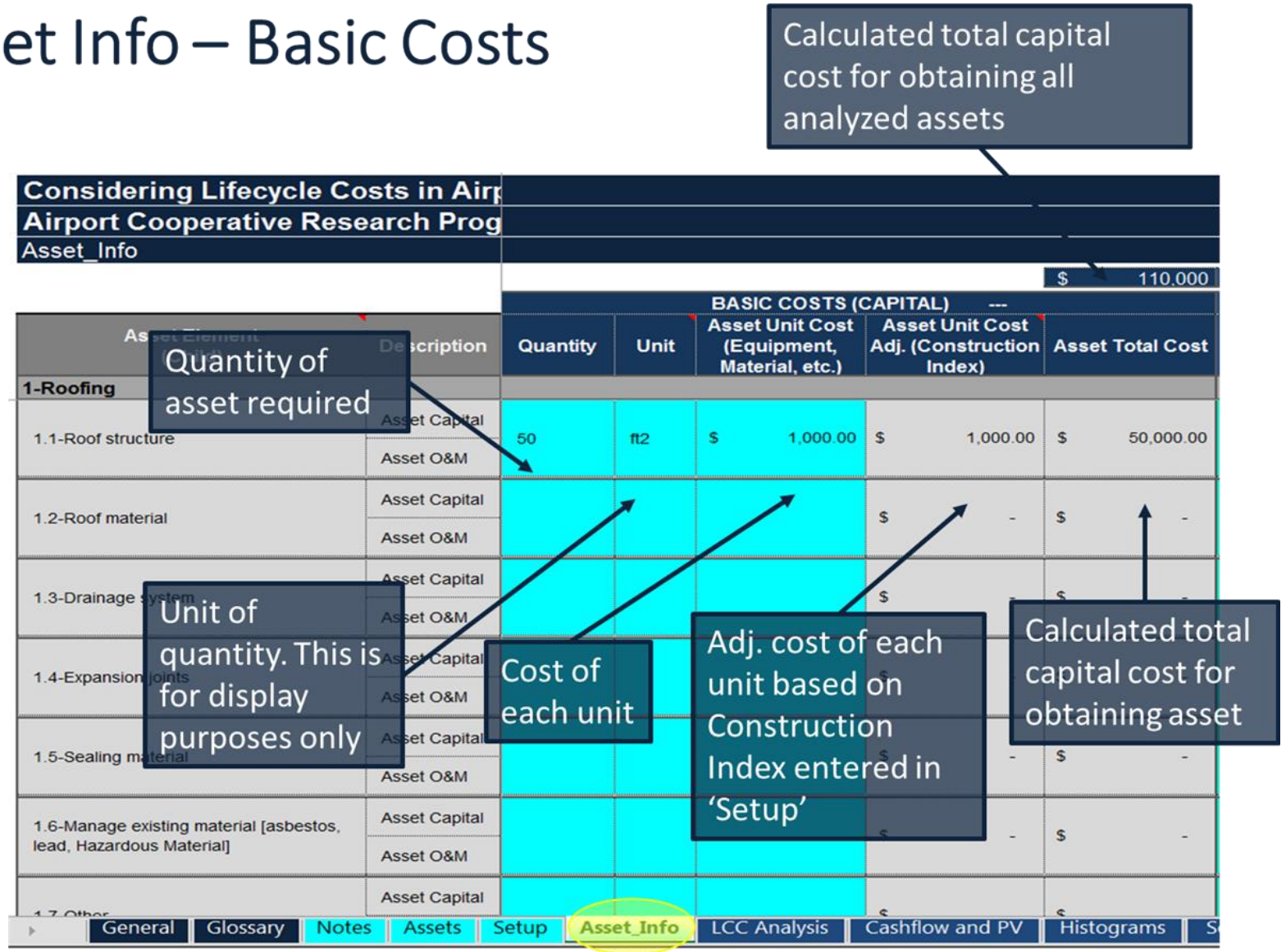
Same for all assets, can be modified in 'Setup' tab

Specifies if O&M costs are incurred in the year of installation or whether they commence 'Expd Service Life' years after

Year from 'Model Start Date' that new / replacement asset costs commence

Asset installation year – N/A if 'Use Default Asset Age' is selected in 'Setup' tab.
If < 'model start year' - replacement
If > 'model start year' - new asset

Asset Info – Basic Costs



Asset Info – Asset Related Costs

The tool contains asset related costs for the following high level categories. Omitted entries are assumed to be "0" cost

- Pre-procurement
- Procurement
- Operation
- Maintenance
- Disposal

Asset Info – Pre-Procurement Asset Capital Costs

- Consulting fees
- Business case development
- Design cost
- Procurement process / Contract cost / Documentation
- Permits / Fees

Considering Lifecycle Costs in Airp
Airport Cooperative Research Prog
Asset_Info

		$ 5,000	$ 10,000	$ 10,000	$ 2,000	$ 10,000	$ -
		PRE PROCUREMENT (CAPITAL) ---					
Asset Element (Child)	Description	Consulting Fees	Business Case Development	Design Cost	Procurement Process/ Contract Cost / Documentation	Permits / Fees	Indirect Costs_1
1-Roofing							
1.1-Roof structure	Asset Capital	$ 5,000.00	$ 10,000.00	$ 10,000.00			
	Asset O&M						
1.2-Roof material	Asset Capital						
	Asset O&M						

Asset Info – Procurement Asset Capital Costs

- Site preparation
- Asset cost (copied from basic cost)
- Processing cost
- Shipping cost
- Insurance cost (shipping)
- Taxes
- Warranty cost
- Installation, configuration & testing
- Health, safety, environment (HSE)
- Temporary arrangements during installation
- Training & professional development
- Annual insurance (Equipment)
- Disposal fee of old equipment
- Salvage value of old equipment
- Update in-house shop drawings
- Indirect costs

Considering Lifecycle Costs in Airp
Airport Cooperative Research Prog
Asset_Info

		$ -	$ 110,000	$ -	$ 1,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
		PROCUREMENT (CAPITAL)		PROCUREMENT (CAPITAL)		PROCUREMENT (CAPITAL)		PROCUREMENT (CAPITAL)		PROCUREMENT (CAPITAL)		PROCUREMENT (CAPITAL)		PROCUREMENT (CAPITAL)		PROCUREMENT (CAPITAL)				
Asset Element (Child)	Description	Site Preparation	Asset Cost (Equipment, Material,	Processing Cost	Shipping Cost	Insurance Cost (shipping)	Taxes	Warranty Cost	Installation Configuration & Testing	Health, Safety, Environment (HSE)_1	Temporary Arrangements (During Installation	Training & Professional Development_1	Annual Insurance (Equipment)	Disposal Fee of Old Equipment (if applicable)	Salvage Value of Old Equipment (if	Update in house Shop	Indirect Costs_2				
1-Roofing																					
1.1-Roof structure	Asset Capital		$ 50,000.00		$ 1,000.00																
	Asset O&M																				
1.2-Roof material	Asset Capital		$ -																		
	Asset O&M																				

Asset Info – Ongoing Operation Costs

- Energy consumption
- System upgrades (software, hardware)
- Capital improvements (building enhancement costs)
- Personnel (management, operator, engineer)
- HSE
- Training & professional development

Considering Lifecycle Costs in Airp
Airport Cooperative Research Prog
Asset_Info

		$ -	$ 1,500	$ 10,000	$ 1,000	$ 400	$ 600	$ -
			OPERATION (O&M) ---		OPERATION (O&M) ---		OPERATION (O&M) ---	
Asset Element (Child)	Description	Energy Cons.	System Upgrades (software, hardware, firmware)	Capital Improvements (building enhancement costs)	Personnel (Management, operator, engineer)	Health, Safety, Environment (HSE)_2	Training and Professional Development_2	Indirect Costs_3
1-Roofing								
1.1-Roof structure	Asset Capital		$ 1,500.00	$ 10,000.00	$ 1,000.00			
	Asset O&M							
1.2-Roof material	Asset Capital							
	Asset O&M							

Asset Info – Ongoing Operation Costs

- Energy consumption
- System upgrades (software, hardware)
- Capital improvements (building enhancement costs)
- Personnel (management, operator, engineer)
- HSE
- Training & professional development

Considering Lifecycle Costs in Airp
Airport Cooperative Research Prog
Asset_Info

Asset Element (Child)	Description	Energy Cons.	System Upgrades (software, hardware, firmware)	Capital Improvements (building enhancement costs)	Personnel (Management, operator, engineer)	Health, Safety, Environment (HSE)_2	Training and Professional Development_2	Indirect Costs_3
		$ -	$ 1,500	$ 10,000	$ 1,000	$ 400	$ 600	$ -
		OPERATION (O&M) ---	OPERATION (O&M) ---		OPERATION (O&M) ---			
1-Roofing								
1.1-Roof structure	Asset Capital		$ 1,500.00	$ 10,000.00	$ 1,000.00			
	Asset O&M							
1.2-Roof material	Asset Capital							
	Asset O&M							

Asset Info – Ongoing Maintenance Costs

- Personnel
- Spare parts
- HSE
- Training & professional development
- Preventive maintenance
- Corrective maintenance
- Predictive maintenance
- Extended warranties
- Temporary arrangement
- Lost revenue
- Indirect costs

Considering Lifecycle Costs in Airp
Airport Cooperative Research Prog
Asset_Info

Asset Element (Child)	Description	Personnel_1	Spare Parts	Health, Safety, Environment (HSE)_3	Training and Professional Development_3	Preventive Maintenance	Corrective Maintenance	Predictive Maintenance	Extended Warranties	Temporary Arrangements	Lost Revenue	Indirect Costs_4
		$ -	$ -	$ 5,000	$ 1,000	$ 1,000	$ -	$ -	$ -	$ 100	$ -	$ -
		MAINTENANCE (O&M)	---	MAINTENANCE (O&M)	---	MAINTENANCE (O&M)	---	MAINTENANCE (O&M)	---	MAINTENANCE (O&M)	---	
1-Roofing												
1.1-Roof structure	Asset Capital				$ 1,000.00					$ 100.00		
	Asset O&M											
1.2-Roof material	Asset Capital											
	Asset O&M											

Asset Info – Disposal Asset Capital Costs

- Decommissioning cost
- Shipping cost
- Disposal fee of old equipment
- Salvage value of old equipment

		$ -	$ 9,000	$ -	$ -
		DISPOSAL (CAPITAL) ---			
Asset Element (Child)	Description	Decommission-ing Cost	Shipping Cost	Disposal Fee of Old Equipment	Salvage Value of Old Equipment
1-Roofing					
1.1-Roof structure	Asset Capital				
	Asset O&M		$ 9,000.00		
1.2-Roof material	Asset Capital				
	Asset O&M				

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Asset Info – Subtotals

- The final column in the Data Entry tab provides a subtotal
  - Capital – the cost of one cycle of purchasing, procurement and disposal
  - O&M – the cost of one cycle of operation and maintenance

Considering Life Cycle Costs in Airp		
Airport Cooperative Research Progr		
Data_Entry		
		$ 178,600
Asset Element (Child)	Description	SUBTOTAL (Each)
1-Roofing		
1.1-Roof structure	Asset Capital	$ 165,000.00
	Asset O&M	$ 13,600.00
1.2-Roof material	Asset Capital	
	Asset O&M	

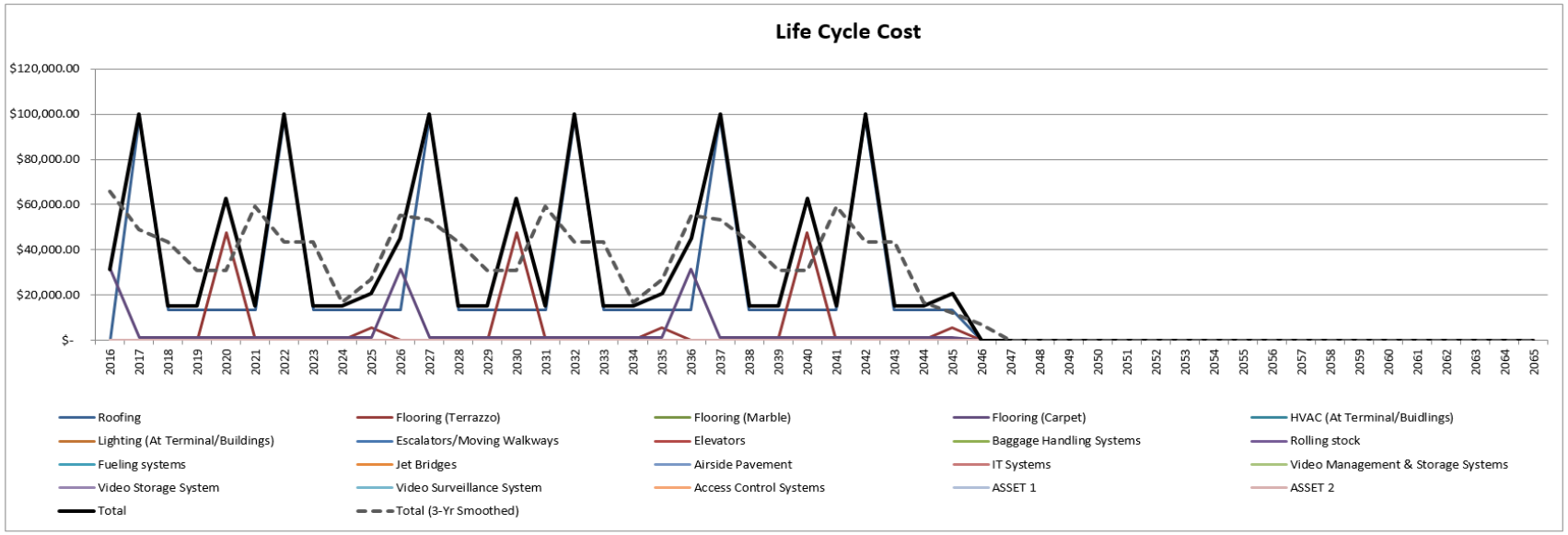
Results

The Results tabs are dark blue

LCC Analysis

- LCC analysis displays the nominal costs over the appraisal period aggregated by parent asset
- Total cost across all assets are shown by the black solid line
- A 3-year averages total is shown by the dashed grey line

Considering Life Cycle Costs in Airport Asset Procurement
Airport Cooperative Research Program (ACRP)
LCC Analysis



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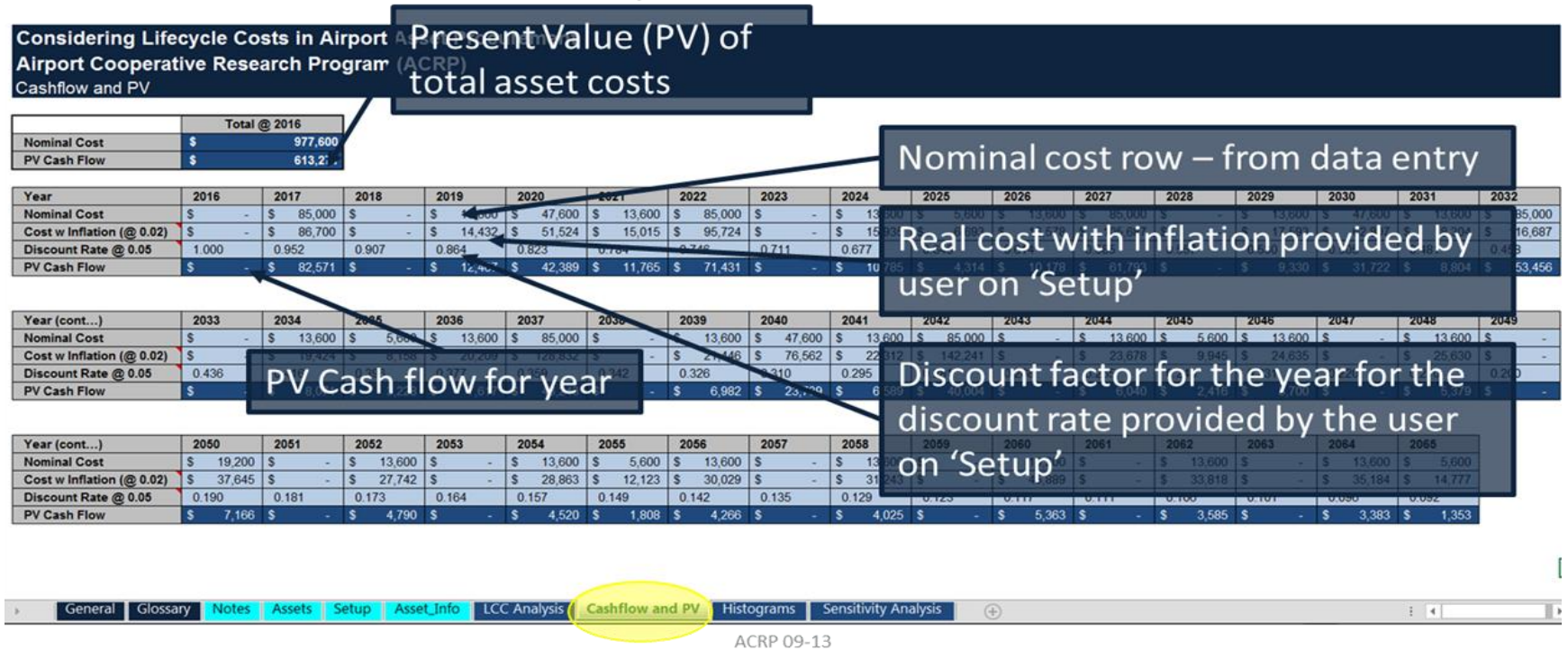
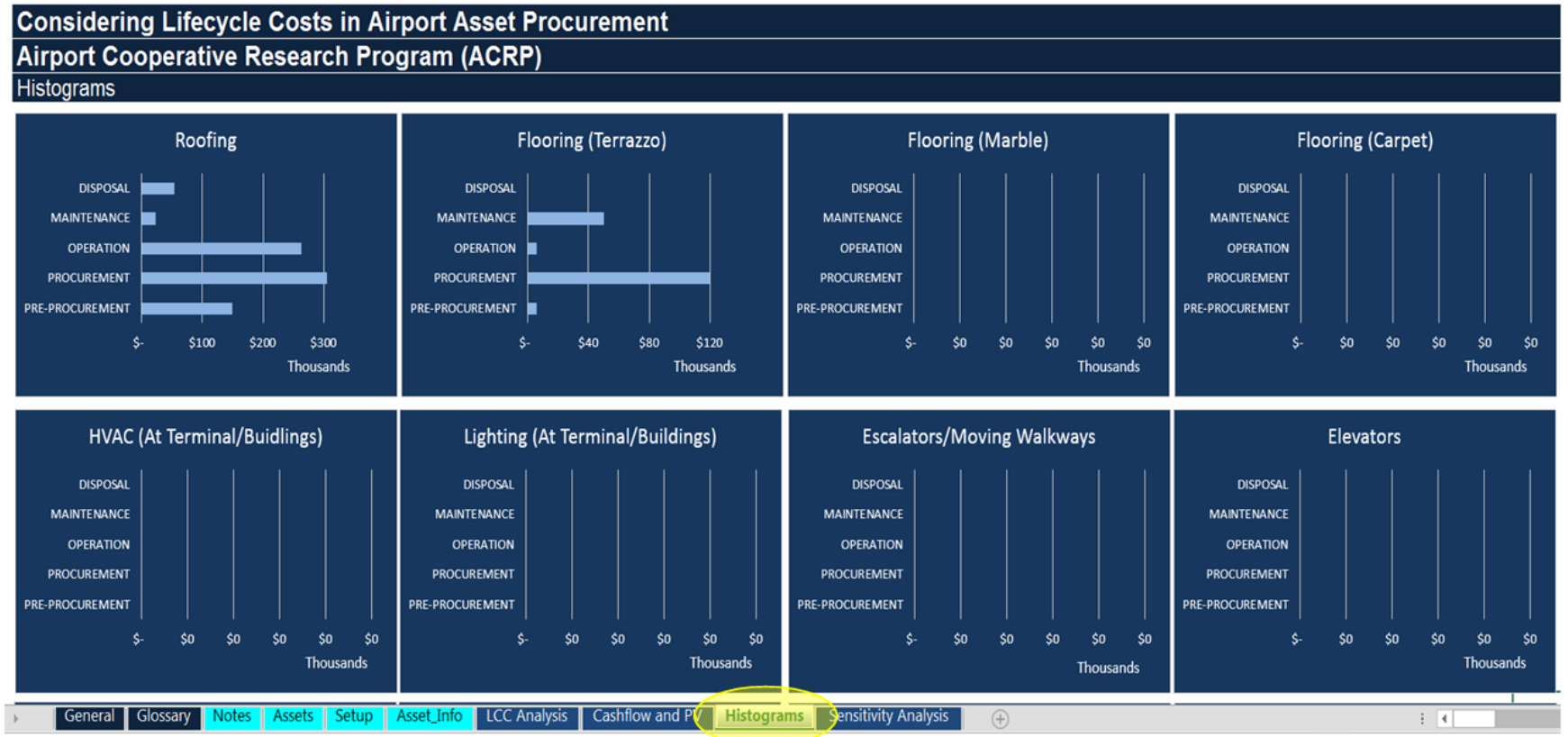
Cashflow and PV

- The present value (PV) cash flow for the appraisal period is derived from:
  - the nominal cost from 'Data Entry'
  - the inflation rate from 'Setup'
  - discount rate from 'Setup'



Histograms

- Histograms show the relative cost category distribution for each parent asset



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Sensitivity Analysis

- Analyzes the impact of the alternate design life scenarios specified in 'Setup'