# Shortfall Analysis

## – Creative Approaches to Problem Quantification –

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# Contents

**Abstract**

Government acquisitions start with problem identification as a means of solving public sector problems or "shortfalls" and inefficiencies with technical hardware and software solutions. To justify government business cases, analysts are tasked to (1) define the problem, (2) identify impacted stakeholders, and (3) creatively quantify and monetize impacts to operations and services. Using a proven approach, the team demonstrates how to effectively perform shortfall analyses and monetize the largest underlying value to justify business cases.

# 1 Introduction

Government capital investments or business cases usually begin with an agency need or problem that it cannot solve without an acquisition or an internal development capital project. This government need could be a (1) service to the general public, like the FAA trying to reduce airport delays in a congested air traffic corridor, (2) an agency infrastructure project, like a new modernized radar system replacing an existing one that is End-of-Life (EOL), or (3) a more efficient service that benefits industry, like modernized air traffic separation software that allows the FAA to shorten flight approaches and save airlines fuel consumption. All of these types of business cases start with a problem that the government agency cannot yet solve without a new investment. This problem is defined as a *shortfall*, and ops research analysts, cost estimators, and data analysts must define these shortfalls, explore their impact, identify stakeholders and impacted users, and quantify the impact on all parties – government, companies, and the public.

The program shortfall and benefits (the part of the shortfall we can solve) define a system or business case's value. While cost estimators focus primarily on estimating a project's cost, to measure the projects value or benefit, we first define and estimate the shortfall that we are trying to solve.

While there are metrics and mathematical and statistical approaches for shortfall quantification, there is no standard approach to identifying and defining business case shortfalls. Through interviews, data analyses, use cases, and impact analyses, program analysts can better define the root cause of the shortfall and a means of quantifying its impact. Shortfalls are the basis for program solution alternatives and the program's requirements, and if they are not properly defined, a business case may not address the root problem the agency needs to solve. This can lead to costly business case scope changes and rebaselines and result in acquisition delays.

Using a thorough process of root cause analysis, stakeholder identification, use case analysis, and process mapping and reengineering, this paper explains the complexities and best practices for shortfall definition, quantification, and monetization.

# 2 Business Cases and Government Acquisitions

## 2.1 Government Capital Investments and Business Cases

Government agencies, like the Federal Aviation Administration (FAA), develop business cases to measure the value – cost estimates and benefits quantification – for major capital investments and acquisitions. Each year, government civil agencies allocate billions of dollars to capital investments and Facilities & Equipment (F&E) spending to (1) retain and restore government infrastructure and services, (2) add new services or capabilities for an agency or for the stakeholders they serve (i.e., for the FAA, the flying public, airlines, airports, and transportation infrastructure), and (3) to improve efficiencies for the delivery of services or capabilities of an agency.

For some civil agencies, the development of these business cases for capital spending serves as a benchmark of investment decision-making. While F&E spending is usually in the billions of dollars each year, these capital amortized allocations are finite and must be carefully allocated over portfolios of programs, systems, and agency functions. Too much funding allocation to programs with new capabilities could risk infrastructure neglect or loss of service. Too large of an annual funding allocation to infrastructure programs could delay the deployment of new technologies or efficiencies. Finding that balance requires a means of evaluating business cases, and some civil agencies provide cost-benefit analysis metrics to distinguish between investments and to assign value to them.

To develop and establish robust business cases, cost estimators must develop accurate cost estimates for (1) multiple alternative implementation solutions and (2) a legacy case, which serves as a benchmark legacy system or a base case from which each alternative can be compared. The analyst must also identify, quantify, and monetize program shortfalls (the problem) and benefits (the solution) to all stakeholders. In the case of the FAA, those stakeholders would be the FAA, the flying public, airlines, airports, and other aviation companies.

For capital investment analysis and cost estimators, the legacy case development is critical for the following reasons:

(1) It serves as a basis of comparison for each alternative and measures the operational and sustainment costs of the legacy system being improved or replaced.
(2) It demonstrates a contrast between the capabilities of the existing system and the new investment.
(3) It helps determine the required timing of the investment decision. If the legacy system cannot be sustained longer than 5 years without significant capital investment or system replacement, a solution must be identified and deployed in advance of that timeline.
(4) It sets a threshold for cost avoidance. The legacy case cost sets a maximum threshold of cost for each investment solution. To provide a more cost-effective or efficient solution, the investment solution must cost less over its lifecycle than the legacy system in place now.

## 2.2 Business Case Justification

In many government agencies, large capital investments in information technology, infrastructure, new technologies, or new capabilities are valued mostly with attention to cost estimating and cost savings. These agencies do not require a full business case analysis and valuation.

In contrast, the private sector conducts capital investment analyses using Discounted Cash Flow (DCF) valuations, measuring future cash flows of revenue and expenses, and evaluating investments according to Finance metrics, like Net Present Value (NPV), payback, Internal Rate of Return (IRR), and Benefit/Cost (B/C) ratio. Only those investments with a positive NPV or whose internal rate of return exceeds the cost of capital will be approved.

In some civilian government agencies, business cases must be justified with a full cost/benefit analysis, much like the private sector. Instead of measuring revenue and expenses, agencies estimate program lifecycle cost against monetized benefits to the agency, stakeholders, and the public (time savings, savings in operating costs, cost avoidance, safety).

For those government investments which require a full business case evaluation, how do we determine benefits? How do agencies identify business cases and measure their value?

Before agency and stakeholder benefits are considered, business cases start with a purpose. Often that purpose is to solve an existing agency shortfall or problem. Identifying and measuring that problem that the agency is trying to solve is a critical first step in business case development and investment analysis, and it is also an artform. In this paper, we will explore how to identify agency and organizational shortfalls and how to dissect those shortfalls into meaningful impacts to stakeholders, using use cases, scenarios analyses, value stream analyses, process mapping, and other techniques to isolate the problem and determine a means of quantification. As we will demonstrate, the problem as first defined is usually not the highest value impact. As cost estimators and analysts, we must ask questions, identify impacted parties, analyze consequences of that ongoing shortfall, compare existing processes and capabilities with the existing shortfall to those if the problems were solved, and peel away layers of the business case onion to identify the largest impacted stakeholders and end users. Often the problem we identify on the surface is just a starting point for business case justification.

# 3 Shortfalls – Identifying & Solving Problems

## 3.1 Shortfall Analysis

What is Shortfall Analysis?

Conceptually, each major government acquisition or capital investment is initiated to meet an agency or stakeholder need that is not currently being met. The project could provide a new capability for the agency, like a new precision metering technology for the FAA to increase the number of planes which could land at a specific airport during a busy time of the day. The project could improve upon an existing technology and reduce the cost of an existing system in operation or add additional efficiencies that do not exist today. An agency might want to improve the quality and resiliency of an existing system which continues to fail at an unacceptable rate. Or, a new system could be a like-for-like replacement of an existing system (a Tech Refresh), which is quickly reaching end-of-life, is beyond economic repair, and can no longer be sustained.

According to the FAA's *Shortfall Analysis Report Template* (2022), a shortfall "is the difference between a future service need and a current capability. A service shortfall is usually addressed by a sustainment action for existing assets or a new service delivery idea, including cloud services, for predicted gaps. A

new idea or concept should deliver existing services more efficiently or provide new services of value to the" agency, industry, or the public (p. 2).

For private industry, capital investments are usually developed as a means to generate revenue growth and to organically expand operations. For the government, capital investments are inspired not just by providing a new capability or service, but also to meet a service need to stakeholders or the public which is not currently being met. For business cases, we need to demonstrate what problem the agency is trying to solve as a basis of justifying the investment and the use of public funding. Cost estimators and operations research analysts identify and define the problem that needs to be solved, determine all the parties which are adversely impacted by the existing shortfall or the defined constraint, which is inhibiting improvement, and quantify the shortfall in a means that can be tangibly and economically measured.

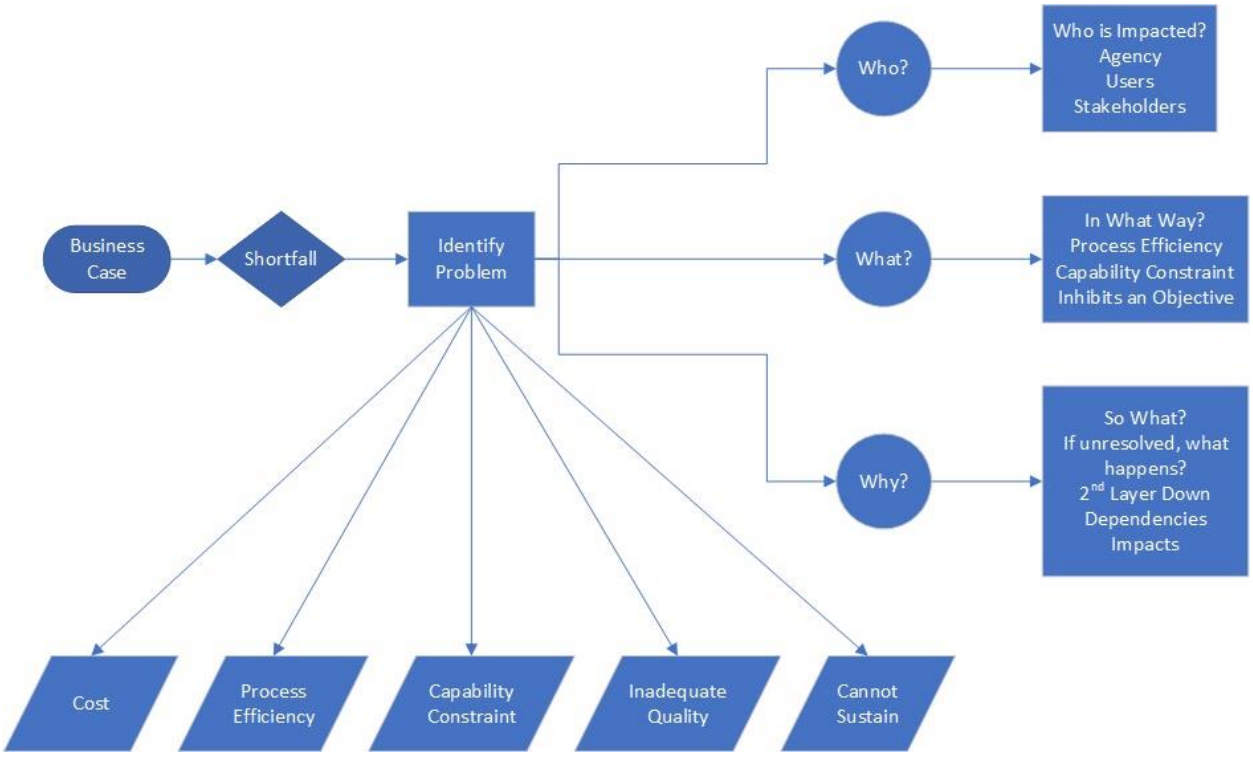


**Figure 1:** Shortfall Analysis – Problem Identification

Figure 1 depicts the critical questions we ask when identifying and quantifying a business case shortfall. Who is being impacted by this shortfall? What is the constraint or problem they are experiencing? Why does it matter if this shortfall persists? What is the impact if we do not resolve this shortfall? At the bottom of the figure, we identify potential shortfall categories – how these impacts manifest as a problem the agency wants to resolve.

## 3.2 Problem Definition

### 3.2.1 As-Is vs To-Be Analysis

To better understand the problem that the agency is encountering, analysts need a point of context from the current systems and processes to see how the agency is falling short of its goals. To better illuminate the contrast between the current system and the intended end-state capability of the system, the analyst should conduct an As-Is versus To-Be Analysis. By better understanding what is done now and comparing to the capability that we are solving, we can isolate the problem and the incremental differences between the legacy and the solution. By examining the current processes and capabilities, the analyst and program office can better understand:

1) What the agency does now and what process it needs to improve,
2) What capability is missing that it needs to enable,
3) What new service it could provide,
4) What data is missing and if collected could provide better predictive forecasting,

By understanding and categorizing the incremental shortfalls versus the end state, we can list the shortfalls into quantitative classifications when we focus on measurability.

What we discover when we identify and isolate the problem in the As-Is state that we are trying to solve is that often the problem or challenge we are trying to solve is not singular. There are multiple parts or shortfalls that need to be resolved, sometimes sequentially, to reach an end-state goal that we cannot achieve today. What are the roadblocks to achieving that end state? If we solve the first problem, what is the next one that prohibits that end state goal?

In many situations, the current As-Is system or processes cannot meet end state goals and require an acquisition or new capital investment to provide data, capabilities, functionality, improved capacity to reach program and portfolio objectives. Just identifying those differences between As-Is and To-Be does not provide a means of quantification.

To quantity the problem and capture the value of the new system, its incremental benefits, the analyst and program manager needs to identify use cases to compare how current users of the system operate with this capability deficit and how they would operate with the new capability, data, capacity, scale, or efficiency a new system would afford. As analysts, we should be able to capture the activities, processes, and capabilities of a diverse set of end-users. There are sometimes users who manually translate data after data collection, establishing new user bases. A new system might eliminate those manual processes through automation or data interfaces, changing current processes and functions.

If a legacy (As-Is) system is process-based, creating an As-Is process-map and comparing it to an equivalent To-Be process will help identify improvements and quantify the elimination of waste. Using a process called Value Stream Analysis, analysts start with an As-Is process that identifies the beginning inputs and the final outputs of the process. Then, by documenting the changes a new system would provide for a To-Be state, the analysts can eliminate or reduce frequency or duration of existing steps that are no longer value-added or required. If the team applies a time study for each of the process steps, by eliminating or reducing these steps in the To-Be state, they can quantify the savings in repeated processes.

For an As-Is versus To-Be Analysis, we recommend the following steps to set the foundation for:

(1) Problem Identification,
(2) Isolation,
(3) Incremental Quantification

**Problem Identification – As-Is Versus To-Be Analysis**

1) **Isolate the Primary Problem**
    a. Start with the end-state or current state and isolate the primary problem.
    b. **From End State –** This could be a statement, "I want to do X more efficiently, in larger quantities, to add capacity, or to add a completely new capability that I cannot do now."
    c. **From Current State –** This could be a statement, "I cannot do X as efficiently, in as large a quantity, as quickly, or at all."
2) **Examine the Legacy System Challenge or Obstacle**
    a. Examine the As-Is or Legacy System and determine why you cannot achieve the end-state goal. What is the challenge or obstacle?
    b. Is the problem or obstacle needing a new technology or capability?
    c. Need to collect data or connect with another data source?
    d. Process change?
    e. System Automation or Efficiency?
3) **Analyze the Underlying Problems**
    a. After examining the surface or primary obstacle, determine if there are more obstacles to the end-state, a sequence of required changes, or other underlying problems.
    b. Assume you solve the primary problem and define how.
    c. Then, examine the As-Is process and system with this change to determine if you can achieve the end-state goal.
    d. If there are still obstacles, list them.
4) **Map out the As-Is State (Process-Oriented)**
    a. If the system is "Process Based," consider creating a process map.
    b. Apply Value Stream Mapping by creating an As-Is Process map from end-to-end and identify process step obstacles which would be eliminated with the new system or reduced in duration.
    c. Draw alternative solution To-Be process maps and compare the two maps side-by-side to validate that the intended end-state or capability would be achieved by these changes.
5) **List End-State Goals and Capabilities and Compare to As-Is Products (Capability-Oriented)**
    a. Define where the As-Is capability falls short.
    b. List the required changes to systems, products, processes, and personnel which would have to change to achieve that new capability.
    c. Identify alternative solutions to achieve the new capability.
    d. What changes need to be made to the As-Is system in each of these examples to achieve the intended capability?
    e. At a high level, define the sequential development and implementation steps required to change the existing system to a new one with the required capability.
6) **Analyze Use Cases – Did We Capture It All?**
    a. The problem and solution to that problem are often not on the surface.

b. The obstacle to achieving a new capability or improving processes to achieve a goal could be many layers down.
c. To identify the most critical problems (and later quantify them), identify current system users.
d. If the intended To-Be system and end-state would require an entirely new set of users or stakeholders, identify these users and their roles.
e. Map out the As-Is processes of each user and identify the user-based shortfalls. What can they not due with the current system?
f. Map out the To-Be processes or application of the new systems for the same user groups and add any which do not exist today.
g. Compare the As-Is to the To-Be.
    i. This should reveal specific obstacles that require change to enable the end-state.
    ii. It also might reveal underlying problems that either (1) can be utilized to quantify the largest and most meaningful shortfalls or (2) could identify required changes not apparent in the initial As-Is versus To-Be analysis.

## 3.3 Shortfall Categorization

To better understand how to identify shortfalls, define intended end-state capabilities of the solution, and to measure and quantify the problem the program office is trying to solve, we need to be able to categorize shortfalls in ways we will measure them later.

### 3.3.1 Shortfall Categories

**Shortfall Categories**

1. Cost
2. Capacity or Scalability
3. Infrastructure
4. Environmental
5. Business Processes/ Operational Processes
6. Data and Information
7. Productivity
8. Quality
9. Efficiency
10. Effectiveness
11. Obsolescence and Sustainability

We define each of these potential categories with context to understand their distinctions and how they can be quantified, and later in Section 3, we will provide some examples of how to categorize and list out shortfalls to prioritize, quantify, and socialize with stakeholders and organizational investment decision makers and organizations.

### 3.3.2 Shortfall Categorization Definition

In the shortfall category list, consolidated from the FAA's *Shortfall Analysis Report Template* (2022), we break down each of the shortfalls with examples (p. 5). Analysts can list shortfalls according to

prescriptive categories as a means of defining the use case, quantifying the problem that the new system will solve, and prioritizing the shortfall list according to the magnitude and criticality of the shortfalls.

1. **Cost**
   When we define shortfalls and program benefits (the measured value of the program solving these shortfalls), cost is one of the main drivers of a program and a means of quantifying and monetizing value. Cost estimators and analysts measure current state cost avoidance or cost savings from operations or maintenance costs that the agency will no longer incur when the legacy system is replaced. Avoided costs can be measured and classified across multiple categories. Some of the most common are (1) administrative costs, (2) maintenance costs, and (3) legacy special circumstance costs.

   a. **Administrative Costs**
      If legacy systems have more manual processes and less automation, or if they are in siloed systems that are not integrated into an enterprise tool, administrative costs are often higher than more modern enterprise solutions. Administrative costs are an easily quantifiable shortfall that monetize as cost avoidance.

   b. **Maintenance Costs**
      To maintain older legacy systems, operational costs and maintenance costs increase over time as the system and its parts fail more frequently. This manifests as measurable corrective and preventative maintenance costs (increasing frequency of maintenance actions multiplied by a labor unit cost). Compared to a newer system which might replace it, this shortfall can be quantified and monetized as cost avoidance.

   c. **Legacy Special Circumstance Costs**
      There are special circumstances related to business cases where legacy systems will incur greater costs over time than a more modern replacement systems or investment acquisition. An example of this, aging systems may incur greater labor costs for software development maintenance and interface changes. In one agency example, a system which had been developed using Cobol software required the hiring of expensive software programmers who knew how to code in Cobol. Since the language was so archaic and no longer used for most systems, the agency had to hire coders out of retirement for a premium to make coding adjustments to new interfaces or incremental functionality. The agency was able to retire this system and replace it with a modern ERP system which required a fraction of the software maintenance costs. The maintenance costs estimated here over the program lifecycle are a shortfall that can be monetized using cost avoidance.

2. **Capacity or Scalability**
   As an example of agency capacity or scalability shortfalls, we will focus on examples from the Federal Aviation Administration (FAA) as our primary use case is from an FAA portfolio. An FAA program may have a capacity shortfall where there is not enough airport arrival capacity during peak arrival push times of the day, limiting the number of flights an airport can accommodate. A

capacity solution might be terminal expansion or the implementation of an air traffic system that can reduce flight separation, increasing air sector or airport capacity.

In another example, a serial hardware communications system at another agency might have limited number of channels for communication, inhibiting its ability to increase the scale of telecommunications operations. A solution to this shortfall might be to add a new telecommunications hardware system using Operations Internet Protocol (Op IP), significantly increasing flexibility and the capacity to scale telecommunications.
The scale in these examples is measurable based on their impact on operations and users, and to quantify these shortfalls, we would need to examine the impact in use cases.

3. **Infrastructure (Facilities, Equipment, Buildings, Maintenance)**
   As infrastructure ages, it becomes harder to maintain, and the maintenance costs increase over time. Systems and equipment require modernization or sometimes a means of connecting to much more modern hardware and software systems via interface or integration. As systems ages, compatibility and modernizations issues become magnified, and the shortfalls become more pronounced.

4. **Environmental**
   At increasing frequency, agencies must consider environmental impacts of operations. More modern systems can reduce emissions compared to systems that have been maintained for several years. FAA systems, processes, flight approaches, and management cause noise pollution, and noise abatement considerations are critical considerations for expanding airspace or in airspace redesign. As agencies are conscious of their carbon footprint, reducing the environmental impact of operations are critical considerations and can be quantified as a shortfall or problem solution.

5. **Business Processes/ Operational Processes**
   Processes can be inefficient or constrained by the capability and data limitations of the existing legacy system. New processes or associated sophisticated software Enterprise Resource Planning (ERP) systems can enable new capabilities, access to data, and abilities to process or calculate data that makes the processes more efficient.

   Using business process reengineering analysis techniques, like Value Stream Analysis, analysts can isolate non-value-added process steps and quantify reduction in process time and efficiency.

6. **Data and Information**
   Data and information shortfalls can include data-driven analysis constraints, business intelligence constraints, planning challenges, and difficulty or limitations on the use or effectiveness of predictive analytics. Sometimes systems, process constraints, lack of system integration, or data ontology (data relationships) can prevent organizations from using data to conduct analyses, generate forward-looking business intelligence, like predictive analytics, and make better informed decisions and forecasts. Data constraints or lack of data collection can also impact shortfalls that impede process and forecast improvements.

7. **Productivity**
   Legacy systems due to software, hardware, process, or capability constraints may not be able to scale and increase productivity levels or the volume of output per level of input. Without scalability and productivity gains, expansion will increase operating costs, and agency and private sector growth can be limited by system design and budgets.

8. **Quality**
   Quality is a consistent means of meeting customer needs. It ensures an expected level of reliability and resiliency for a given unit cost. Quality can be a measurable shortfall by comparing product or system reliability against a mean or anticipated average frequency. By utilizing specific analytical measures, like Mean Time Between Failure (MTBF) or Mean Time Between Service (MTBS), analysts can identify system shortfalls which with further investment and replacement can be improved. The cost estimator could estimate the legacy cost or the frequent continuous replacement of failed parts over time or the impact of those failed parts by loss of system service or operation over the anticipated lifecycle of operation. Then, comparing this cost to the associated cost of operating a higher quality system, the cost estimator can estimate the incremental cost avoidance of operating a newer and higher quality system.

9. **Efficiency**
   By process improvement, systems and data integration, new data interfaces, user interfaces, query capabilities, trend analyses, or even simpler labor processes, agency systems and practices can be more efficient, finishing tasks or analyses much quicker or with less effort than compared to a legacy case. If a system is not efficient now, but with a new one can be more efficient, this shortfall can be quantified and monetized over its lifecycle cost.

10. **Effectiveness**
    Effectiveness refers to the level of quality that when a task is completed leads to better performance or results. As an example, by improving availability, system consolidation, and process improvement, conducting analyses or operations may result in a more effective (more often correct or accurate) yield than the legacy system can currently achieve. By highlighting the distinction in performance between the legacy system and a new system in an As-Is versus To-Be analysis, analysts can quantify and monetize efficiency shortfalls.

11. **Obsolescence and Sustainability**
    Over time, systems become obsolete or End-of-Life (EOL) where the agency can no longer procure replacement parts, companies can no longer repair broken parts or systems, software or hardware systems generate compatibility issues with new systems, impeding their ability to communicate, and systems risk running out of parts, risking loss of operational service. If a legacy system has sustainability or EOL issues, the program office can use historical data and forecasting to quantity the shortfall and conduct an impact analysis to demonstrate additional user-based shortfalls.

Each of these shortfall categories can be used to define a legacy system's shortfall and justify an investment or acquisition. To organize and analyze potential business case shortfalls, the analysis team should list the primary categories of the shortfalls and their classification for traceability.

As an example of shortfall categorization and traceability table application, in the analysis of an FAA safety-based business case, we categorized a comprehensive list of shortfalls, most of which we would quantify, including a shorter list of these shortfalls which we would monetize for a cost/benefit analysis.

In the table, we listed the following:

- Shortfall Capability
- Shortfall Classification (Category Applied)
- Program Phasing or Application
- Traceability – Agency Basis
- Traceability – Shortfall Description

By providing the details for each intended end state capability, defining each category, how it will be applied during program implementation, and the basis and definition of the shortfall, we have an organized means of presenting our shortfalls and quantifying them individually.

Agency Safety System Shortfall Traceability Example

| | Name | Shortfall Classification | | | Implementation Phase | | | | Shortfall Traceability | |
|---|---|---|---|---|---|---|---|---|---|---|
| ID | Shortfall Capability | Productivity | Efficiency | Effectiveness | 1 | 2 | 3 | 4 | Basis | Category Description |
| 1 | Safety Quality Process | | ✓ | ✓ | 75% | 25% | | | - Based off Agency Strategic Plan<br>- Ties to proposed Safety System end-state objective #1 | **Efficiency & Effectiveness**<br>- Safety program will increase efficiency automating processes for safety analysts and providing data that would normally be a time-consuming manual process.<br>- Safety program will increase effectiveness by helping analysts make easier correlations between safety data and by providing additional filterning criteria for historical events. |
| 2 | Safety Collection & Analysis | | | ✓ | 30% | 25% | 25% | 20% | - Based off Agency Strategic Plan<br>- Ties to proposed Safety System end-state objective #2 | **Effectiveness**<br>Improved availability, consolidation, and standardization of data in Safety System will facilitate safety analysts understanding of similar events and allow for correlations to help determine causality. Analyzing and focusing on historical events will improve impact analysis and be a more effective analysis technique. |
| 3 | Risk Analysis Process | ✓ | ✓ | | 25% | 40% | 25% | 10% | - Based off Agency Strategic Plan<br>- Ties to proposed Safety System end-state objective #3 | **Efficiency & Productivity**<br>**Efficiency -** When the safety analyst designates an event in one system, it will be correlated in other anlaysis systems for the same historical event. This will save time and manual research to draw conclusions about events.<br>**Productivity -** The analysts will be able to process more volume of events to analyze using the automated and integrated system. |

**Figure 2:** Shortfall Analysis Traceability Matrix

## 3.4 Why Does This Matter?

In investment analysis, defining, quantifying, and monetizing shortfalls is one of the most critical factors in business case justification. At the FAA, a review organization that conducts Independent Evaluation Reviews (IERs) and comprehensive cost/benefit analyses to evaluate business cases will ask the Program Office (PO) to explain with evidence the value of the investment and the problem the PO is solving. They ask, "Why does this business case matter?" Shortfall analysis, if it results in substantial monetization, answers that question. Essentially, it says, "If the agency does not fund this investment and solution, the consequence of the shortfall that persists is X."

For the FAA, the consequence could be:

1) An inevitable loss of service of the legacy Air Traffic Control System,
2) A continued safety vulnerability that over time could result in a high-risk flight incursion,
3) The inability to increase en route air traffic sector capacity that will limit the number of flights to a busy corridor of the United States,
4) Continued inefficient data analysis relying on manual inputs and analyses,
5) Stove-piped data systems incapable of predictive analysis that might help the agency identify maintenance vulnerabilities preventatively rather than reactively to unplanned maintenance.

Shortfalls demonstrate and quantify the consequences of not investing in an acquisition, system replacement, or capital investment.

The artform of shortfall analysis is fostered by the analyst's ability to execute the following steps.

**Shortfall Analysis Process**

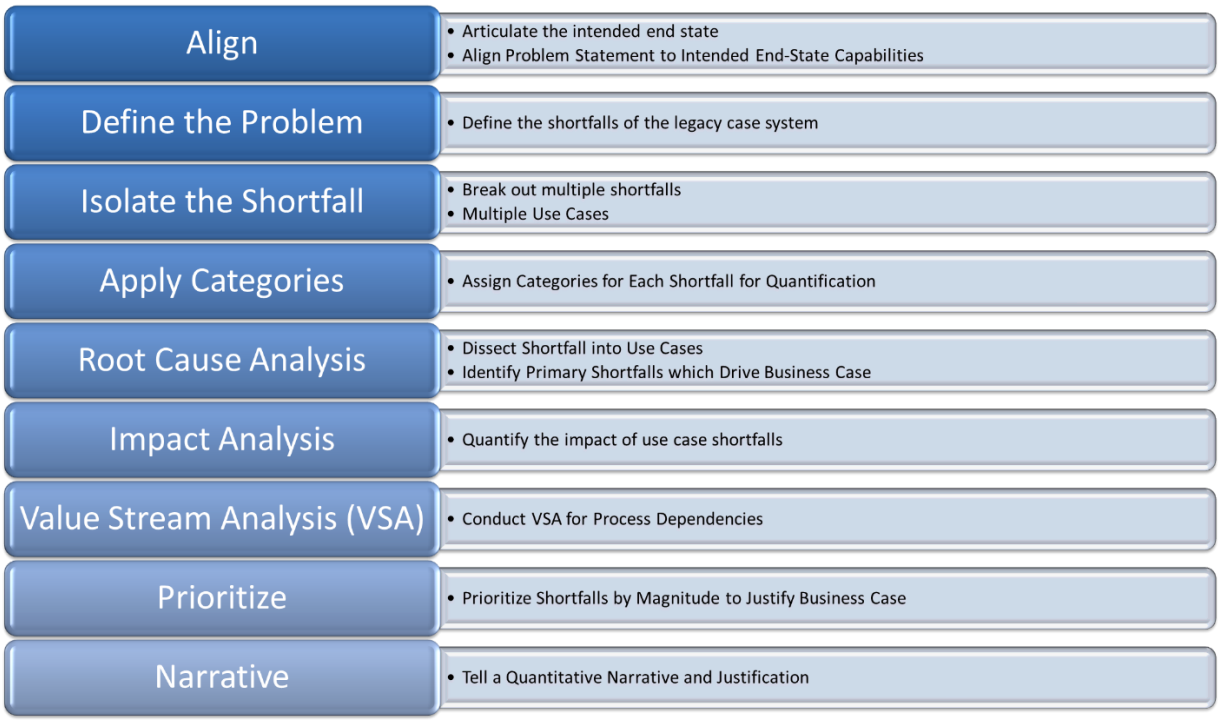


**Figure 3:** Shortfall Analysis Process Steps

## 3.5 Root Problem Analysis – An Investigation

When program offices and organizations describe why they are designing a business case and going into investment analysis, they know why. They can define an end state capability, data need, or infrastructure sustainment need they want to achieve or maintain. The need for the investment on the surface is well understood, and program offices can easily define the need at a high level. If they cannot, the business case will not get funded, or it may be redefined.

However, articulating and measuring the impact of a shortfall is much more difficult than defining the program objective. Why can the agency not achieve that objective now? What is preventing the agency from continuing a service it provides now or improving it without this investment? What is the investment or business case going to do to fix the shortfall? The analyst needs to articulate the path from legacy system or absence of a capability to achieving the intended outcome.

### 3.5.1 Root Cause Analysis to Quantify Shortfalls

Root Cause Analysis is a technique analysts can use to dissect a problem and trace it back to the origin of the problem. It is often used to identify the cause of a problem, like a system outage – a means of fixing the primary problem, not just replace it with a new system that may have that same failure vulnerability. Identify the primary problem and fix it.

Government systems are not unlike those in commercial industry from a sense of operation, failure, sustainability, improvement, and adding incremental capabilities. For shortfall analysis, we use root cause analysis not just as a means of finding root causes and measuring the impacts of the shortfalls. Root cause analysis allows analysts to look deeper and quantify shortfalls.

When conducting a root cause analyses, as highlighted in Figure 4, the team will first define the program objectives by the intended end-state capabilities the agency wants to achieve. After program implementation, what new capability, improved system or process, or continued service or capability (sustainment program) will the agency deliver. Once the end-state defines the program objectives, the team can investigate why the current legacy system falls short and cannot achieve this end-state without further investment.

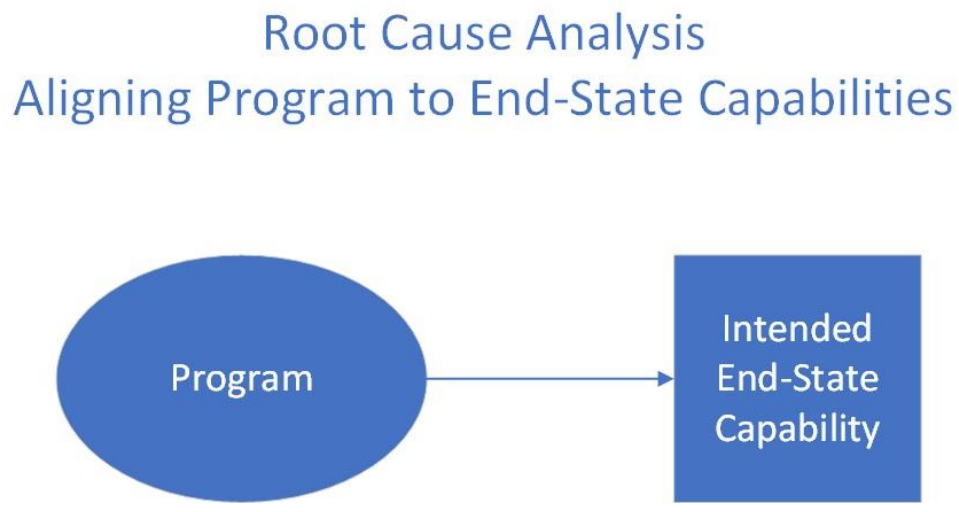


**Figure 4:** Root Cause Analysis – Problem Alignment with End-State

As highlighted in Figure 5, the team will then examine how the new capital investment or acquisition will resolve the shortfall that persists with the legacy system. What is the root cause of the shortfall? How does the new investment solve the shortfall and achieve its end-state capability. This next step is still kept a high level, but the solution should be comprehensive to the problem the agency is trying to solve. If the solution only solves the first problem the team can identify, the investment or project may only solve part of the shortfall and alone may not help the agency achieve its end-state objectives. In further steps, we break down the causes of the shortfall, examining and tracing use cases to better understand the program solution and the underlying problems.

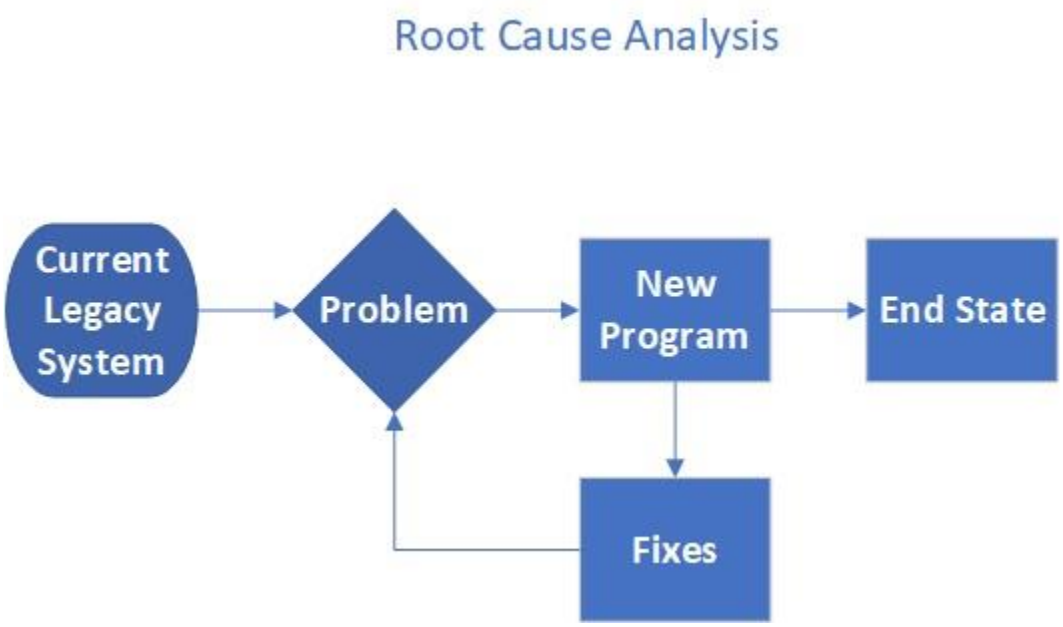


**Figure 5:** Root Cause Analysis – Problem Identification and End-State Alignment

As depicted in Figure 6, identifying an initial problem or shortfall is just the beginning of shortfall analysis and solution design and implementation. To achieve an intended agency objective and program end-state capability, the program office needs to uncover each impacted user and use case in the legacy system, understand their underlying constraints, trace the *symptoms* of the problems back to each potential origin or cause, and identify the primary problem the investment needs to solve. Working backward from the end-state to find the gaps in the legacy system, the program office can determine what shortfalls need to be solved more comprehensively, can establish program scope, and can break down system requirements to meet user needs. Shortfall analysis and root cause analysis is the starting point for system scope, design, and requirements. Root cause analysis also allows the estimating team to quantify all of the primary shortfalls and identify the shortfalls with the largest quantifiable consequence or impact. In Section 3.6, we will explore how to approach and measure shortfalls and their potential consequences.

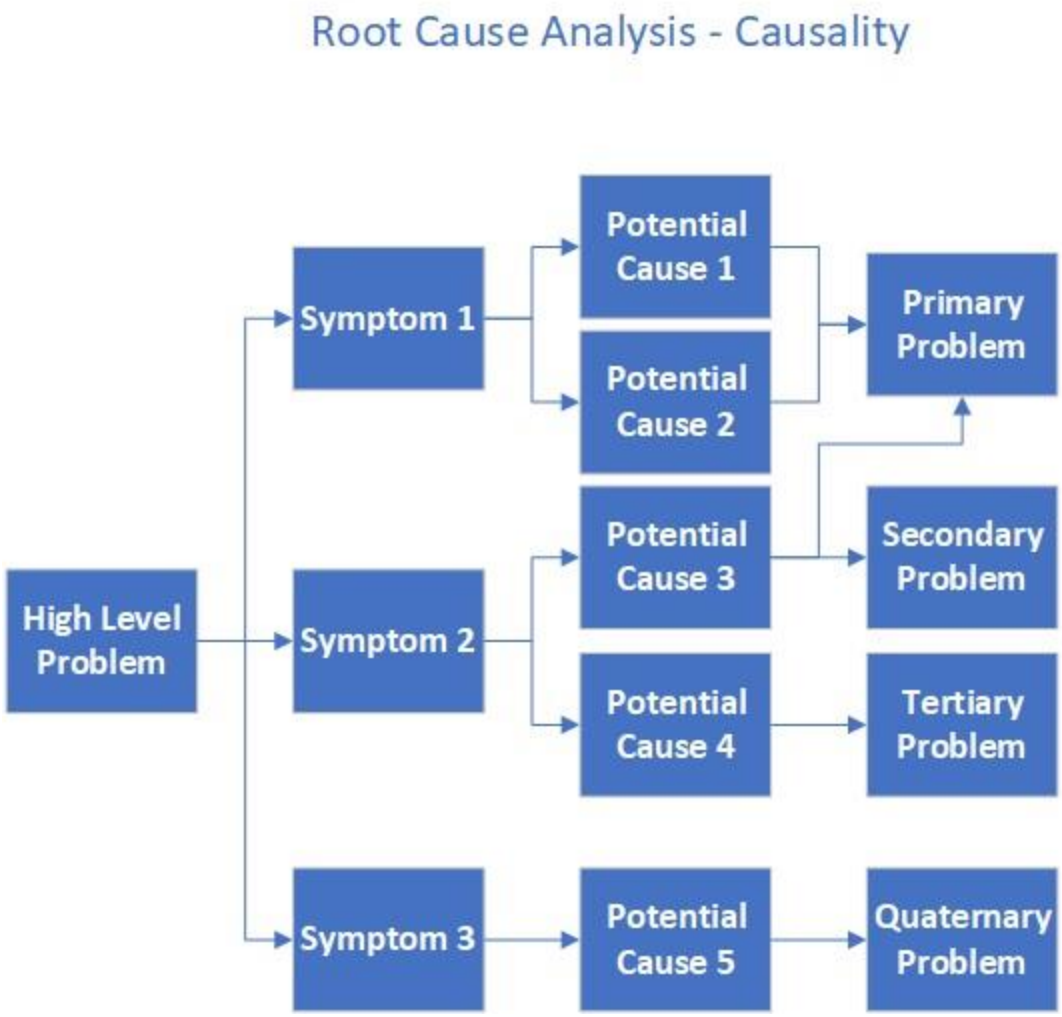


**Figure 6:** Root Cause Analysis – Determine Causality and Primary Problem

After the team lists each of the potential root causes and identifies multiple shortfalls, they can next assess whether the discovered shortfalls and legacy use cases are quantifiable. If they are quantifiable, and the team can establish an As-Is and To-Be measure for incremental improvement, the program office can categorize and quantify the shortfall. Once the shortfall is quantified, the team should reassess and determine if that shortfall solution solves the full problem and enables the end-state. If not, the team can examine what is still wrong with the legacy system and why it does not provide a comprehensive solution. By modeling use cases, the analysts can identify the remaining underlying problems or root causes and quantify those shortfalls. Once the team has uncovered all of the primary shortfalls in the root cause analysis, they should categorize, monetize (where applicable), list, and catalogue the shortfalls. During impact analysis, the team should prioritize the shortfalls by largest monetary impact to conduct a cost/benefit analysis and to justify the business case for investment approval.

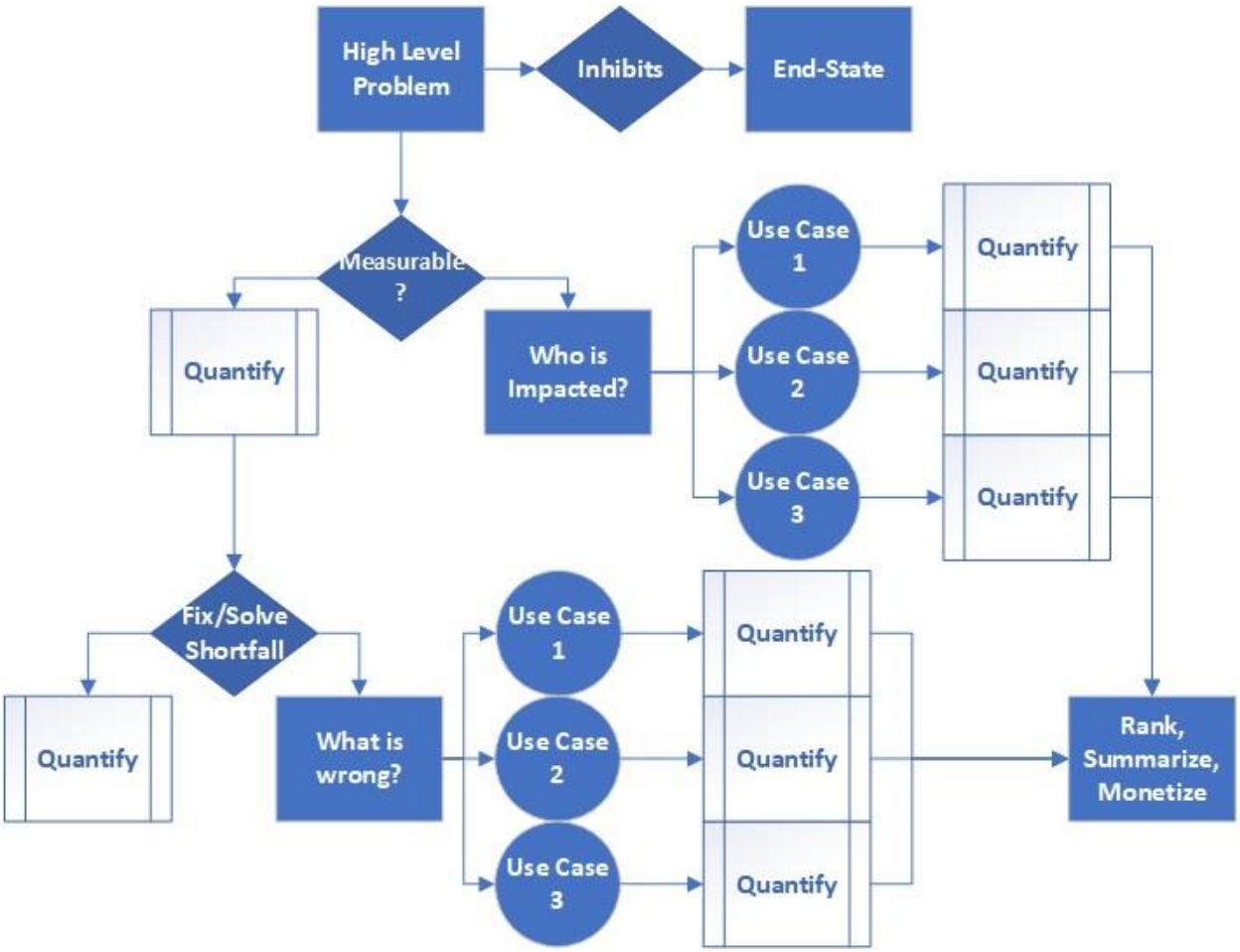


**Figure 7:** Root Cause Analysis – Shortfall Monetization and Summary

In traditional root cause analysis, the analyst identifies the initial and high-level problem, lists problem symptoms, and brainstorms and investigates potential problem causes to find the root cause or primary issue. For shortfall analysis, we use root cause analysis to identify root cause shortfalls at the use case level that we can quantify and demonstrate monetizable value.

## 3.6 Impact Analysis

Once the analysis team has conducted root cause analysis, the next step is to perform an impact analysis. First, recapping our shortfall analysis steps,

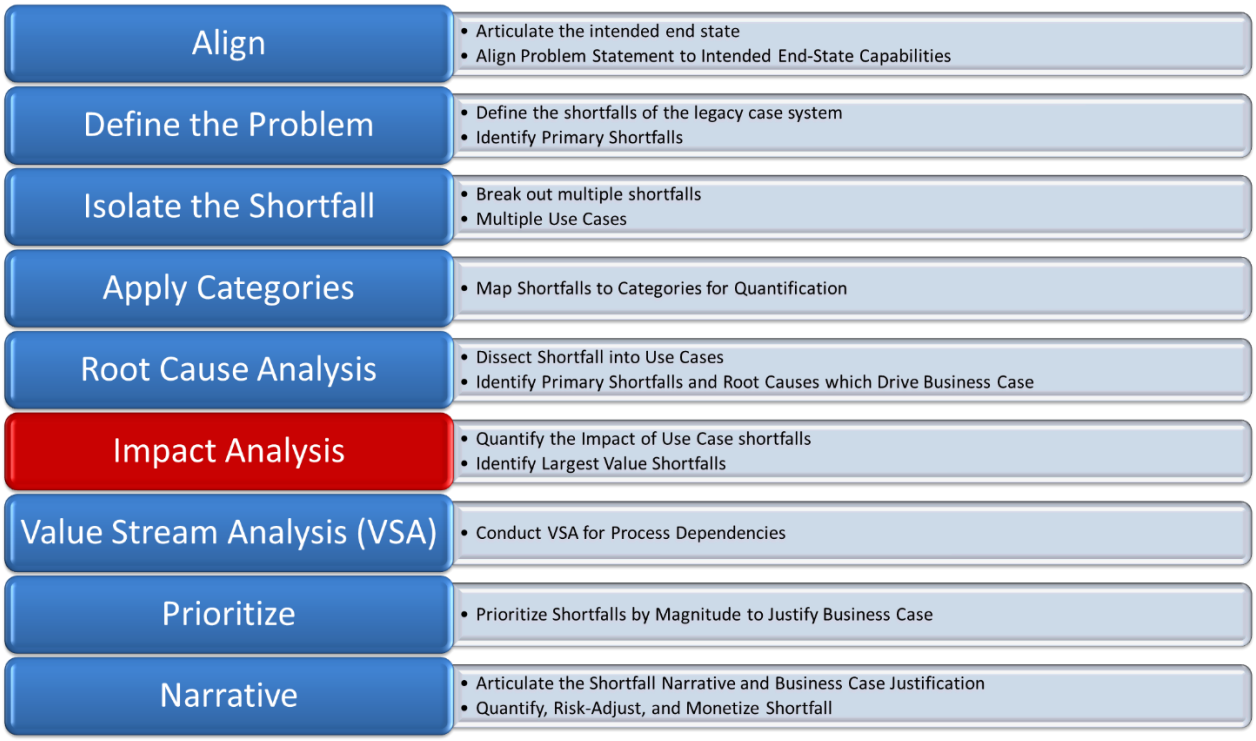


**Figure 8:** Shortfall Analysis Process Steps – Impact Analysis

In the impact analysis, the team will examine use cases to measure the impact of the persisting problem on users versus if the shortfall were solved by the new investment.

### 3.6.1 Inefficient Process Shortfall Example

If the problem the program office is trying to solve is an inefficient process, the team can conduct a time study to measure the current time it takes to complete a tasking or analysis. Using Business Process Reengineering or Value Stream Mapping, the team can measure the equivalent duration to complete the tasking or analysis in the To-Be case.

### 3.6.2 Sustainment Shortfall Example

If the problem is the inability to sustain a system past a specific date due to parts obsolescence and system End-to-Life (EOL), the analyst can conduct a sustainability analysis study, estimate the date of End-of-Service (EOS), and quantify the impact of the end date. This is where the shortfall analyst has to dig a little deeper. To monetize the impact of the EOS date, we need to better understand the "consequence" of that adverse end-result.

At this point, the analysis team tries to find a means of quantifying a shortfall and answers the following questions:

- What is the impact of **not** making the investment?
- How can we measure the "consequence" of **not** making the investment or acquisition?

### 3.6.3 Break Down the Problem

In the case of sustainment, what happens if the system loses service, and the agency must turn off this service at certain sites? We can measure the inability to perform the service with the legacy system

(maybe it is a slow manual process for which we can only serve half the number of customers) versus the capability and service we can perform now when fully operational. The incremental difference as we turn off more and more sites over time, measured for the project lifecycle is what we can monetize as the shortfall.

For the FAA, we could analyze the sustainability of air traffic displays. If we cannot sustain them, and we turn them off at certain Air Traffic locations, the FAA would increasingly have to reduce air traffic, increase flight delays and cancellations, and impost greater costs on airlines and the flying public. Digging into the root cause on a use-case basis and defining the "consequence" of **not** going forward with the investment allows us to quantify a meaningful and impactful shortfall.

## 3.7 Value Stream Analysis

While we cannot explore all shortfall identification and quantification methodologies, in this paper, we wanted to highlight a very specific process analysis methodology, which will be useful if the problem a program office analyzes includes business process inefficiencies, manual processes that can be replaced by automation, or even incremental process improvements, like interface integration.

### 3.7.1 What is Value Stream Analysis?

The purpose of value stream analysis is to study, map, and analyze current processes and steps from end to end. Then, by identifying a way of improving the process through automation, data integration, system consolidation, more powerful analytical capabilities, or some other means, the agency can eliminate *non-value-added* process steps and streamline processes to *reduce waste* in the system and maximize value.

### 3.7.2 Value Stream Mapping

Before we conduct value stream analysis and establish a means of measuring and eliminating waste in a current business process, we have to map out the processes we plan to examine. This process is called value stream mapping.

The primary steps for value stream mapping are the following (American Society for Quality, 2023). For this paper, we focused on the seven primary steps, highlighted in Figure 9 (American Society for Quality, 2023).

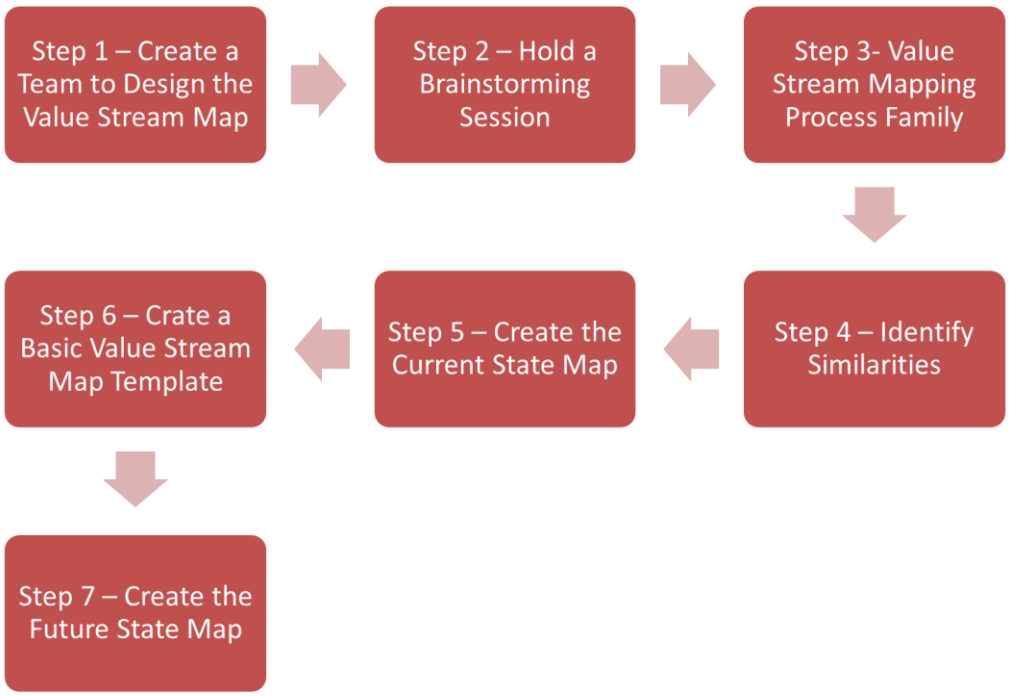


**Figure 9:** The Steps of Value Stream Mapping

#### *3.7.2.1 Step 1 – Create a Team to Design the Value Stream Map*

When considering the makeup of the team, the members should include users of the current As-Is process or business, so the team will include subject matter experts and can articulate the current state and process. Ideally, the team should include a variety of users, so it can capture and isolate all the primary As-Is process steps and estimate their duration or quantity.

#### *3.7.2.2 Step 2 – Hold a Brainstorming Session*

In this session, the team will establish and define the problem being solved, the existing process, identify and define users and use cases, and draw out all the process steps in the current business process. Then, understanding the goals of the investment or program end-state, the team would collectively map out the To-Be process, step-by-step in a process map. This would define the future state that solves the shortfall. The rest of what we do is a refinement of this brainstorming session and a means of designing measurement or quantification of the value stream analysis.

#### *3.7.2.3 Step 3 – Value Stream Mapping Process Family*

In step 3, the team creates a matrix that maps and documents the process steps. On one axis, the team will list the process steps sequentially, and on the other axis, the team will list the products impacted. For a government agency, instead of a product mapping, this measure might be a time study of the process, where the team would capture the time it takes to conduct each process step when providing a service. As an example, for a Maintenance and Repair Organization (MRO), the activities in the matrix might include part ordering time, part repair timing, and part shipping time.

This matrix helps the team to be comprehensively inclusive of all steps in the value stream. It also provides a measure of units by which the team can quantify the shortfall.

#### *3.7.2.4 Step 4 – Identify Similarities*

In the next step, the team will identify similar steps that may be material in a time study, but which can be consolidated into a streamlined series of process steps. This will allow the team to focus on unique steps that can be reduced or eliminated in the To-Be case and will help the team identify and isolate non-value-added steps during the As-Is analysis.

#### *3.7.2.5 Step 5 – Create the Current State Map*

In this step, after identifying all process steps and quantification metrics, the team maps out sequentially and consolidated steps for the As-Is process. For quantification, the team will note only units like volume, cycle time, inventory, or any time study measure.

In our Section 4 use case example, this paper will walk through a value stream map of maintenance logging at a government agency.

#### *3.7.2.6 Step 6 – Create a Basic Value Stream Map Template*

The template for a team's value stream map should follow and be inclusive of how the team will quantify the steps and measure waste.

In the Section 4 example, this paper will demonstrate how to measure an average low and average high duration for tasks in each process step in a value stream mapping time study. Our team set up a means of measuring each task of the user, defined scenarios, and created a time study template which allowed the team to calculate the duration of each step.

Our team also recorded a risk register and set risk ranges on specific parameters we could collect and measure with users' data and using estimates from subject matter experts. Then, we used the risk ranges of our quantifiable time study to conduct a Monte Carlo Simulation. The FAA's IP&A Group follows the OMB guidelines and examines program shortfalls and benefits along a risked distribution curve as the benefits floor. The OMB requires civilian agencies to use the 20$^{th}$ percentile of benefits and the 80th percentile of costs to calculate business case finance metrics (Net Present Value (NPV), Benefits/Cost ration, and Internal Rate of Return (IRR)) in a business case cost/benefit analysis.

#### *3.7.2.7 Step 7 – Create the Future State Map*

In step 7, we create the future state or To-Be process map, determining how the program solution would streamline processes and eliminate or reduce in magnitude (or duration) individual process steps. Some examples of this type of reduction realized in a To-Be state include system consolidation, data or legacy system integration, and automation, all of which would eliminate manual processes and reduce completion time.

# 4 Shortfall Analysis Case Study – Maintenance Logging

## 4.1 Shortfall Analysis – Program and End-State Alignment

Over the last four years, the FAA conducted investment analysis for a major maintenance logging system capital investment. The program was designed to solve several shortfalls centered around a legacy software system and the agency's portfolio objectives of enhancing predictive maintenance capabilities and Reliability Centered Maintenance (RCM). The end state objective was a streamlined and integrated maintenance system in the FAA's supply chain that allows for better flow and utilization of data, more

efficient processes, and better response times for infrastructure sustainment. With better recording and sharing of data, the FAA could be more proactive in its maintenance and repair planning.

As defined in Section 3, the program office had defined the end-state goals of the program and portfolio, and it started to define scope to meet those goals. In Step 1, it "aligned" the program to the intended end-state capabilities and objectives. The next step of investment analysis is to "define the problem" and identify the primary shortfalls.

## 4.2 Problem Definition, Shortfall Isolation, and Categorization – Maintenance Logging

The infrastructure and enterprise architecture of Maintenance Logging significantly reduced the integrity of maintenance data, failed to provide timely situational awareness to field maintenance personnel and stakeholders impacted by maintenance events, and impeded the ability of maintenance personnel to perform predictive maintenance activities. These shortfalls impacted the ability of the agency's maintenance system to improve efficiency and to apply organizational end-state goals of the Reliability Centered Maintenance (RCM) and data-driven decision-making initiatives. Furthermore, the manual logging of work status information and maintenance data into multiple reporting systems significantly detracted from the productive time for maintenance personnel to conduct analyses and to record and retain consistent maintenance logs for tracking events.

After (1) program alignment to organizational goals and program end-state, the program office and shortfall analysis team (2) defined primary legacy system shortfalls, (3) isolated the shortfalls into multiple use cases and challenges, and (4) applied shortfall categories for each shortfall as depicted in Figure 11.

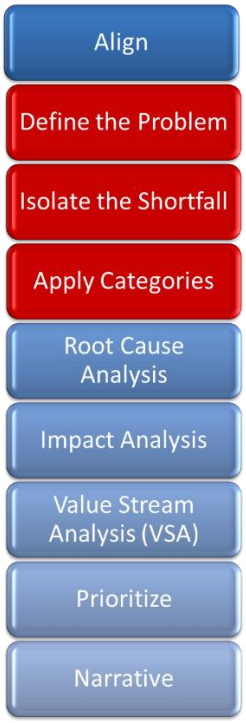


**Figure 10:** Shortfall Analysis Process Steps Focus

In Figure 11, the shortfall analysis team identified the deficiencies of the legacy system that would impede it from achieving end-state goals and listed each of these shortfalls separately. Each shortfall has a classification or category by which the team can segment shortfalls and quantify their impact, but how did the team quantify the efficiency, quality, effectiveness, data, and capacity shortfalls identified and isolated in the shortfall analysis? In the following sections, we break down each of the primary shortfalls and describe how we quantified the shortfalls for the business case using Value Stream Analysis and a time study.

**Figure 11: Program Shortfalls**

**"Define the Problem"**

**"Isolate the Shortfall" | "Apply Categories"**

- **Redundant Logging** (Efficiency) – Inefficient time and wasteful cost for duplication of data entry activities which required validation.
- **Manual Data Entry Errors** (Quality) – Without automation, reliance on unintegrated systems and manual data entry resulted in data errors.
- **Delays** (Effectiveness) – Unintegrated systems caused delays in planned and unplanned maintenance event coordination and resolution.
- **Absence of Situational Awareness** (Data and Information) – With integrated systems, maintenance data transparency could be improved.
- **RCM** (Inefficiency, Data) – Unintegrated systems provided less effective Reliability Centered Maintenance (RCM) capabilities.
- **System Integration** (Efficiency) – Without some interfaces to external systems, maintenance notification process time took longer, including manual coordination.
- **Maintenance Restoration Delays** (Capacity, Inefficiency) – Manual processes and time-consuming logging delayed restoration of NAS equipment and services, potentially impacting airspace operations.

For this business case, the agency wanted to focus on improving maintenance logging. The FAA manages a large infrastructure of systems, and the supply chain and maintenance organizations provide timely parts distribution, system maintenance planning, and system outage tracking via multiple databases and software systems. The ability to manage the maintenance of FAA equipment and systems efficiently is critical to sustain reliable National Airspace (NAS) operations. The agency wants to make continuous improvements to its maintenance management system and improve legacy case software to support the mission need. By identifying and isolating the system shortfalls, the team was able to develop program scope, Concept of Operations, and detailed program requirements to meet target end-state objectives.

| Shortfall Category | Shortfall | End-State Objective | Description | Quantification Approach |
|---|---|---|---|---|
| Efficiency | Redundant Logging | System Integration and Automation to reduce maintenance logging time | Utilizing different legacy logging systems, maintenance tracking and field teams record duplicate maintenance logging entries without transparency to each other's logs, increasing the time for maintenance event resolution. | Value Stream Analysis Time Study |
| Quality | Manual Data Entry Errors | Incremental system interfaces and system integration will result in fewer manual entries and greater data fidelity | Without integrated internal logging systems and external system interfaces, maintenance personnel record logs manually, copying and pasting data from one system to another, sometimes resulting in errors. | Value Stream Analysis Time Study |
| Effectiveness | Delays | Incremental system integration to improve efficiency | Unintegrated Systems can cause delays in planned and unplanned maintenance event coordination | Value Stream Analysis Time Study |
| Data and Information | Absence of Situational Awareness | Increased situational awareness for Maintenance and Logistics community | With integrated systems, maintenance data transparency could be improved | Value Stream Analysis Time Study |
| Inefficiency & Data | Reliability Centered Maintenance (RCM) | Increase application of RCM Capabilities | Multiple systems used to track and record maintenance logs can impede data transfer and slow RCM application | Value Stream Analysis Time Study |
| Efficiency | System Integration | With increased external system integration, can reduce time of maintenance restoration | Without some external interfaces, maintenance logging requires more manual entry and validation. | Value Stream Analysis Time Study |
| Capacity & Inefficiency | Maintenance Restoration Delays | Restore Airspace Sooner | Manual processes and time-consuming logging delayed restoration of NAS equipment and services, potentially impacting airspace operations | Constrained Airspace Maintenance Event Monetization |

**Figure 12:** Shortfall Categorization Matrix

To categorize and prepare a quantification strategy for each of the primary shortfalls, the shortfall team developed a shortfall matrix (see Figure 12) to list out the plan for the business case. Then, the team

prioritized the shortfalls and established a methodology for quantification of the maintenance logging process, establishing a Maintenance Logging Value Stream.

## 4.3 Value Stream Analysis

The maintenance logging business case was primarily centered around process improvement and efficiency with system integration, data exchange, and new system capabilities. Since the system focused on processes, the team needed to better understand the current maintenance logging process and how to change and improve the process as it added functionality and automation.

### 4.3.1 Value Stream Mapping

To identify all the process shortfalls, root causes, and the magnitude of these shortfalls, the team conducted a Value Stream Analysis, starting with a Value Stream Map of the As-Is processes end-to-end. To trace the steps of maintenance logging, the shortfall analysis team met with user groups across multiple facilities to collect and observe the series of steps the teams take to record, log, track, and resolve maintenance events for the FAA. By getting a broad spectrum of users, the team was able to establish a comprehensive list of sequential process steps under different circumstances and scenarios and consolidate those steps into a quantitative Value Stream Map. The team identified, traced, and developed flow diagrams for 36 As-Is maintenance event logging process steps and added influence diagrams to demonstrate sub-steps and differences in maintenance logging based on shift and time of day.


To quantify the value stream, the shortfall team conducted a time study, gathering frequency of event data from historical databases and interviewing and observing maintenance subject matter experts to record the average minimum and average maximum duration for each step and scenario of each step. Adding volume with number of facilities and number of maintenance events each year, the team was able to extrapolate the time study to encapsulate and quantify the total duration from end-to-end, across the critical path of a maintenance event, by facility and facility type, and in aggregate for the agency. This As-Is process was an objective quantitative approach for measuring current maintenance logging.

After estimating the duration of individual maintenance event logs for the As-Is state, the shortfall analysis team met with additional facility maintenance subject matter experts (SMEs) and with logistics and supply chain integration SMEs to estimate the potential savings per event for an average low (likely better case scenario) and average high (likely higher case scenario) and ran a Monte Carlo Simulation to get a full risk distribution. For risk, the team also estimated potential program management delays in program implementation, acceptance testing, user acceptance, and funding to account for slower adoption in higher risk scenarios. Applying the risk adjustment, the team estimated that the duration of maintenance logging per event across the NAS compared to the As-Is case saved more than 50 minutes.

Using hypothetical data in the example, Figure 13 displays the first seven steps of the Maintenance Logging Value Stream Analysis time study, highlighting the structure of the value stream steps in the As-Is process map and the associated durations for each event in the As-Is and To-Be processes. In some cases, for the To-Be, the step is eliminated completely.

| Value Stream Time Study Steps | | Maintenance Logging Value Stream | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | As-Is Avg (Mins) | | | Predicted Percentage | | To-Be | | |
| | | Maintenance Center 1 | | | Reduction | | Maintenance Center 1 | | |
| | | Low | High | Avg | Scheduled | Unscheduled | Low | High | Avg |
| 1 | MANUAL - Maintenance Analyst calls Control Tower to confirm | 2.00 | 3.50 | 2.75 | 75% | 20% | 0.77 | 1.35 | 1.06 |
| 2 | MANUAL - Failure Confirmed | | | | 0% | 0% | | | |
| 3 | MANUAL - Maintenance Center logs in failure event in System 1 | 2.50 | 4.00 | 3.25 | 25% | 25% | 1.88 | 3.00 | 2.44 |
| 4 | MANUAL - Maintenance Center determines if NOTAM (indicator) is required | 1.25 | 2.50 | 1.88 | 45% | 10% | 0.80 | 1.59 | 1.20 |
| 5 | MANUAL - Maintenance Center analyst logs into System 2 | 1.00 | 1.50 | 1.25 | 100% | 100% | - | - | - |
| 6 | MANUAL - Maintenance Center analyst logs details into System 2, enters in System 3 | 2.50 | 4.00 | 3.25 | 75% | 75% | 0.63 | 1.00 | 0.81 |
| 7 | MANUAL - Maintenance Center analyst publishes NOTAM (indicator) | 0.25 | 0.50 | 0.38 | 100% | 100% | - | - | - |

**Figure 13:** Value Stream Analysis Time Study and Quantification

As with many government capital investments, the team could not prove the cost/benefit analysis business case justification with time savings alone as there were no guarantees that time savings efficiency would result in any labor savings.

## 4.4 Impact Analysis and Shortfall Monetization

Since the shortfall analysis team could not monetize the time savings per maintenance event for the business case, it needed to explore the secondary use cases downstream of the maintenance logging value stream analysis. How could the team monetize these program efficiencies? How would we translate the time savings into dollars and value? As with many shortfall analyses, the primary shortfall analysis is not comprehensive to each user, and although process improvement resulted in true program efficiencies and defined the program shortfall narrative, the program office needed a means of monetizing program value to the agency, airlines, and the flying public (primary FAA stakeholders).

By examining the purpose of these process efficiencies and answering the question, “So what?” after identifying time savings in the value stream, the team discovered that resolving maintenance events faster could have a material impact on flight operations. This was the answer to, “So what?” We could now relate the time series value stream to agency operations and stakeholder value.

During an unexpected system outage, some systems will impact flight operations, causing flight delays, cancellations, and other measurable impacts to the airspace. The agency has indicators which can help organizations identify which systems can cause flight delays, and using historical flight data, the team can measure the flight impact of event-specific system outages and quantify the incremental impact. The shortfall analysis team collected equipment and event-specific outage data and quantified the outages, extrapolating the data by the volume of events over the last few years to get an annualized

value. Then, the team monetized that value using FAA metrics for the flight impact to stakeholders, primarily to airlines and to the flying public.

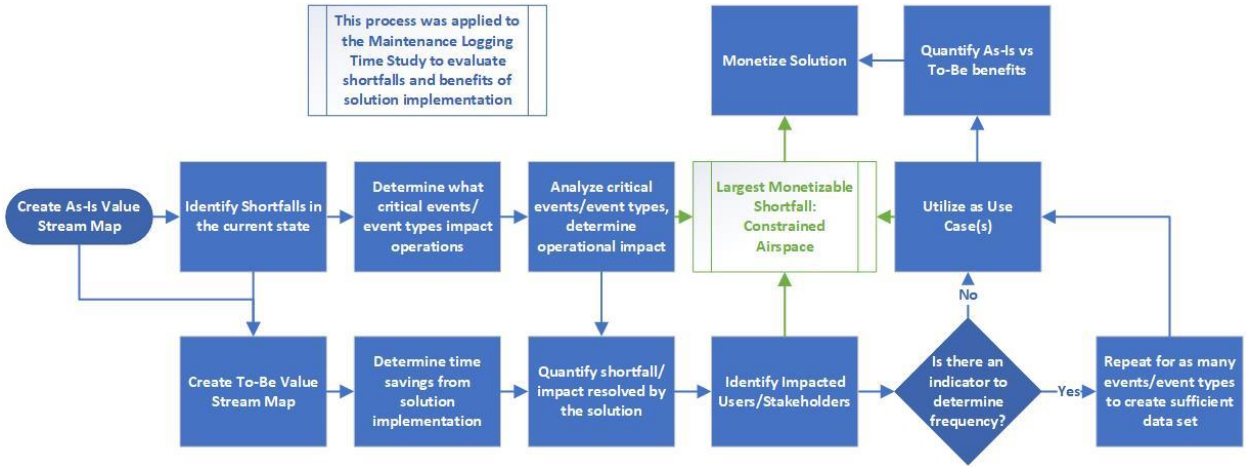


**Figure 14:** Shortfall Impact Analysis and Use Case Monetization

In Figure 14, we can trace the steps of conducting the value stream mapping for As-Is and To-Be processes. Then, we highlight the consequence of those shortfalls – the delay of maintenance event resolution due to inefficient processes can constrain airspace for longer periods of time until the maintenance outage is resolved. In some cases, during equipment outages, flight operations are impacted, causing flight cancellations and delays. This use case of NAS system outages allowed the shortfall analysis team to monetize the incremental time from the value stream analysis between the As-Is and To-Be case.

By applying the average time savings from the maintenance logging value stream analysis to historical flight operational analyses and historical quantities, the team was able to monetize the business case shortfall attributed to the maintenance logging business case. It is important to note that without an impact analysis, the shortfall team might not have correlated that the largest shortfall value was an extrapolation of the value stream and related to flight operations. Not all shortfalls are on the surface, and it is important to examine all underlying use cases in an impact analysis.

# 5 Conclusions

Government capital investments are challenging to design, define scope, align with agency strategic goals and portfolio objectives, and, most prominently, justify quantitatively. They begin with an agency need or problem that the organization wants to solve – (1) the inability to add system capacity, new capabilities, or services with a legacy system that would add value to stakeholders, (2) the inability to make incremental efficiency improvements, or (3) infrastructure system sustainment challenges for an End-of-Life system. To arrive at a viable program solution, program offices need to first define the shortfalls.

To creatively quantify critical investment problems and define business case value, shortfall analysts use proven shortfall analysis strategies and processes, including:

- End-State Analysis to align the problem statement with required program end-state capabilities,
- Root Cause Analysis to identify primary shortfalls and their root causes,
- Impact Analysis to quantity the underlying use case shortfalls,
- As-Is Versus To-Be Modeling to quantify incremental value,
- Value Stream Analysis to map process dependencies and isolate shortfall waste.

With a crowded program management field of new investments, infrastructure sustainment acquisitions, and constrained capital budgets, agencies need creative approaches to shortfall quantification and business case justification. Without robust shortfall and business case benefits quantification, cost/benefit analyses may be inadequate to justify business cases and secure needed F&E funding, risking investment delay or cancellation.

# 6 References

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