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THESIS

**DISCRETE EVENT SIMULATION
OF U. S. COAST GUARD PREVENTION WORKFORCE**

by

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June 2023

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**DISCRETE EVENT SIMULATION OF U. S. COAST GUARD
PREVENTION WORKFORCE**

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Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

The United States Coast Guard (USCG) Prevention workforce plays a crucial role in conducting marine safety activities essential to the nation's maritime transportation system. As the demands of this mission evolve, the USCG is considering adjustments to Prevention personnel policies. These changes have the potential to significantly impact the workforce and lead to unintended consequences. To support this decision-making process, we utilize Athena Lite, a discrete event simulation tool, to simulate the USCG Prevention workforce. Our objective is to assess the performance and accuracy of the simulation tool in capturing workforce dynamics and its suitability as a decision support tool for USCG workforce planning. By analyzing personnel data, achievement records, position information, and specialty codes, we extract meaningful insights and construct simulation inputs. Focusing on the Prevention active duty officer workforce, we create and execute multiple scenarios in Athena Lite, comparing the results with real-world data for evaluation. The study reveals the challenges and limitations associated with simulating the complex USCG Prevention workforce and identifies areas for improvement in accurately representing workforce dynamics. These findings underscore the ongoing need for refining the tool and scenarios to enhance accuracy and provide a robust workforce planning solution for the USCG.

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List of Acronyms and Abbreviations

ADF	Australian Defence Force
CG-1B2	Strategic Workforce Planning and Human Resources Analytics Division
DCO	direct commission officer
DES	discrete event simulation
KSA	knowledge, skills, and abilities
LOS	length of service
MAPE	mean absolute percentage error
OCS	officer candidate school
OOS	opportunity of selection
OSC	officer specialty code
PAL	Personnel Allowance List
PY	promotion year
ROR	retired officer recall
TEMPSEP	temporary separation
USCG	U.S. Coast Guard
USCGA	U.S. Coast Guard Academy

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CHAPTER 1:

Introduction

Workforce planning is critical to ensure the U.S. Coast Guard (USCG) has sufficient numbers of skilled personnel available to meet current and future mission demands. A military organization with limited mid- and senior- level external hires, the USCG must rely on junior personnel moving up the organization to fill future, senior positions. There are unique constraints on hiring, promoting, training, and separating personnel in the USCG which must be considered in managing the workforce. The Service’s marine safety mission overseeing the U.S. maritime transportation system—completed by its Prevention specialty workforce—is particularly difficult to plan for. The Government Accountability Office noted this and raised concerns with the Coast Guard’s marine safety workforce planning efforts, highlighting the difficulty in managing a workforce subject to dynamic, cyclical private industries which influence the number of positions needed [1].

In order to ensure it can meet future mission requirements and the evolving demands of the maritime industry, the USCG is undertaking significant changes to workforce management and personnel policies. Admiral Karl Schultz, 26th USCG commandant, outlined a strategy in “Ready Workforce 2030” to meet current and future demands by “creating a system with the ability to generate the force we need, when and where we need it” [2]. In particular, the Prevention Workforce Planning Team is exploring multiple courses of action to maximize the number of marine safety positions filled with personnel of the appropriate rank and skill level [3]. These proposed changes to assignment and training policies have the potential to impact the officer corps and the Service’s ability to fulfill its roles and missions that support homeland security and national prosperity.

The *Ready Workforce 2030* strategy also outlined the need for analytics and data-driven decision support tools to inform leadership regarding resource and personnel policy trade-offs as they shape the future workforce. Strategic workforce planning is overseen by Coast Guard Strategic Workforce Planning and Human Resources Analytics Division (CG-1B2), sponsor of this research. Their motivation is to understand if a particular workforce simulation tool, Athena Lite [4], can provide leadership with more accurate and rapid simulations

of proposed workforce policy changes [5]. Various tools are currently employed to forecast future personnel numbers, and evaluate the impact of workforce planning decisions, such as promotion rates, promotion zone sizes, and special retention programs. Currently, these tools are not capable of modeling the complex and changing Prevention workforce with the speed and detail needed for decision makers. Workforce planners must develop bespoke models, which are too time-consuming to meet the pace of change, in order to evaluate career progression and policy proposals for impacts to the workforce. The work outlined here is intended to evaluate a potential tool capable of completing these analyses and provide a workforce baseline from which to evaluate proposed policy changes.

Athena Lite is a workforce simulation and decision tool, specifically built for military workforce planning, developed in 2019 by the Australian Defence Force (ADF) [4]. A discrete event simulation (DES) software, Athena Lite, models the supply and demand of a military workforce over time. It has provided the ADF with valuable analysis on the transition to a new type of military aircraft and is in active use [6]. Our research uses Athena Lite to simulate the USCG Prevention workforce, offering an alternative tool for USCG workforce planners. We analyze existing workforce data in order to adapt Athena Lite model inputs for the USCG workforce system, and compare simulation results with real-world data to evaluate accuracy of the tool.

1.1 Coast Guard Prevention Background

The USCG has a long history of ensuring safe and secure maritime commerce. Established by Congress in 1790 as the Revenue Marine, the Service's original mission was to collect tariffs on seaborne cargoes [7]. Today, the USCG is entrusted with 11 statutory missions, including search and rescue, environmental response, maritime law enforcement, and vessel safety. The Service operates as both a branch of the military and a federal law enforcement agency within the Department of Homeland Security [8].

The marine safety mission of the U.S. Coast Guard (USCG) is of paramount importance in supporting the nation's maritime transportation system, which encompasses a staggering \$4.6 trillion of economic activity [9]. Entrusted with regulating a wide range of vessels, from tour boats and cruise ships to barges and oil tankers, the USCG's Prevention professionals play a vital role in ensuring the safety and security of these maritime assets. They are

responsible for overseeing various aspects, including construction, manning, operations, and accident investigations, all aimed at ensuring compliance with both U.S. and international laws and regulations.

The demand for USCG marine safety services primarily stems from everyday activities of commercial shipping. As new ships and waterfront facilities are developed, existing equipment undergoes maintenance and upgrades, emerging technologies are integrated, and new waterway users emerge, the need for robust oversight and safety measures intensifies. The USCG's Prevention workforce is at the forefront of addressing these demands, ensuring that proper standards are upheld and potential risks are mitigated.

By providing oversight and enforcement, the USCG's Prevention professionals contribute to the safe and efficient functioning of the maritime transportation system. Their work upholding regulations and ensuring compliance helps safeguard not only the vessels and their crews but also the environment and the broader economic activities associated with maritime commerce.

The marine safety field, commonly referred to as the Prevention specialty, is made up of five major areas: vessel inspections, accident investigations, facility inspections, waterways management, and marine engineering. Vessel inspections handle U.S. and foreign vessel examinations, including issuance of required documents and certificates, inspection of equipment, and crew competency. Figure 1.1 shows a vessel inspection in progress. USCG accident investigators work to determine facts following an incident involving a vessel or licensed mariner, make recommendations to prevent future incidents, and take necessary enforcement action against companies and individuals. Facility inspections ensure compliance of waterfront facilities, such as container and cruise ship terminals, with safety and security regulations. Waterways management personnel handle waterway use permitting, stakeholder engagement, and oversight of the aids-to-navigation system. Finally, marine engineering sets vessel construction standards, as well as reviews and approves engineering plans for construction, repair, and modification of U.S. vessels. Fewer than one thousand officers dispersed throughout the world are assigned to this broad mission at any given time.



Figure 1.1. Coast Guard Marine Inspector Conducting a Vessel Inspection.
Source: [10].

1.2 Purpose

The purpose of this project is to examine the USCG Prevention officer workforce to understand gaps between available personnel and workforce demands, in order to inform potential policy changes, using the ADF's Athena Lite DES tool [4]. This tool was specifically requested to be used by the project sponsor, CG-1B2. In this project, we address the capabilities of the Athena Lite tool, hurdles to simulating the USCG Prevention workforce, and use scenarios to evaluate the tool's performance and results.

1.3 Methodology

To guide this research, we use the process outlined in Figure 1.2.

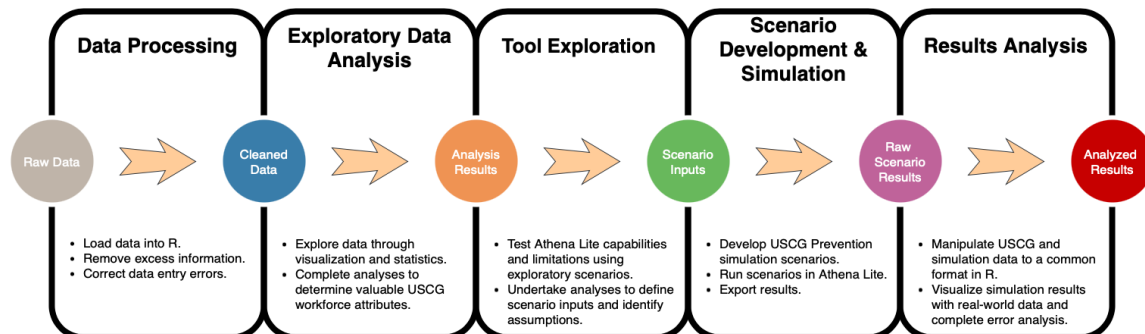


Figure 1.2. Workforce Simulation Research Process

Our research process begins with raw data provided by USCG sources which covers 2017–2022 personnel and position information. We remove excess information and correct data entry errors, in order to prepare it for analysis. Next, we explore and analyze the cleaned data using R to determine valuable information on Prevention workforce dynamics. We focus on active duty USCG officers, grades O1–O6, working in the Prevention field, as well as positions in the Prevention field. The analysis results then inform our Athena Lite tool exploration, where we use fictional workforce scenarios to test simulation features.

Next, we use our data analysis results, additional USCG data, and insights from the tool exploration step to create scenarios in Athena Lite to understand supply and demands on the Prevention workforce. The basis for the scenarios are the Coast Guard workforce from January 2017 to November 2022, with personnel on January 2017 serving as initial personnel in the simulated workforce. This research focuses on active duty Prevention officers and is not applicable to the USCG’s enlisted, civilian, reserve, or auxiliary workforces.

We run the USCG Prevention workforce scenarios in Athena Lite and export simulation results. Finally, we analyze simulation results and compare against real-world data to determine challenges for the workforce, and accuracy and reliability of the tool. The thesis sponsor, CG-1B2, can use these results and tool evaluation to understand the impact of changes to the Prevention workforce, while improving and refining policies to meet future needs.

1.4 Limitations and Assumptions

Aspects of the Prevention workforce were not modeled due to software and data constraints. Training positions (e.g., Apprentice Marine Inspector) in the Prevention workforce are primarily coded as O2 or O3 positions. However, officers in grades O1–O3 are routinely assigned to these positions regardless of position rank. Athena Lite is not able to model personnel at multiple grades being assigned to a single position nor positions at different grades [11].

Training programs, required schools, and other career progression requirements are not modeled. All officers of the matching grade are assumed to be eligible for transfer to any open position in the model. In reality, there are complex business rules in place to ensure officers of appropriate experience are assigned to the position of most benefit to the Coast

Guard and their personal growth [12].

In 2017, military service members became eligible to opt into the Blended Retirement System from the legacy retirement system, and accessions after 1 January 2018 were automatically enrolled [13]. This change in retirement benefits likely had significant impact on the retention of personnel. Wastage rates (i.e., the rate personnel depart the Service) used in this research were calculated from data covering this period, and there may be limitations in their use for older data.

Changes to the officer corps management system were implemented in 2020 and resulted in officer specialty codes (OSCs) being re-coded and renamed. The data used in this research spans the impacted time and old codes are included in records of senior personnel. These changes may have impacted career progression and the assignment process but were not considered in this research [14].

Weaknesses in the accuracy of the achievements dataset have been previously noted [1]. In particular, competencies and OSC may not be entered into the dataset in a timely manner. We assume negligible effect on our analysis.

Many careers in the Coast Guard follow interesting paths which can make modeling all the possibilities difficult. Officers who enter Prevention will take positions outside of the field at different points in their career. Limitations in the software prevent this from being modeled and these officers are assumed to have departed from the Prevention workforce.

We assume all Prevention positions have a similar tour length of 2–4 years in the simulation. Tour length is position specific and the available data did not contain this information.

1.5 Organization

This work is organized into six additional chapters. Chapter 2 covers USCG officer workforce management, promotions, separations, and assignment process. We include the challenges and tools currently used to match supply and demand in the USCG. Chapter 3 gives background on previous work in workforce modeling, DES, survival analysis, and Athena Lite. Chapter 4 describes the data, challenges we face working with it, and provides preliminary analysis. Chapter 5 explains the Athena Lite program and simulation logic, and provides

results of exploratory scenarios. Chapter 6 describes the USCG simulation inputs, presents Prevention workforce scenario results, and provides a comparison to real-world data. Finally, Chapter 7 summarizes our findings, covers challenges of Prevention workforce planning, and makes recommendations for further work.

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CHAPTER 2: USCG Workforce Background

This chapter provides an overview of the process and policies that govern the management of the USCG workforce. It delves into the complexities of workforce management, including multiple stakeholders, complex policies, and planning considerations. The mission statement of the Assistant Commandant for Human Resources (CG-1) is: “To get the right people, to the right place, at the right time” [15]. This requires balancing workforce supply and demand, considering factors such as seniority and skills, and anticipating future needs. There are many policy levers available to leadership to shape demand and supply of the workforce. Understanding the short and long term impact of adjusting these levers is necessary to maintain a mission-ready workforce. Workforce simulation serves as a valuable tool to understand the potential effects of policy adjustments on the workforce and ensure its long-term health and effectiveness.

It is common to use the terms “rank,” “grade,” and “paygrade,” interchangeably as they refer to related aspects of officer hierarchy. We primarily use “grade” (and its abbreviations) which refers to levels in the officer corps and “paygrade” which is a classification based on grade or rank to determine basic pay [16]. Table 2.1 provides a summary of Coast Guard grades.

Table 2.1. Grade, Grade Abbreviation, and Paygrade of Officers. Adapted from [17], [18].

Grade	Grade Abbreviation	Paygrade
Ensign	ENS	O-1
Lieutenant (junior grade)	LTJG	O-2
Lieutenant	LT	O-3
Lieutenant Commander	LCDR	O-4
Commander	CDR	O-5
Captain	CAPT	O-6
Rear Admiral (lower half)	RDML	O-7
Rear Admiral	RADM	O-8
Vice Admiral	VADM	O-9
Admiral	ADM	O-10

2.1 Demand

Demand for personnel plays a crucial role in the workforce balancing act and requires thorough analysis and modeling. It represents the workload that must be accomplished to align with congressional, national, and Coast Guard strategies. The translation of this demand signal into actual positions within the Coast Guard is done through the budgeting process and the manpower requirements process [19]. The Coast Guard uses the “Sector Staffing Model” to determine the required number of positions for its Prevention units, ensuring sufficient personnel to handle the mission workload [20]. These positions are documented in the Personnel Allowance List (PAL), which serves as the official record of authorized positions in the Coast Guard [5].

There are thousands of positions in the Coast Guard. These cover all mission areas and support functions. Out of a total 7,233 active duty officer positions in June 2022, 885 were classified as Prevention [21], [22]. We see in Figure 2.1 that vessel inspection positions made up the greatest share of these Prevention positions. Some positions are assigned to more than one category.

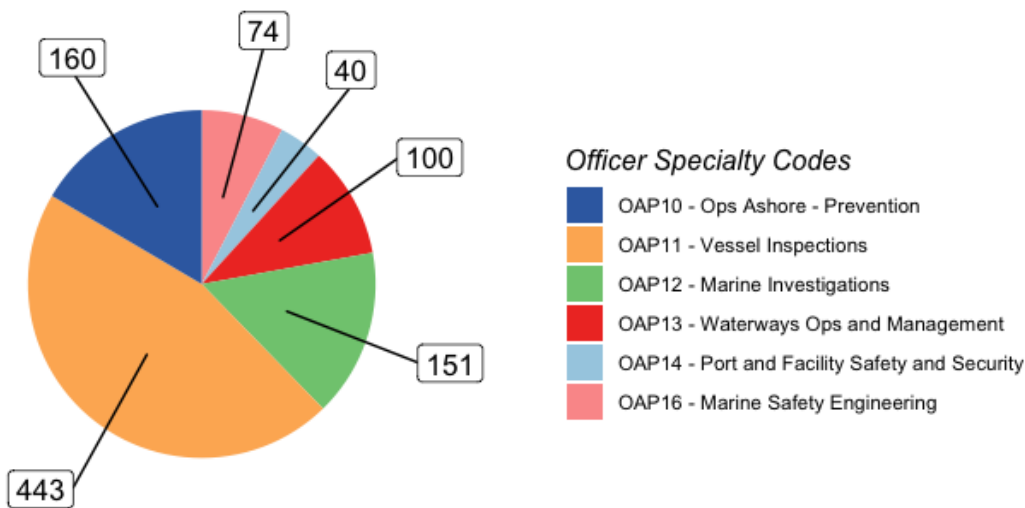


Figure 2.1. Prevention Positions with Number of Positions by Category, as of June 2022.

Individual positions are attached to a unit and, generally, a unit is made up of multiple positions. Positions are classified by the nature of the work and type of person that can be assigned to the job. Each position has a designated rank which indicates the preferred paygrade of the person assigned to the job. Positions are also assigned competency codes which represent the necessary skills or experience to be successful in the position. This is discussed in greater detail in Section 2.2.4.

Position competency codes are critical to link skills and experience needed for a position with available officers who possess them. The strength of this link is set by a position's competency code importance value captured in the PAL. Importance values indicate the criticality of the knowledge, skills, and abilities the competency code represents to successful completion of position tasks. These competency importance values range from Level 5, "Competency is position critical," to Level 1, "Competency included for professional development purposes, but is not necessary for execution of primary responsibilities of position" [23]. Most positions have competencies assigned an importance value of Level 3: "Competency is position important: performance in the position would likely be degraded without the OSC/competency. If not already earned, OSC/competency will be earned in this type of billet" [23].

2.1.1 Demand Management

Diligent management of the number of positions is critical to a sustainable workforce. Changes in the demand for personnel are driven by budget processes and resourcing decisions. Removing units, increasing mission scope, and a tightening fiscal environment all are examples of situations that impact the number of personnel needed. These actions and budgeting tools are available to drive demand in the direction dictated by leadership and national strategy.

A unique aspect of the military workforce is that personnel can only enter at junior levels and advance based on applicable laws and Service policies. Unlike civilian organizations, the Coast Guard does not hire from outside the organization to fill senior or mid-level positions. Instead, it must rely on personnel already in the Service. This places significant constraints on the Service, limiting its ability to add positions to an expanding mission and requiring diligent management of the workforce to ensure the number of junior personnel whom enter the Service today will meet the any number of demand scenarios for senior personnel in 20+ years.

As demand for positions fluctuates, Coast Guard offices submit resource change proposals to CG-1B2 for evaluation. CG-1B2 uses the Force Structure Model, a custom in-house Excel-based tool, to provide insight into impacts of a proposed position addition or removal. Changes in the number of positions affect the balance between junior, mid-level, and senior positions within a specialty (e.g., Prevention). According to guidance from CG-1B2 [24], there must be sufficient junior positions for officers to gain expertise along with adequate senior positions for career progression. The same guidance explained there is an ideal percentage of positions at each grade to maintain a healthy balance across the workforce. For example, using the suggested ratios from the guidance, the addition of a CAPT position should be supported by 2–3 CDR, 5–6 LCDR, 11–12 LT, and 9–10 LTJG/ENS positions within the same specialty. Additionally, the impact of position changes on statutory caps and promotion points must be taken into account.

2.2 Supply

Personnel supply is a vital component of workforce planning as it determines the number of individuals available to fill positions and carry out the Coast Guard’s mission. The

supply of personnel is influenced by multiple factors, including the number of personnel entering the Service, the rate at which personnel separate (commonly known as the retention rate), and the speed of progression up the grade pyramid [25]. These factors collectively determine the size and composition of the workforce, ensuring that the Coast Guard has a sufficient number of personnel to meet operational requirements. Effective workforce planning involves closely monitoring and managing these supply factors to ensure a balanced and sustainable workforce that can effectively fulfill the Coast Guard's mission.

Congress has set conditions on personnel levels along with many other aspects of USCG workforce policy. These requirements are defined in 14 U.S. Code §§2101–2182, and cover the conduct of accessions, promotions, and separations/retirements. A cap of 6,900 Coast Guard officers was instituted in 2014, raised to 7,100 for fiscal year 2022, and will continue to incrementally rise to 7,400 officers for fiscal year 2025 and after [26].

Throughout an officer's career progression, the USCG has various tools to shape the size and composition of the workforce. A standard career progression begins at one of three accession points, and following accession training, the person is assigned to positions every 1–4 years throughout their time in the Service. At each position they gain experience and earn competencies, and at various points in their career they are evaluated for promotion to the next higher grade. Their performance, along with the demand and supply of personnel, in a specialty determines success in promotion. Failure to promote eventually leads to involuntary separation from the Service. In this section, we discuss the relevant aspects of Prevention officer career progression and its impact on supply.

2.2.1 Accessions

Personnel enter the Coast Guard through one of three accession sources: USCG Academy (USCGA), officer candidate school (OCS), or direct commission officer (DCO). The Service strives to have sufficient number of people, as laid out in the annual Officer Accession Plan [5], [27], enter and complete training at each source to meet short and long term demand. Table 2.2 provides accession targets for 2023. OCS and DCO commission officers at ENS to LT, and USCGA only commissions ENSs. The minimum requirements for entry into the officer corps and accession training programs are laid out in [12], [28].

Table 2.2. FY23 ADPL Accession Targets by Grade. Adapted from [29, table 1].

Grade	Year Group	Accessions
ENS (CGA)	2023	231
ENS (OCS/DCO)	2023	270
LTJG (DCO)	2021 (before 1 Jan 2023) 2022 (after 1 Jan 2023)	23
LT (DCO/ CWO-LT)	2019	38
TEMPSEP/ ROR	TBD based on rank	Up to 25
EAD	TBD based on rank	Up to 86
Total FY23 Accessions		673

Following accession training, officers enter the workforce, with a portion of these new officers reporting directly to Prevention positions. There is no requirement for training between accession and reporting to a Prevention unit and position.

Most accessions to the officer corps are obligated to serve a minimum number of years and this impacts personnel retention. For example, officers commissioned from the USCGA have a minimum obligated service period of five years [12] and generally cannot depart the Service during this period.

2.2.2 Assignment

Following initial accession training, officers are assigned to positions, called tours, for a specific period (e.g., 1–4 years). The PAL is the authoritative source for positions and members are assigned to these positions. At the end of their time at a position, officers are eligible for a change of position. Each subsequent position is generally more challenging, with greater responsibility, than the last. The assignment process begins with the officer submitting a list of preferred positions to assignment officers at the Officer Personnel Management office. In addition to member preferences, assignment officers gather unit input to determine the necessary skills for open positions using OSCs and importance values. Finally, a matching process takes place to fill open positions with available officers. When there is an excess of personnel, multiple officers may be assigned to the same position.

In the event of a shortage, with too few officers to fill positions, assignment officers, with input from stakeholders, prioritizes and determines which positions go unfilled. In certain cases, positions may be filled with personnel of a higher or lower rank and/or personnel with less experience or skills than desired. Some positions are intended to have a flexible rank requirement. For example, within the Prevention specialty, Apprentice Marine Inspector positions are entry-level training jobs and are routinely filled with O1–O3 officers.

Prevention officers have a multitude of assignment options at each point in their career within the Prevention workforce. A few of these tracks are detailed in the Operations Ashore Junior Officer Career Guide [30], shown in Figure 2.2. There is no requirement for an officer's career to follow one of these tracks. Officers may be assigned outside of the Prevention field at different points in their career.

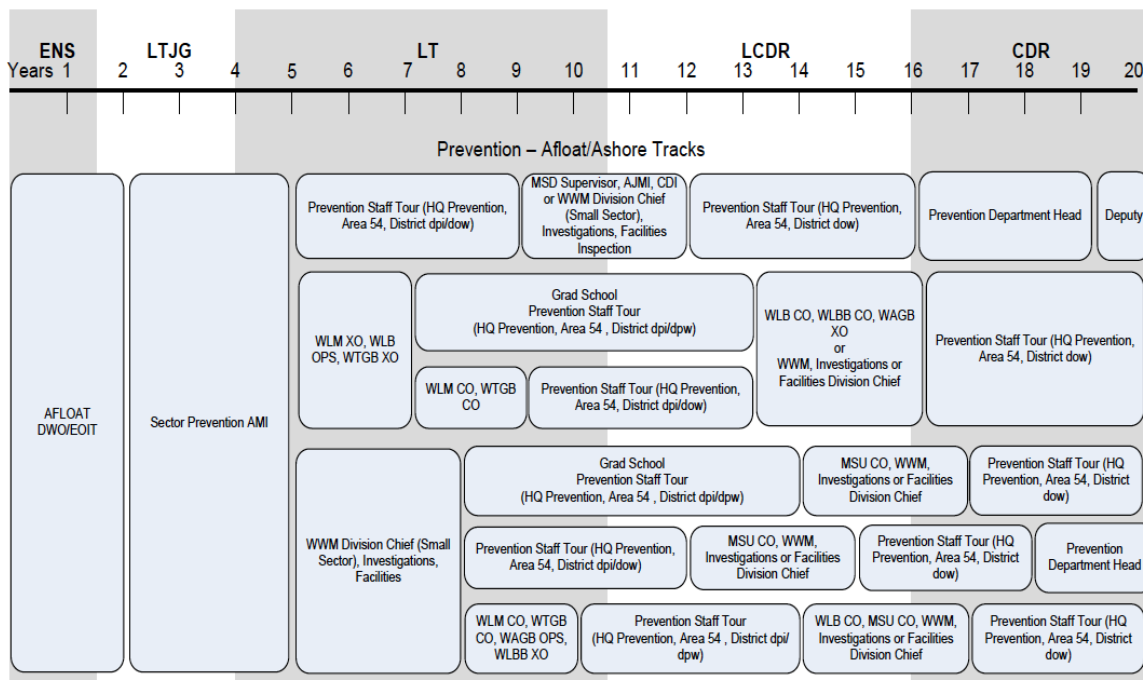


Figure 2.2. Prevention Career Tracks. Source: [30, appendix C].

Transfers between position assignments are generally scheduled during a summer transfer window. Transfers outside of this window take place for those graduating accession training and unexpected position vacancies.

2.2.3 Promotion

Promotions determine progression up the officer hierarchy and are a key component of military workforce management. Promotion refers to an officer being designated at the next higher grade and promotion eligibility is determined by length of time served in a particular grade. For example, LTs are eligible for consideration for promotion to LCDR after three years of service at the LT rank [12]. The number of officers selected for promotion “shall be equal to the number of vacancies existing in the grade, plus the number of additional vacancies estimated for the next twelve months, less the number of officers on the selection list for the grade” [31].

All officers eligible for selection, regardless of specialty, are evaluated by the same selection board [12]. This means Prevention officers compete not just against their Prevention peers, but also against officers from across the Service.

The annual Officer Corps Management Plan [25] contains the policy decisions which lay out how promotions are to take place each year. The plan sets promotion zone sizes that are based on the number to be selected for promotion divided by opportunity of selection (OOS) percentage. A promotion zone refers to the pool of officers considered for promotion to the next grade [25]. The plan states that the goal when determining number of promotions is to fill vacancies, while OOS percentages are set to maintain desired career progression and time in service benchmarks. OOS refers to the percentage of officers in the promotion zone who will be selected for promotion [12]. For example, in 2022, the approved OOS for selection to O4 was 85% [25]. The maximum difference in opportunity of selection between year groups is 6% to maintain comparable opportunities [25].

Each year, promotion selection boards meet to determine which eligible officers at a particular grade are selected for promotion to the next higher grade. Promotions from O1 are determined twice a year, while other grades are annual [12]. Selection boards can select officers up to the cap established in the Officer Corps Management Plan [12], [25].

Officers selected for promotion are promoted to the next grade based on vacancies or after meeting a time in grade requirement [12]. Generally, officers at O1–O3 grades not selected for promotion at two subsequent promotion selection boards are separated from the Service [32]. This policy is commonly referred to as an “up or out” promotion system.

For those officers at grades O4 and O5 not selected for continuation or promotion at two subsequent promotion selection boards, they may remain on active duty until 20 years of service. Reference [32] provides additional details.

The cap on the number of active duty officers was set at 6,900 officers for fiscal years 2017–2022 by 14 U.S. Code §2103 [26]. Per this statute, the required grade distribution of officers in grades O4–O8 is shown in Table 2.3. The statute also allows the Secretary of the Department of Homeland Security to set distribution requirements on O3 and below. There is no Prevention-specific grade distribution requirement prescribed by law.

Table 2.3. Statutory Grade Distribution. Adapted from [26].

Grade	Distribution Percentage	Max. Number in Grade
Rear Admiral, O8	0.375	26
Rear Admiral (lower half), O7	0.375	26
Captain, O6	6.0	414
Commander, O5	15.0	1035
Lieutenant Commander, O4	22.0	1518

2.2.4 Knowledge, Skills, and Abilities

Officers develop knowledge, skills, and abilities (KSA) as they gain experience and progress through their career. The Coast Guard groups KSAs into competencies. A competency is “[a] collection of tasks with the associated knowledge, skills, abilities, and wherewithal (tools, methods, information, doctrine, procedures, materials, etc.) needed to perform the tasks to a predetermined, measurable, performance standard. The tasks are usually related as parts of a larger process in support of or contributing to the goals of the organization, unit, or work group” [33].

The purpose of competencies is to provide a standard method to quantify KSAs and link positions with personnel. Competencies are used throughout the workforce and human resources processes for this purpose. Figure 2.3 illustrates the linkage competencies play between position demands and personnel supply [33].

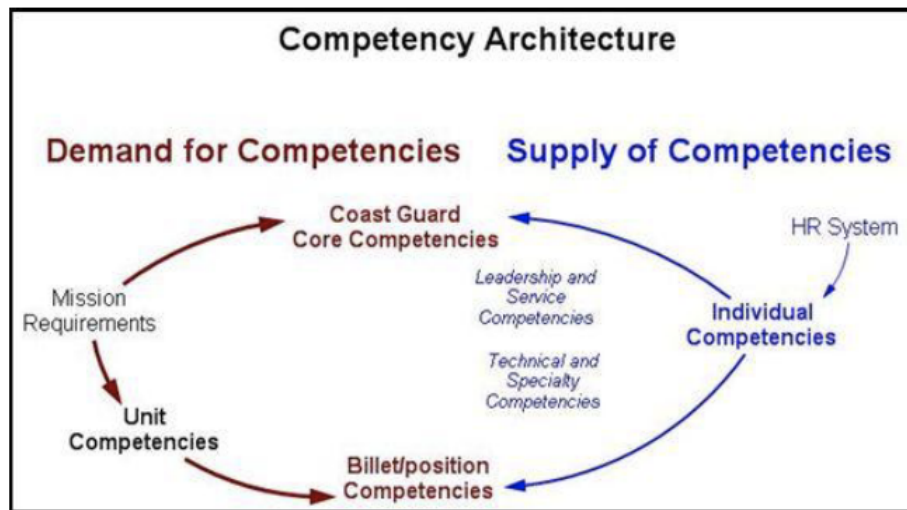


Figure 2.3. Integrated Competency Architecture. Source: [33, figure 1-2].

An officer's competencies in the Coast Guard are influenced by various factors, including their current position assignment, the duties of that position, the needs of the unit, the demands of the industry for USCG services, and the officer's own professional development. These competencies are acquired through a combination of classroom training, on-the-job experience, verified tasks, written tests, and oral examinations.

In the Prevention field, competencies often build upon each other, forming a progression. For instance, to conduct an examination of a foreign-flagged oil tanker, an officer must first possess the competency to examine foreign vessels, followed by the competency specifically related to oil tank vessel examinations. The progression of competencies reflects the officer's assignment history and work experience, as they acquire the necessary skills and knowledge to perform their duties effectively.

The officer corps management system is responsible for overseeing and documenting the KSAs of the workforce [14]. This system utilizes specialties and subspecialties to categorize and assign members based on their qualifications for specific positions. Each specialty and subspecialty is assigned a code and consists of various levels that represent different tiers of ability and requirements.

These levels are indicative of the necessary competencies, licenses, education, position history, and years of experience required for each level. The codes provide a standardized

method for the Coast Guard to assess the experience and qualifications of officers and determine the specific skills and abilities needed for each position [14]. This ensures the workforce is properly matched with the skills required for their assigned roles.

There are 22 levels across the six codes representing Prevention specialty and subspecialties. The Prevention specialty is named "Operations Ashore - Prevention," and coded as CG-OAP-10 [34]. The five areas discussed in Section 1.1 make up the Prevention subspecialties. A specialty code has three levels—Apprentice, Journeyman, and Master—and a subspecialty code has four levels—I through IV—with Master and level IV representing the most advanced skill and/or experience.

There are complicated dependencies between the codes and levels. To illustrate this, we discuss one of two ways to earn OAP-10 at the Journeyman level, denoted as OAP-10J. This code is the foundation of most Prevention officers' careers as it is required prior to assignment in a Sector Chief of Prevention position (also referred to as Prevention Department Head) [34], [35]. Figure 2.2 illustrates the critical component this position plays in career progression. The requirements for OAP-10J code are:

1. Vessel Inspections (OAP-11, Level IV) code,
2. either a Waterways Management Representative, Maritime Casualty Investigator, or Facility Inspector competency,
3. one year of experience using the competency from bullet 2, and
4. four years of experience as a Prevention Officer at a shore operational unit [34].

The requirements to earn specialty codes in the Prevention field are complex and have a significant impact on the training and career progression of officers. For example, it takes six years of experience to earn a level IV vessel inspections code, and an additional year using the competency from bullet 2. This process involves multiple positions and assignments over a span of seven years.

Capturing such detailed and intricate career progression requirements in a model presents significant challenges. The complexity of the process, the varying lengths of time, and the specific qualifications needed make it difficult to accurately simulate and describe within a workforce model. It requires careful consideration and comprehensive data to effectively capture the nuances of career progression in the Prevention field.

2.2.5 Supply Management

Effective workforce management requires a careful balance between supply and demand, ensuring that sufficient personnel are available to meet future mission requirements while providing career consistency for service members. On the supply side, the Coast Guard utilizes a set of workforce management tools outlined in annual Officer Corps Management Plans and Officer Accessions Plans to maintain desired inflow and progression of personnel [25], [27].

Available tools include altering officer accession targets, adjusting promotion opportunity of selection percentages, utilizing continuation boards, and employing specialty considered selections. Promotion opportunity of selection percentages are adjustable to influence the rate of personnel progressing up or out of the Service, helping to align workforce distribution with mission needs. Continuation boards are used to consider officers in understaffed specialties for continued service at their current grade following their failure to promote to the next higher grade [12]. The specialty considered selections program is another tool that can be employed to address gaps between supply and demand, and allows for targeted selection of personnel for promotion. Eligible personnel have specific experience in a specialty that has shortages or critical needs [12].

It is important to note that, with the exception of the limited specialty considered selections program, gaps between supply and demand for a particular specialty do not directly impact promotions. The promotion process primarily relies on other factors such as performance, qualifications, and time in service [12].

These workforce management tools provide the USCG with mechanisms to influence the supply side of the workforce, ensuring that personnel are directed to areas of need and retention is appropriately managed. By utilizing these tools strategically, the USCG can effectively shape its workforce and meet mission requirements.

CHAPTER 3:

Literature Review

This chapter provides a comprehensive overview of three key topics: discrete event simulation in military workforce planning, the utilization of Athena Lite as a simulation tool, and the application of survival analysis to workforce management. This chapter explores the existing research and best practices in these areas, highlighting their significance and relevance to the study of military workforce planning.

3.1 Discrete Event Simulation in Military Workforce Planning

Workforce planning and management, or manpower modeling, concerns the planning and forecasting of an organization's human resources system to match people and skills to positions at the appropriate time [36]. Military workforce planning is focused on military organizations and their distinct workforce characteristics, such as hiring and separations rules [37]. Armenia et al. [38] describes four differences between civilian and military workforce planning: 1) Outside personnel cannot be used to mitigate a lack of personnel, 2) Military personnel cannot be easily let go (e.g., laid off) due to excess personnel, 3) Military personnel cannot be in multiple grades, service branches, specialties, etc. at once, and 4) Gaps between supply and demand may be inevitable. These points highlight the unique challenges of military specific workforce planning.

This paper used a DES tool to evaluate the USCG Prevention workforce. DES is a type of simulation, and Nelson [39] provides a description of the term:

A DES model represents a system that is characterized by 'states.' The system state only changes at discrete points in time, and these points are characterized by "events." The simulation advances time on a 'clock,' moving from event to event in chronological order, and executing a series of actions depending on what type of event just occurred.

As Jnitova, Elsayah, and Ryan [37] explain, there are different military workforce modeling methods depending on the nature of the system to be modeled. Their research covers the

three common types of simulation models used for workforce planning: DES, agent based, and system dynamics [37]. They conclude DES is a flexible and highly customizable model, which works well with stochastic entities and random events. An example of DES workforce planning is representing people as entities and a person's status (grade, position, etc.) as states in the model.

DES modeling has previously been used in the military workforce context, including for Marine Corps training [40], U.S. Navy Supply Corps workforce planning [41], and military clinic staffing [42]. However, these studies used commercial simulation software such as ARENA [40], [42] and Simkit [41], which require models to be built from scratch. While these softwares may serve as an alternative approach to model the Prevention workforce, they require in-depth knowledge of the tool and are not tailored to military workforce planning.

3.2 Athena Lite Research

Athena Lite is a DES tool developed for military workforce planning, and the tool used in this paper. It was developed with, and is complementary to, Athena Pro, an agent-based, DES tool. Athena Pro models the workforce with greater emphasis on training and career progression [6].

Mortimer, Pike, and Nguyen [6] used Athena Lite, in conjunction with Athena Pro, to model and forecast the ADF Army Aviation workforce during a period of aircraft type transition. Three scenarios were evaluated, focused on aircraft pilots and all positions, including an analysis of the current state of the workforce, testing various plans for the aircraft transition, and optimizing recruitment and promotion to satisfy workforce demands during the transition. Each scenario covered 10 years and 30 replications per scenario. While the size of the aviation workforce modeled was not discussed, it was noted that the tool has been used to model over 20,000 personnel in the Royal Australian Navy. The study found that Athena Lite efficiently conducted the scenarios, optimization outcomes were similar to those of linear programming, and simulation results offered insights at various levels, encompassing individual personnel, units, and the overall workforce, over a 10-year time frame. The robustness of modeling military specific workforce policies, speed of the tool, and accuracy of optimization suggests Athena Lite may be an appropriate and powerful tool

for military workforce planning.

While Mortimer provided valuable insights into the use of Athena Lite, it is important to note that the ADF Army Aviation workforce differs significantly from the USCG Prevention workforce. Factors such as country-specific regulations, service-specific policies, and specialty-specific constraints make it challenging to directly apply the Athena Lite tool to a new workforce. Despite studies on the military workforce using DES and using Athena Lite, no work was found specific to the Coast Guard workforce. This lack of research shows the need for a proof of concept and evaluation of the tool for the USCG workforce problem.

3.3 Survival Analysis

Survival analysis is a statistical method to understand the probability of an event of interest occurring within a period of time [43], [44]. It is commonly applied in various fields such as healthcare, social sciences, and finance. The event of interest can be anything that involves a time-to-event outcome, such as the time to failure of a machine, time to death in medical studies, or time to departure of an employee in a workforce [43]. For example, a common survival analysis in actuarial sciences is calculation of a person's probability of survival based on age and other attributes. Probability of survival based on the length of time a person survives until the event of interest occurs, such as death, retirement, illness, etc.

Hazard rates are an important concept in survival analysis. The hazard rate at a particular time point represents the instantaneous rate at which events occur, given that the individual has survived up to that time point [43]. It provides insights into the risk or likelihood of an event happening at any given time [43].

A survival analysis was conducted in course of this research to calculate wastage rates, an Athena Lite model input. Wastage rates are another term for hazard rates. Wastage rate calculations are discussed in Sections 5.1.2 and 6.2.4. Athena Lite uses wastage to account for personnel leaving the system and Mortimer [6] refers us to Bartholomew [45] for discussion of wastage rates. Bartholomew calculates personnel wastage rates based on length of service and classes (e.g., officer grades) within a workforce. To do so, Bartholomew states wastage rates are the probability a person leaves an organization with length of service in the time interval $(x, x + \delta x)$ given survival till time x .

The Coast Guard provided unpublished results [46] of a survival analysis on the Prevention workforce. The study was completed on all officers assigned a Prevention OSC to determine the rate at which they depart the Service based on years served. The analyst created 42 bins (e.g., 0–0.99 years of service, 1–1.99 years of service), each representing years of service in the Coast Guard. Based on date of entry to active duty, Prevention officers were added to each bin. For each bin and each officer, it was determined if they remained in the Coast Guard one year in the future. The number lost over the year divided by the total was used to calculate hazard rates for each year bin. Finally, the average wastage rate over a sample of 36 months was calculated. However, as discussed in Section 6.2.4, for our research we needed to know hazard rates at each grade for Prevention officers. As such, we expand on this work in Chapter 6.

Our research builds upon prior DES research in order to model the Prevention workforce using the Athena Lite tool. We utilize survival analysis work presented in this chapter to complete a survival analysis necessary for the model. Next, we present the data used in our research and preliminary analysis.

CHAPTER 4:

Data Introduction

In this chapter, we cover the data used in our research, discuss data origin and quality, and provide preliminary data analysis.

4.1 Data Acquisition

CG-1B2, the project sponsor, provided the primary datasets, made up of nine files [21], [22], [47], [48], used for our research. Various offices have responsibility to submit and maintain the information in Coast Guard personnel and pay systems. These datasets cover demographic and experience information on Coast Guard personnel and force structure information related to position characteristics and quantities. Our research used this data as inputs for the simulation tool and to compare against simulation results. Prior to use in our simulation scenarios, we prepared and analyzed the data for useful information on the Prevention workforce.

Each file captures different information but is made up of monthly “snapshots.” A snapshot captures data from USCG’s human resources system, Direct Access, on the date taken. Within the employees files discussed in Section 4.1.1, this means an individual serving over a full calendar year appears twelve times, once for each monthly snapshot. Each row contains the information of an individual as entered in the database on the snapshot date. All personnel data was anonymized prior to receipt for privacy reasons.

4.1.1 Personnel Datasets

Personnel data plays a crucial role in our research as it provides information about the supply of officers in the workforce. We utilized personnel data from six comma-separated value files spanning the period from 2017 to 2022 [48]. These files contain various variables and data that serve as inputs to our model. Key variables in the dataset include paygrade, the active duty entry date, the date of rank, and the position entry date, among others. Each file contains multiple snapshots of the workforce, and every employee in the USCG is represented by an observation (or row) in the file. To link related data across files, a unique

personnel identifier was used as a key. It is important to note that the 2022 file does not include a snapshot for December 2022. The dimensions of each file, including the number of rows and columns, are summarized in Table 4.1.

Table 4.1. Dimensions of Personnel Datasets

File	Observations	Variables	Snapshot Freq
employees_2017	624,528	49	Monthly
employees_2018	629,508	49	Monthly
employees_2019	625,198	49	Monthly
employees_2020	620,759	49	Monthly
employees_2021	621,762	49	Monthly
employees_2022	567,291	49	Monthly (Jan–Nov)

4.1.2 Personnel Achievements Dataset

In addition to the personnel data, we also utilized a dataset containing achievement records of each Coast Guard member as of the November 2022 snapshot [47]. This dataset captures the qualifications, competencies, and officer specialty codes earned by service members throughout their careers. An excerpt of the dataset is shown in Figure 4.1. To link these achievement records to the corresponding officers in the personnel dataset [48], we used an anonymous identifier. By combining these two datasets, we were able to gain insights into the accomplishments and professional development of Coast Guard members. Table 4.2 provides an overview of the dimensions of the achievement dataset.

Snapshot Date	Anonymous ID	Achievement Code	Effective Date	Achievement Description	Year Acquired	Proficiency
11/8/22	9405768345687940000	CVSJMI	11/5/22	Journeyman Marine Inspector	2022	3
11/8/22	7426158329824590000	CVSAMI	11/3/22	Apprentice Marine Inspector	0	3
11/8/22	8790883988959620000	CVSTI	11/3/22	T-Boat Inspector	2022	3
11/8/22	3851025220453820000	CVSTI	11/3/22	T-Boat Inspector	2022	3
11/8/22	1597940678999570000	CVSMI	11/2/22	Machinery Inspector (Diesel)	2022	3
11/8/22	6683080820824360000	CVSML	11/2/22	Foreign Chem Tank Vsl Examiner	2022	3
11/8/22	4908208990456710000	CVSFV	11/2/22	Foreign Freight Vsl Examiner	2022	3
11/8/22	9043238508459280000	CVSTV	11/2/22	Foreign Tank Vsl Examiner	2022	3
11/8/22	8357094435788680000	CVSTV	11/2/22	Foreign Tank Vsl Examiner	2022	3
11/8/22	1814373264143080000	CVSMS	11/1/22	Machinery Inspector (Steam)	2022	3
11/8/22	1124982675966440000	CVSKI	11/1/22	K-Boat Inspector	2022	3
11/8/22	1124982675966440000	CVSTI	11/1/22	T-Boat Inspector	2022	3

Figure 4.1. Achievements Dataset Excerpt. Source: [47].

Table 4.2. Dimensions of Achievements and Position Datasets

File	Observations	Variables	Snapshot Date(s)
achievements	1,198,997	13	8 Nov 2022
personnel allowance list	4,264,216	41	Monthly (2017–2022)
job requirements	121,584	11	6 Jun 2022

4.1.3 Personnel Allowance List Dataset

Another dataset we utilized in our research is the PAL, which provides information on all positions in the Coast Guard [21]. This dataset includes details about each position, such as unit name, position rank, and position title. The PAL serves as the official record of all approved positions in the Coast Guard. Table 4.2 provides an overview of the dimensions of the PAL dataset. The PAL contains comprehensive information about the positions within the Coast Guard, enabling us to analyze the organizational structure and qualities of positions within the workforce.

Figure 4.2 shows an excerpt of the PAL dataset, providing a glimpse into the available position data that we used in our research. This dataset played a crucial role in understanding the characteristics and attributes of different positions within the Coast Guard.

Snapshot Date	Department ID	Department Name	Department Type	Position Number	Position Rank	Paygrade	Position Title	Occupation Information	City	State
1/1/17	7162	SEC LIS PREVENTION DEPT	SECTOR	117	CDR	O5	PREVENTION DEPT HEAD	CG-OAP10 - Ops Ashore- Prevention (OSC)	NEW HAVEN	CT
1/1/17	625	CG ACTIVITIES EUROPE	ACTIVITIES	131	LT	O3	MARINE INSP/PSCO-JRNYMAN	CG-OAP11 - Vessel Inspections (OSC)	SCHINNEN	
1/1/17	625	CG ACTIVITIES EUROPE	ACTIVITIES	132	LT	O3	MARINE INSP/PSCO-JRNYMAN	CG-OAP11 - Vessel Inspections (OSC)	SCHINNEN	
1/1/17	8142	D1 PREVENTION DIV (DP)	DISTRICT	144	CAPT	O6	PREVENTION DIV CHIEF	CG-OAP10 - Ops Ashore- Prevention (OSC)	BOSTON	MA
1/1/17	8152	D1 WATERWAYS MGMT BR (DPW)	DISTRICT	148	LT	O3	WW MGMT - DUTY	CG-OAP13 - Waterways Ops & Mgmt (OSC)	BOSTON	MA
1/1/17	7304	SEC MARYLAND-NCR INVEST DIV	SECTOR	207	LT	O3	SENIOR INV OFFICER	CG-OAP12 - Marine Investigations (OSC)	BALTIMORE	MD
1/1/17	7286	SEC NEW YORK INSPECTIONS DIV	SECTOR	208	LTJG	O2	MARINE INSP/PSCO-APPRENTICE	CG-OAP11 - Vessel Inspections (OSC)	STATEN ISLAND	NY
1/1/17	7286	SEC NEW YORK INSPECTIONS DIV	SECTOR	209	LTJG	O2	MARINE INSP/PSCO-APPRENTICE	CG-OAP11 - Vessel Inspections (OSC)	STATEN ISLAND	NY
1/1/17	7723	SEC NOLA INSPECTIONS DIV	SECTOR	210	LTJG	O2	MARINE INSP/PSCO-APPRENTICE	CG-OAP11 - Vessel Inspections (OSC)	NEW ORLEANS	LA
1/1/17	7556	SEC LOWER MISS WTRWAYS MGT DIV	SECTOR	211	LT	O3	WATERWAYS MGMT DIV CHIEF	CG-OAP13 - Waterways Ops & Mgmt (OSC)	MEMPHIS	TN
1/1/17	7539	SEC JACKSONVILLE WTRWAYS MGT DIV	SECTOR	371	LT	O3	WATERWAYS MGMT DIV CHIEF	CG-OAP13 - Waterways Ops & Mgmt (OSC)	ATLANTIC BEACH	FL
1/1/17	7533	SEC JACKSONVILLE PREVENTION DEPT	SECTOR	374	CDR	O5	PREVENTION DEPT HEAD	CG-OAP10 - Ops Ashore- Prevention (OSC)	ATLANTIC BEACH	FL
1/1/17	7538	SEC JACKSONVILLE INSPECTIONS DIV	SECTOR	527	LT	O3	FACILITY INSP SUPV	CG-OAP12 - Marine Investigations (OSC)	ATLANTIC BEACH	FL
1/1/17	6416	MSD PORT CANAVERAL	MSD	528	LCDR	O4	MSD SUPERVISOR	CG-OAP11 - Vessel Inspections (OSC)	CAPE CANAVERAL	FL

Figure 4.2. Personnel Allowance List Dataset Excerpt. Source: [21].

4.1.4 Job Requirements Dataset

The final dataset contains specialty codes and competencies associated with positions. The job requirements dataset has a June 2022 snapshot date and was linked to the June 2022 snapshot of the PAL dataset [22]. The job requirements in this dataset are connected to

positions in the PAL dataset through the Position Number key. Figure 4.3 displays a sample of the dataset, and Table 4.2 provides the dataset dimensions. As described in Sections 2.2.2 and 2.2.4, unit commands and specialty managers assign specific competencies to positions, along with their relative importance [5]. For example, as shown in row two of Figure 4.3, Position Number 131 requires an officer with competency code CG-OAP-113, which has an importance value of three. These importance values assist Assignment Officers in matching the required experience and skill demands of a specific position with the most suitable candidate during the assignment process.

Snapshot Date	Position Number	Job Family	Effective Date	Competency	Competency Description	Importance Code	Importance Code Description	Proficiency Code
6/6/22	131	COMOFF	4/25/22	CGOAP113	Vessel Inspections - Tier 3	3	Average	3
6/6/22	132	COMOFF	4/25/22	CGOAP113	Vessel Inspections - Tier 3	3	Average	3
6/6/22	144	COMOFF	4/25/22	CGOAP10J	Prevention-Ashore - Journeyman	4	Above Avg	6
6/6/22	207	COMOFF	5/3/22	CGOAP122	Marine Investigations -Tier 2	3	Average	3
6/6/22	208	COMOFF	4/25/22	CGOAP112	Vessel Inspections - Tier 2	2	Below Avg	3
6/6/22	209	COMOFF	4/25/22	CGOAP112	Vessel Inspections - Tier 2	2	Below Avg	3
6/6/22	210	COMOFF	4/25/22	CGOAP112	Vessel Inspections - Tier 2	2	Below Avg	3
6/6/22	347	COMOFF	4/25/22	CGOAP113	Vessel Inspections - Tier 3	3	Average	3
6/6/22	527	COMOFF	5/3/22	CGOAP122	Marine Investigations -Tier 2	3	Average	3
6/6/22	528	COMOFF	12/10/21	CGOAP121	Marine Investigations - Tier 1	3	Average	3
6/6/22	528	COMOFF	4/25/22	CGOAP113	Vessel Inspections - Tier 3	4	Above Avg	3
6/6/22	528	COMOFF	5/3/22	CGOAP121	Marine Investigations - Tier 1	3	Average	3

Figure 4.3. Job Requirements Dataset Excerpt. Source: [22].

4.2 Data Preparation and Analysis

In order to prepare for the next research phase, we utilized R, a statistical programming language, for data cleaning, reformatting, and analysis [49]. The data analysis phase involved conducting exploratory data analysis and preparing specific portions of the data for utilization in the model. Key aspects of workforce modeling such as supply, demand, tenure at positions, and time spent at ranks before promotion were investigated to gain insights into the behavior of the Prevention workforce.

Our analysis focused on active duty Prevention officers and Prevention positions. To start, we utilized a subset of the provided total USCG datasets. We employed various keys to merge the separate datasets and developed functions to calculate values across different snapshots. To provide transparency and clarity, we followed Buttrey and Whitaker's suggestion [50] and created flowcharts outlining our data preparation process for personnel and position datasets, as depicted in Figures 4.4 and 4.5.

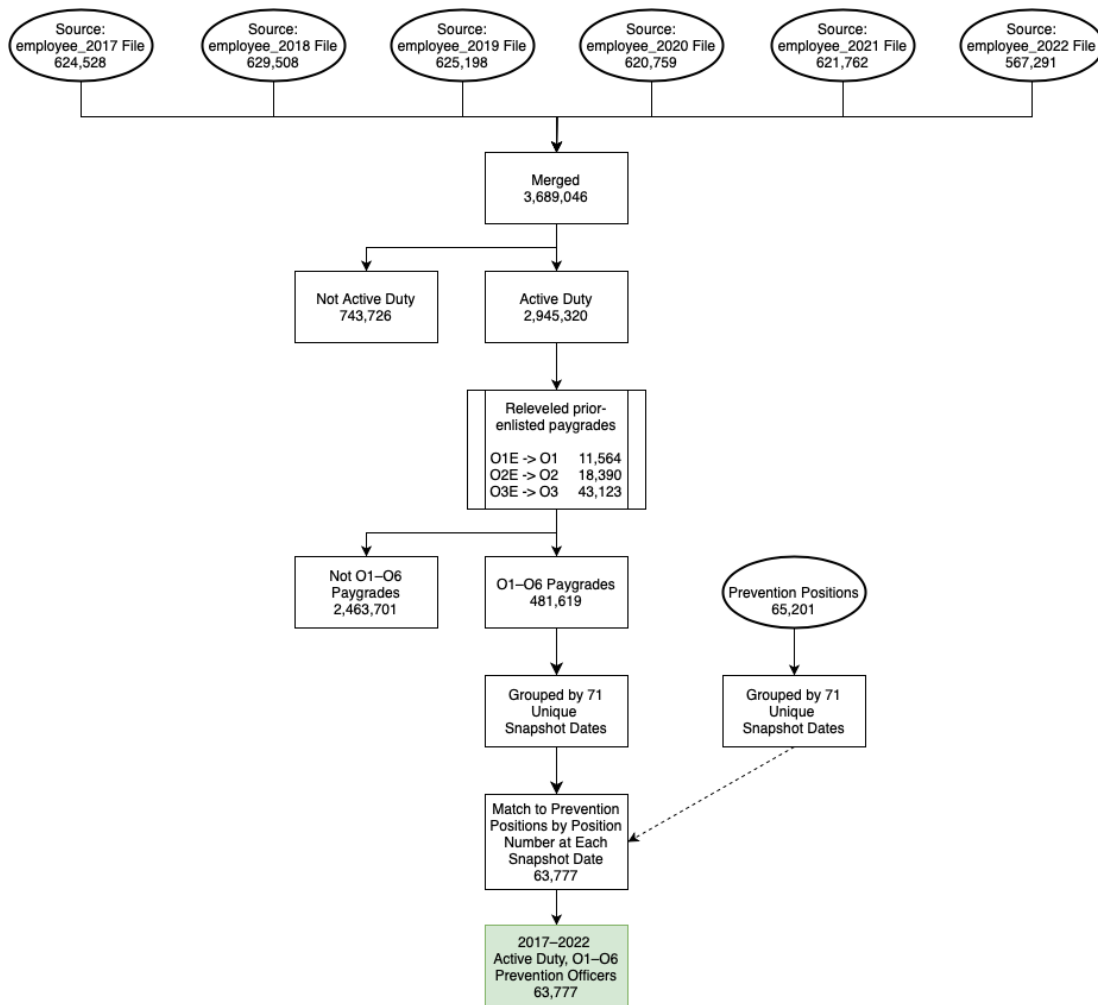


Figure 4.4. Personnel Data Preparation Flowchart

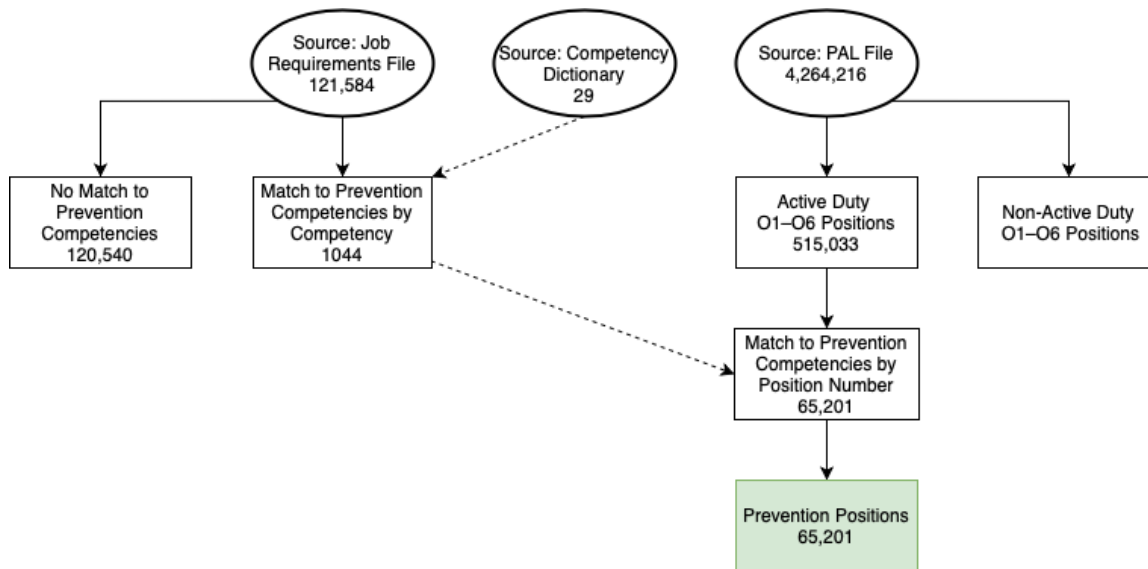


Figure 4.5. Position Data Preparation Flowchart

4.2.1 Data Quality and Challenges

Numerous data quality issues were identified in the nine datasets while completing data preparation and exploratory data analysis. Issues included missing data and erroneous data entries. For instance, in the achievements dataset some entries in the “year acquired” column were outside the range of possible years, including years in the future (e.g., 3008). Additionally, some positions in the PAL did not include a unit identification. It was noted that these errors were corrected on future snapshots. Overall, the columns used for this research had minimal issues and, as errors were corrected in subsequent snapshots, we removed and corrected data entry errors and blanks sparingly.

Differing snapshot dates across the nine data files created difficulties linking elements in these files. Further, datasets with monthly snapshots have snapshots taken on different days of the month—the January 2017 snapshot in the employee_2017 file was taken on 9 January 2017, while the PAL file has a snapshot date of 1 January 2017. A particular challenge was dealing with the achievements and job requirements datasets. The achievements data were captured in November 2022 while employee data was captured monthly from 2017–2022. Personnel achievements captured at any time other than November 2022 were unknown. As the personnel achievements data includes the date an achievement was entered, we were able to understand the achievements of personnel serving on November 2022. The data

missing were achievement data for any personnel who departed the Service prior to the November 2022 snapshot date. Similarly, job requirements data were captured in June 2022 and otherwise unknown for other snapshots. The impact of disparate data capture dates is unknown but the small change in overall personnel and position numbers leads us to conclude it had little impact on the overall research. Ideally, we would have used data with matching snapshot dates and snapshot frequency.

4.3 Preliminary Analysis

Exploratory data analysis was completed to better understand the data and provided insights prior to building the model and populating it with USCG data. We completed summary statistics and graphical representations of the data. Select analyses in this section directly informed model inputs further discussed in Chapter 6. The full set of summary statistics for variables used in the data analysis and simulation model are included in Appendix A.

4.3.1 Demand and Supply

Figure 4.6 displays the number of Prevention positions with the number of Prevention personnel over time [21], [48]. Personnel supply fluctuates as officers enter the workforce, move in and out of Prevention positions, and separate or retire. The number of positions is fairly constant with a mean of 898, median of 896, standard deviation of 16.8, and range of 867–931. The green area of the figure shows more personnel are available than total positions and red represents fewer personnel than positions. While it may appear there has generally been oversupply of personnel, this figure depicts counts of the entire Prevention workforce—individual units may have gaps in number of personnel and competencies. The supply level shown does not include Prevention officers assigned to non-Prevention positions (e.g., out of specialty, advanced education). These officers may be assigned to a Prevention position in the future. Differences in number of positions here and Figure 2.1 are minor and due to differences in counting utilized support positions [51].

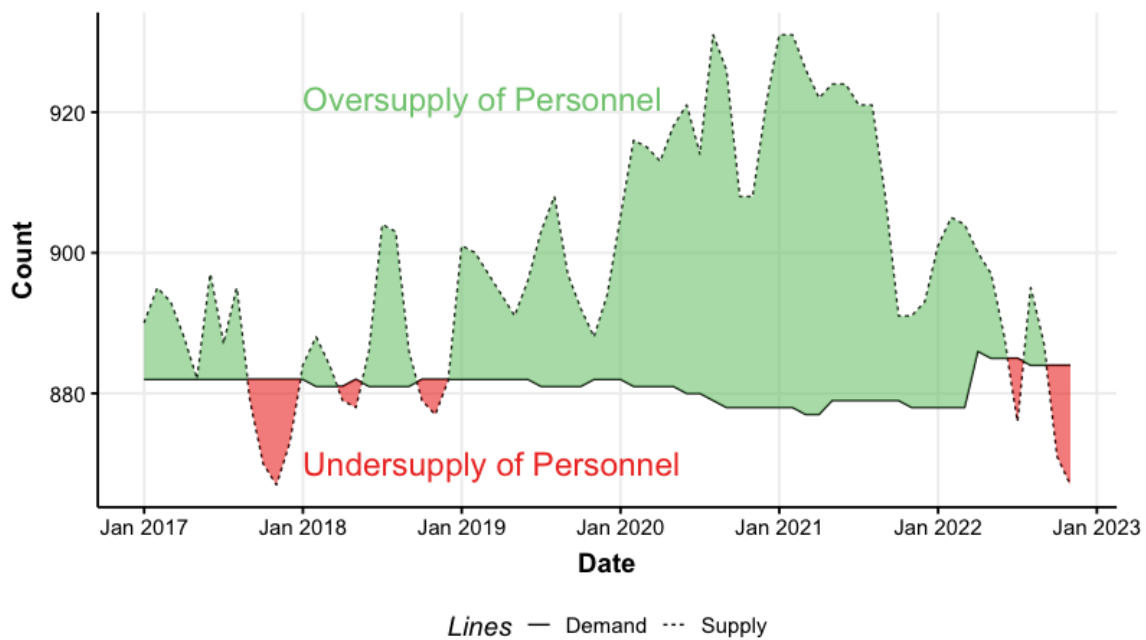


Figure 4.6. Prevention Workforce Supply and Demand Gap Over Time.
Adapted from [21], [48].

4.3.2 Supply of Personnel

Between 2017–2022, an average of 448 officers were commissioned into the USCG each year according to our calculations from USCG accession plans [27]. Figure 4.7 displays the number of new officers over time, categorized by accession source, for the entire officer corps [48]. Note this is not the number of personnel entering the Prevention workforce. As discussed in Section 2.2.1, there are minimal points of entry into the workforce system. The USCGA source accesses the largest number of officers and maintains fairly steady supply over time. We see greater fluctuation in numbers from other accession sources. This observation is in alignment with the USCG’s goal to maintain steady flow of personnel through the USCGA as stated in the Officer Accession Plan [27].

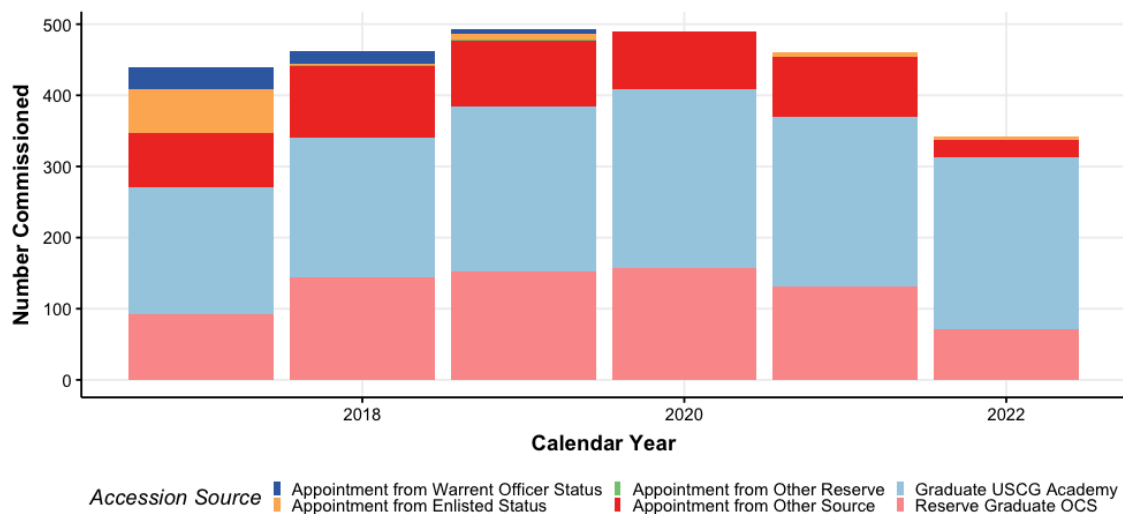


Figure 4.7. Accessions by Source Over Time. Adapted from [48].

4.3.3 Time at Posting

The majority of officers spend three years assigned to a Prevention position before transferring to another position. As we see in Figure 4.8, from January 2017 to November 2022 data, the number of months officers serve at Prevention positions [21], [48]. Each instance represents the assignment of an individual officer to a Prevention position. It does not represent the total length of time an officer served at Prevention positions over a career. There are greater numbers of officers that have served at Prevention positions for 12, 24, 36, and 48 month periods. Around 36 months is the most frequent length in a position. This corresponds with Coast Guard assignment policy that assigns an officer to a position for a specific number of years, and with policy which aligns most transfers between positions for the entire workforce to a summer transfer window [52].

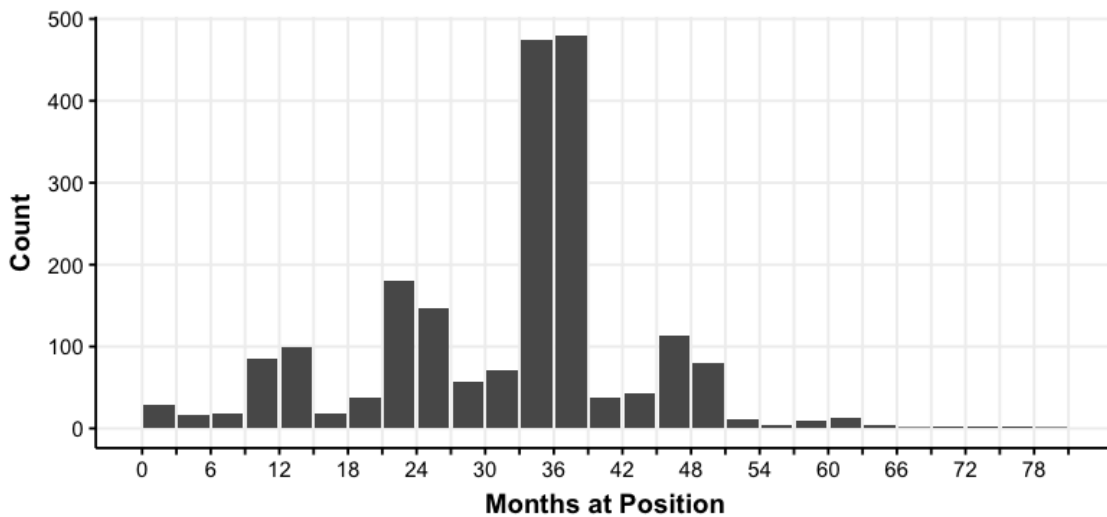


Figure 4.8. Months Served at Prevention Positions. Adapted from [21], [48].

4.3.4 Time in Grade

Promotion policies determine the minimum and maximum length of time a person spends at a particular grade before promotion to next higher grade. Figure 4.9 displays the length of time officers spend at each grade before promotion to the next [21], [48]. For CAPTs, we calculated the number of months spent at CAPT before separation or promotion, to account for the fact the vast majority of officers retire at this grade. We see the impact of promotion policies for ENS and LTJG in the top row of Figure 4.9. Nearly all promotions from ENS to LTJG take place after 17–18 months at ENS. For promotions from LTJG to LT, most take place after 29–30 months spent at LTJG. The time spend at a grade before promotion is more variable for higher grades. The standard deviation for time at LT is 10.21, dropping to 7.67 and 5.55 months for LCDR and CDR respectively.

The impact of continuation boards and other retention policies likely accounts for some of the variability. Continuation boards allow the Service to retain officers in a particular grade and specialty who would otherwise be separated for failure to be selected for promotion [25]. Officers selected for continuation spend a greater length of time at a particular grade.

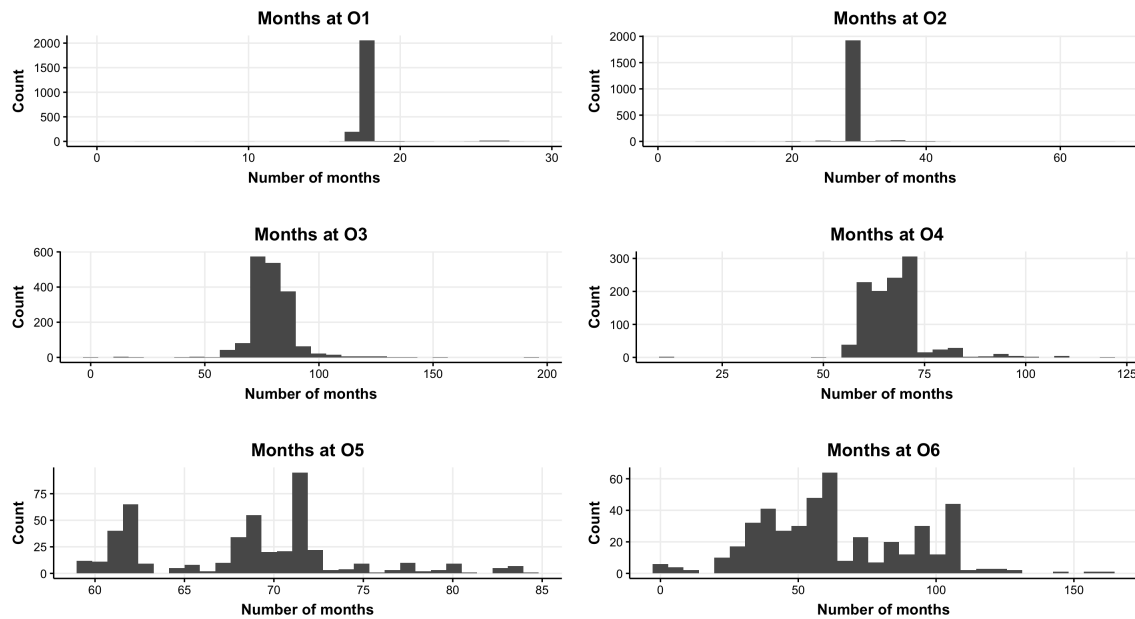


Figure 4.9. Months Served at Each Grade for Prevention Officers. Adapted from [21], [48].

4.3.5 Number and Timing of Promotions to RDML

Our model was targeted at officers from ENS to CAPT. Since flag officers (RDML and above) were not included in the simulation, those officers leaving the system by promotion to RDML must be accounted for. As shown in Figure 4.10 [21], [47], [48], between January 2017 and November 2022, 38 CAPTs were promoted to RDML of which seven were Prevention officers. An average of 6.33 CAPTs are promoted to RDML each year. All but two of these promotions took place in the month of July. This information was used to inform the Personnel Outflow worksheet in Section 6.2.10.

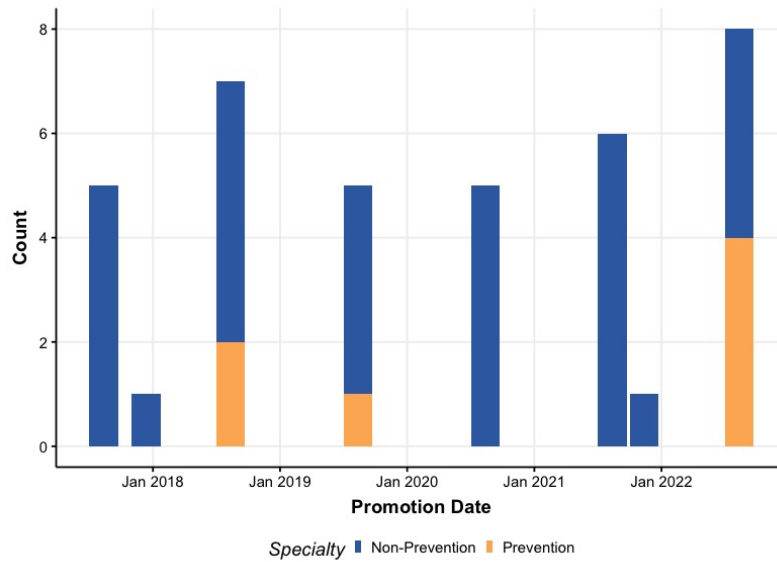


Figure 4.10. Promotions to RDML Over Time. Adapted from [21], [47], [48].

CHAPTER 5: Simulation Tool

In this chapter, we present the Athena Lite tool, provide an overview of the simulation logic, and explain necessary inputs to complete a simulation. We also discuss simulation setup, inputs, and results of five illustrative scenarios. These simple, fictional workforce scenarios allowed us to understand the impact of workforce policies and simulation configurations, and provide a foundation as we look to simulating the USCG workforce in the next phase of our research.

5.1 Athena Lite Overview

The Athena Lite User Manual [53] provides extensive explanation of how Athena Lite, a discrete event simulation workforce decision tool, operates. We use the user manual and other references to summarize applicable aspects of the tool in this section. The user manual begins with how workforce simulations are structured. Workforce simulations are grouped by studies, with a study, as seen in Figure 5.1, containing study meta-data, a workforce profile, simulation configuration, and simulation results.

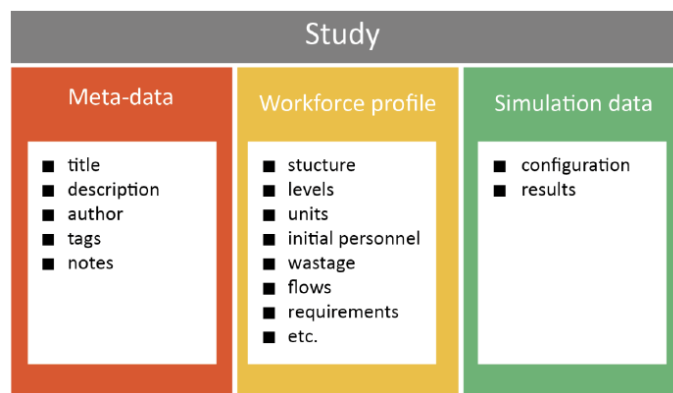


Figure 5.1. Anatomy of an Athena Lite Study. Source: [53, figure 11].

According to the Athena Lite User Manual [53], the tool allows users to define or import meta-data, workforce profiles, and simulation configurations. The workforce profiles are integral to the functionality of the tool and are composed of two main constituents: structure

elements and data elements. Structure elements shape the overall representation of the simulated workforce, whereas data elements, which make up the majority of simulation inputs, allow users to specify workforce-related information [53]. The manual specifies twelve types of data elements used to define workforce information, including but not limited to initial personnel, personnel inflow and outflow, position demand, and promotion rates. Additionally, the simulation configuration forms the last user-defined input, determining general settings for the simulation, such as the number of replications, the simulation window, and the optimizer [53].

5.1.1 Structure Elements

The Athena Lite User Manual outlines that each study within the software includes a workforce profile, which consists of user-defined structure and data elements [53]. There are three structure elements: workgroup structure, level structure, and unit structure, each of which helps to shape the overall configuration of the workforce.

The workgroup structure is a significant component as it enables the user to establish distinct groups or communities within the workforce profile. This is beneficial as it allows users to specify workgroup-related inputs in other elements [53]. For instance, users can allocate personnel and job positions to various workgroups, which can then provide workgroup-specific results. However, it is important to note that personnel cannot transition between different workgroups [11].

The user manual provides an explanation of the term “level,” which Athena Lite uses when referring to the hierarchy personnel progress through in the workforce system. The level structure element defines this hierarchy in the workforce profile [53]. Most often set to grades, other workforce hierarchies can also be used for the level structure according to the manual. We use level when referring to officer grades within our simulation and scenarios. The final structure element is unit structure, which defines all the units personnel can be allocated to in the system. Units can be combined into groups for results analysis [53].

5.1.2 Data Elements

Besides structure elements, a workforce profile in an Athena Lite study encompasses 12 user-defined data elements. In this discussion, we will exclude the elements related to personnel

transitions, health factors, experience, and optimiser parameters, as they fall outside the scope of this study.

Throughout this analysis, we frequently use the term “postings” from Athena Lite terminology. A posting in this context is a combination of a workgroup-level-unit, as defined by the entries in the structure elements [53]. For our purposes, we regard postings as equivalent to the concept of positions as utilized by the USCG.

Initial Personnel, Wastage, and Promotion Elements

Initial personnel constitute the first data element of a workforce profile. The Athena Lite User Manual [53] tells us this element is populated with personnel who are active at the onset of the simulation period, as defined by the user. For each person included in initial personnel, the user also specifies the person’s attributes, such as workgroup, level, unit, length of service (LOS), time in level, and time in posting [53].

The subsequent element after initial personnel is the wastage properties element. This element is intended for specifying the conditions under which personnel exit the system [53]. Personnel are chosen for wastage at random, taking into account their individual attributes and the user-defined wastage percentages [53]. “the percentage probability that a person will leave the workforce given that they have the attributes defined (workgroup, level, length of service) at the [simulation] time defined (between start time and end time)” [54]. The length of service (LOS) for wastage can be expressed as a specific month or as an interval [53]. Figure 5.2 demonstrates wastage inputs with LOS defined in terms of intervals. In this depiction, personnel with more extended service lengths are more likely to leave the system, as indicated by the higher wastage percentages in comparison to those with shorter service lengths.

The user manual further elaborates that wastage percentages can be assigned for distinct intervals within the simulation period. For example, the wastage rate could be specified at one rate for the first five years of the simulation period, and then adjusted to a different rate for the rest of the period. Despite wastage being applied daily within the simulation, it is defined by the user as a monthly or annual rate [53].

Wastage Properties ⓘ

# ⓘ	Workgroup ⓘ	Start Time ⓘ	End Time ⓘ	Length of Service	Annual/Monthly	Wastage Percentage
1	Prevention	0	240	0-60	Annual	1
2	Prevention	0	240	61-120	Annual	5
3	Prevention	0	240	121-180	Annual	10
4	Prevention	0	240	181-228	Annual	20
5	Prevention	0	240	229-240	Annual	100

Figure 5.2. Athena Lite User Interface – Wastage Properties

Promotions in Athena Lite refer to the process of assigning personnel to the next higher level, as established in the level structure element [53]. The user manual explains that promotions are characterized by two elements: promotion properties and promotion probabilities.

Within the promotion properties element, users dictate the conditions and timing of promotions. Pike writes that there are three possible promotion schemes: “pull”, “push”, and “constrained push” [55]. The pull promotion scheme, which is the tool’s default setting, sets the desired number to promote equal to the gap between positions and personnel at the next level [53]. The push scheme, on the other hand, allows users to designate a specific number or percentage of personnel eligible for promotion to be advanced [53]. Eligible personnel for promotion are those who have fulfilled the minimum time in their current level [55]. Notably, when using the push scheme, the number of promotions does not get influenced by the gap between supply (personnel) and demand (positions) [55]. Lastly, the constrained push scheme computes the results of both the push and pull promotion schemes and employs the lower value of the two [53].

In addition to defining the promotion scheme, the user establishes the workgroup, level, and time in level for each promotion to each respective level. The time in level column permits the user to set a promotion rate for a certain portion of eligible personnel, depending on their time spent in a particular level [53]. Similar to the wastage element, promotions can be stipulated for specific sections of the simulation window [53].

The second promotion element is called promotion probabilities. This element allows the user to define promotion based on time in level using a promotion probability curve [53]. We do not use this element in our work.

Time in Level and Time in Posting Elements

The time in level data element defines the minimum and maximum time a person can spend at a particular level [53]. The minimum time in level column sets the length of time a person must serve at the designated level before being eligible for promotion [53]. The maximum time in level sets the maximum time a person can be at a level before being auto-promoted to the next level [53].

The time in posting element concerns the assignment of personnel to postings. The user manual explains this element defines the minimum and maximum time a person can be allocated to a posting. A person will not be allocated to a new posting prior to meeting the minimum time in posting requirement [53]. The manual continues to state all personnel that pass the maximum time in posting requirement are re-allocated. All postings (i.e., workgroup-level-unit combinations) should be represented in this element [53].

Personnel Requirement Element

On the demand side of the simulation, the user defines number of personnel needed in the personnel requirement element. The number of personnel and when they are required is defined for each workgroup-level-unit combination [53]. The user also has the option to define priority for each requirement [4]. For example, unit A can be defined to require ten level-1 personnel at priority 1 while unit B requires five level-1 personnel at priority 2. The simulation will prioritize allocating personnel to unit A over unit B. The requirements can be specified for portions of the simulation window, allowing the user to account for posting additions and removals [53]. An example of personnel requirements defined in Athena Lite is provided in Figure 5.3.

# ⓘ	Workgroup ⓘ	Level ⓘ	Unit ⓘ	Time ⓘ	Priority 1 Req.
1	Prevention	O1	1_1	0-240	20
2	Prevention	O1	1_2	0-240	20
3	Prevention	O1	1_3	0-240	20
4	Prevention	O1	1_4	0-240	20
5	Prevention	O1	1_5	0-240	20
11	Prevention	O2	1_1	0-240	10
12	Prevention	O2	1_2	0-240	10
13	Prevention	O2	1_3	0-240	10

Figure 5.3. Athena Lite User Interface – Personnel Requirement

Personnel Inflow and Outflow Elements

The final two data elements we cover are personnel inflow and personnel outflow. These elements schedule when and how many personnel enter and leave the system [53]. Personnel inflow provides the user the ability to define the workgroup, level, and initial LOS of personnel entering the system [53]. In Figure 5.4, we see an example of personnel inflows defined in Athena Lite. At each row of the figure, 15 personnel at level O1 enter the system at the times specified in the Time column. Personnel outflow is similar to personnel inflow and schedules when and how many personnel leave the system at a specified workgroup-level [53]. Personnel leaving the system due to outflow are in addition to those which depart due to wastage.

# ⓘ	Workgroup ⓘ	Level ⓘ	Initial Length o	Time ⓘ	Number of Personnel ⓘ
1	Prevention	O1	0	0	15
2	Prevention	O1	0	12	15
3	Prevention	O1	0	24	15
4	Prevention	O1	0	36	15
5	Prevention	O1	0	48	15
6	Prevention	O1	0	60	15
7	Prevention	O1	0	72	15
8	Prevention	O1	0	84	15

Figure 5.4. Athena Lite User Interface – Personnel Inflow

5.1.3 Simulation Configuration

After defining the structure and data elements, users can then specify the settings that will determine the operation of the simulation. These settings encompass the simulation period, results time step, number of replications, and the optimizer, as illustrated in Figure 5.5 [4].

The screenshot shows the 'Simulation Configuration' panel in the Athena Lite User Interface. It is divided into three main sections: 'Run Configuration', 'Simulation Filtering', and 'Optimisation'.
1. 'Run Configuration' section contains four fields: 'Simulation Start Time' (31/12/2019), 'Simulation End Time' (30/12/2039), 'Simulation Time Step' (Monthly), and 'Number of Monte Carlo Trials (1-100)' (5).
2. 'Simulation Filtering' section has a 'Workgroups' dropdown menu currently set to 'Select...'.
3. 'Optimisation' section includes a dropdown menu set to 'None'.
4. 'Health Factors' section has a toggle switch that is currently turned off (indicated by a grey circle and an 'x').
5. 'Output Time Averaging' section has a toggle switch that is currently turned on (indicated by a green circle and a checkmark).

Figure 5.5. Athena Lite User Interface – Simulation Configuration

The user determines the start and end dates of the simulation window. Through the time step drop-down menu, a user defines the time step at which results are produced, for instance, monthly, weekly, or daily. If a weekly time step is selected, the results are recorded on the first day of each week, even though the simulation processes each day individually.

The number of Monte Carlo trials field allows the user to set how many times the simulation should run (i.e., number of replications). Each run represents different sampling from the workforce profile and includes randomness [53]. This allows the simulation to report out result averages and bounds.

We do not use the optimizer or health factors in this work, however, they can be defined here. Health factors is a feature to control the allocation of personnel when priority is defined within personnel requirements [53]. The final setting, output time averaging, lets the user decide how results are calculated. With output time averaging selected, daily results of a simulation are averaged over the simulation time step previously defined in simulation configuration [53]. If averaging is not selected, the results will only include the first day of the simulation time step. For example, with a weekly simulation time step, output time averaging will report out the average of seven days of results. In contrast, without output time averaging, the results will contain only the first day of the week.

5.1.4 Simulation Logic

While Athena Lite is a DES, it uses discrete daily time steps and agents to schedule events. The simulation states are the list of personnel, attributes of each person, and posting each person is assigned to [55]. At each time step, the simulation advances through different events to update attributes, allocate personnel, create new personnel, and remove personnel from the system. Figure 5.6 shows the nine events that take place at each time step. Figure 5.7 provides a more detailed look at the allocation event.

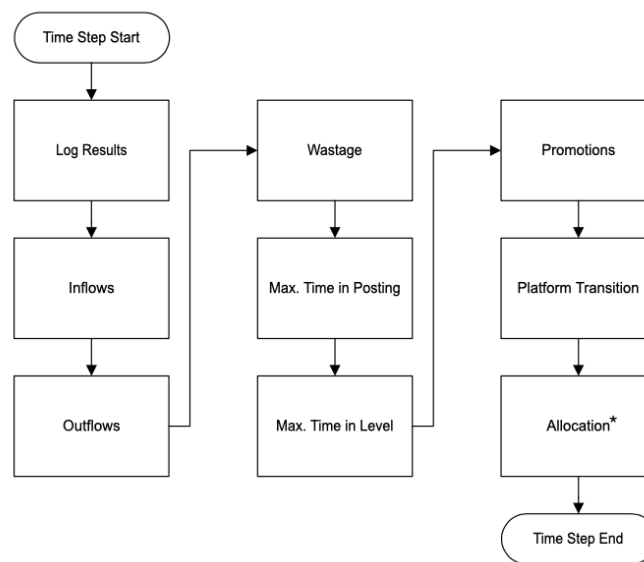


Figure 5.6. Athena Lite Simulation Logic – Events Diagram. Adapted from [55].

The first event of each daily time step is to log results. This event records the current simulation states. Pike [55] explains that while the simulation uses a daily time step, the user specifies the interval at which to record results.

The next three events deal with personnel entering and exiting the system. Personnel enter at inflow and exit the system at outflow events, resulting in updates to the list of personnel, personnel attributes, and assigned postings [55]. Inflow and outflow events are set by input data prior to simulation run.

Next, the wastage event takes place. Wastage events remove personnel from the simulation [53]. Each person is assigned a daily wastage percentage value from the wastage properties

data element based on their workgroup, level, and LOS [54]. Personnel with a daily wastage value greater than a random number sampled from the continuous uniform (0,1) distribution are removed from the system on that day [54].

The next two events, maximum time in posting and maximum time in level, update the attributes of personnel and assigned postings. At the maximum time in posting event, if a person has served the maximum time in the assigned posting, they are assigned to a buffer unit for future allocation [55]. The maximum time in level event promotes personnel (i.e., updates the person's level attribute) who have reached the maximum time in level set by input data [53].

Promotion Event

Promotions are the seventh event to take place at each time step. Promotion events are scheduled by the user prior to running the simulation using the time step column of the promotion properties element [53]. This means promotions only take place on specified days and not every day (i.e., time step) of the simulation [55]. Multiple steps are executed within each scheduled promotion event. The first step is to determine the desired number to promote and this value is based on the user specified promotion scheme [55], [56].

Pike [55], [56] tells us the next step, after desired number of promotions is determined, is to sort promotion eligible personnel based on time in level. Persons with the greatest time in level are the first for potential promotion. Pike continues that for each person in the sorted list, a random number is generated and compared to the promotion probability defined by the user. If the random number is less than the promotion probability, the person is promoted, and if the random number is greater than, the person remains at the current level until the next promotion event [55], [56]. This process continues through the list until the desired number of promotions has been reached or the list is exhausted [55], [56].

After promotions, platform transitions take place. Platform transitions are not applicable to the Prevention workforce and not used in this study.

Allocation Event

The final event is allocation. Allocation assigns eligible personnel to open postings [55]. Each posting is a combination of workgroup, level, unit, and priority. A posting becomes

open when a person leaves the system (due to outflow or wastage), reaches the maximum allowable time in the posting, or departs the posting after promotion [55]. The steps of the allocation event are displayed in Figure 5.7 [55].

The first and second steps are to list and prioritize all eligible postings. This is shown in blocks A and B, respectively, of Figure 5.7. Eligible postings are those that have fewer personnel than required. The number of required personnel is user-defined in the personnel requirement element. The prioritization of eligible postings starts with sorting by level, then user-defined priority, and finally by fill percentage. Fill percentage is an entry in the health factors element.

Upon leaving block B, the allocation event reaches a decision point. The decision point checks to see if unfilled postings and available personnel remain. If so, then Athena Lite moves to block E. Block E consists of the steps for posting allocation and contains blocks C and D. Within block C, the eligible personnel are identified. Eligible personnel are those personnel who have met the minimum time in posting requirement.

Eligible personnel are prioritized in block D. The preference is for personnel who do not require a promotion and those serving longest in current posting. Next, persons are allocated to postings until all postings are filled or available personnel exhausted. Athena Lite then steps out of block E, returns to the decision point, and follows the false arrow. The final step results in allocation of remaining personnel to oversupply. Personnel in oversupply are randomly assigned to postings. This completes the allocation event and completes all events in the daily time step.

Maximum time in level and platform transitions are mentioned in Figures 5.6–5.7. These parameters were left blank and not used in our simulations as they are not applicable to USCG workforce dynamics.

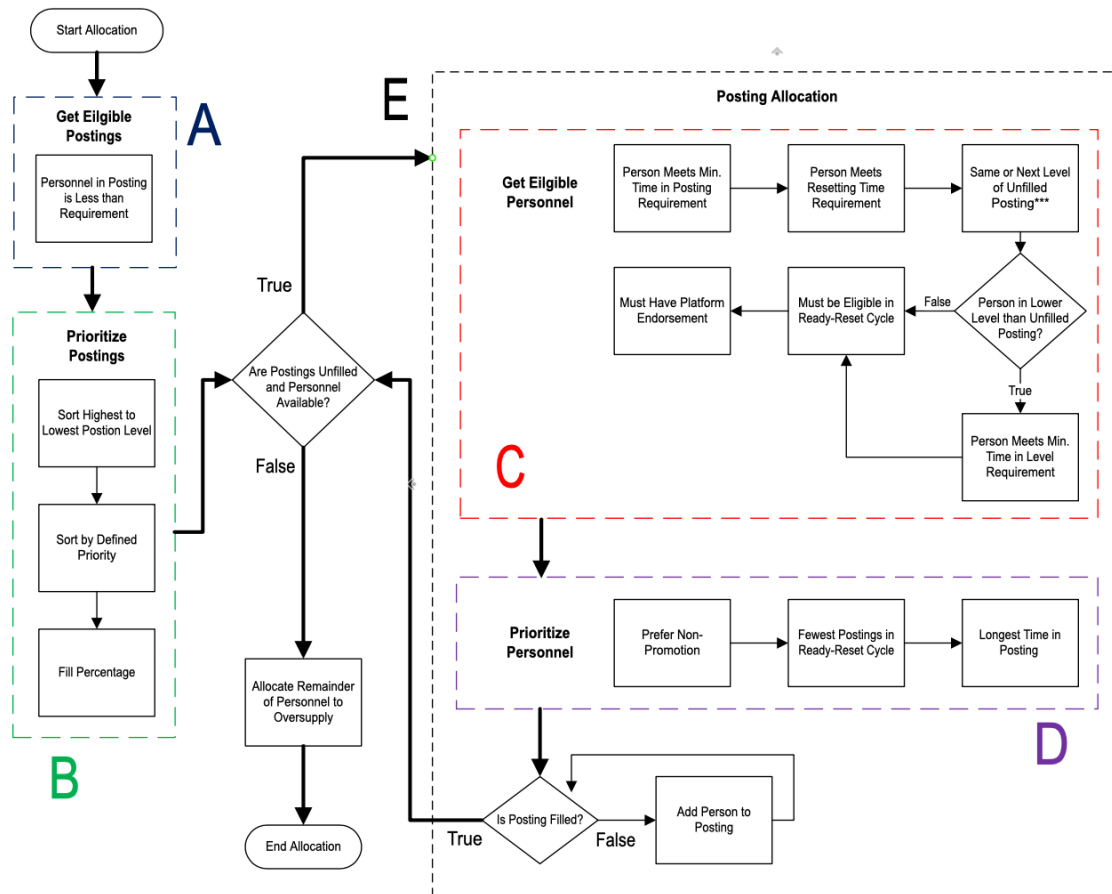


Figure 5.7. Athena Lite Simulation Logic – Allocation Event Diagram.
Adapted from [55].

5.2 Exploratory Scenarios

Our initial exploration of Athena Lite’s capabilities involved conducting simulated scenarios to gain a better understanding of its features and potential applications. We began by utilizing Athena Lite to explore small-scale scenarios, allowing us to delve into the intricacies of the tool, understand its user interface, evaluate the impact of varied inputs, and examine the simulation outputs. To initiate this exploration, we created scenarios centered around a fictional military workforce system consisting of 200 positions evenly distributed across five units. At the start of the simulation period, the system had no personnel. Every 12 months, a group of 15 O1s joined the system, with no other personnel entering. Departures from the system were determined by wastage rates, which were based on the officer’s LOS.

During their tenure in the system, personnel were eligible for promotion after fulfilling the minimum time requirements for each level. On the demand side, each unit required a specified number of positions at each level that needed to be filled by personnel.

We built off a baseline scenario, completing five scenarios in total, to see the impact of different wastage rates, including initial personnel, and the three promotion scheme options. Though Athena Lite has the ability to change inputs for different intervals of the simulation period, we kept all inputs constant for the duration of each scenario. A summary of the inputs for these simulation scenarios are provided in Tables 5.1, 5.2. Table 5.2 covers wastage, initial personnel, and promotion element inputs of the five scenarios.

Table 5.1. Inputs for All Scenarios

Data Element	Input
Workgroup Structure	“Prevention.”
Level Structure	Officer Grades O1–O6.
Unit Structure	Five units named Unit 1_1, Unit 1_2 ...
Initial Personnel	Scenario-specific. See Table 5.2 for details.
Wastage	Wastage rates applied based on length of service. Rates are annual. Scenario-specific. See Table 5.2 for details.
Promotions	Scenario-specific. See Table 5.2 for details.
Time in Level	Minimum time in level set at two years. Maximum time in level not used.
Time in Posting	12-36 months for all postings.
Personnel Inflow	15 officers enter at O1 level per year.
Personnel Outflow	None.
Personnel Requirements	Demand for a total of 200 personnel throughout the simulation. There are five units, each with 20 O1s, 10 O2s, 6 O3s, 2 O4s, 1 O5, and 1 O6 postings to be filled.
Simulation Configuration	20 year simulation period with five replications.

Note: Inputs for wastage, promotions, and personnel requirement are constant over the entire simulation period.

Table 5.2. Scenario-Specific Inputs

Input	Scenarios				
	Baseline	Increased Wastage	Increased Wastage & Initial Personnel	Push Promotions	Constrained Push Promotions
Wastage (LOS months: Annual %)					
0–240: 5%	✓				
0-60: 1%					
61-120: 5%					
121-180: 10%		✓	✓	✓	✓
181-228: 20%					
229-240: 100%					
Initial Personnel					
None	✓	✓			
200 personnel with 100% match to demand.			✓	✓	✓
Promotions					
Promotion Scheme	Pull	Pull	Pull	Push	Constrained Push
Promotion Percentage (Level: Time Step @ Promotion %)					
O1: 6 months @ 99%					
O2: 6 months @ 85%				✓	✓
O3: 1 year @ 80%					
O4: 1 month @ 7%					
O5: 1 month @ 5%					

Figures 5.3 -5.4 of Section 5.1.2 are excerpts from Athena Lite of personnel requirements and personnel inflow inputs. Figure 5.4 displays the first 84 months of scheduled personnel inflow events. The time column lists the months from simulation start (start = 0 months) that 15 personnel at level O1 enter. In Figure 5.3 [4], we see the number of positions required for the first few workgroup-level-unit combinations. The time column dictates (in months) when the specified postings are required in the simulation interval. For example in row one, we see Unit 1_1 requires 20 personnel at Prevention-O1 from 0–240 months of the simulation. If these 20 personnel were only required for the first half of the 20 year

simulation period, we would change the time column to 0–120 months.

5.2.1 Baseline Scenario

Results from the baseline scenario, seen in Figure 5.8, showed the number of personnel increased as time progressed. We see regular inflows of O1s (represented by blue) with slow growth, over time, in the number at higher grades. The oldest O1s promote to O2 and higher levels as they pass the two-year minimum time in level requirement and vacancies at the next level exist. The 5% wastage rate causes the slight decrease in number of personnel over the course of a year, clearly seen in the jagged line for O1 level in later years. Due to personnel not exiting the system, the number of personnel steadily increases in size and LOS increases over time. We changed wastage rates in the next scenario to increase outflow and take into account retiring and separating officers.

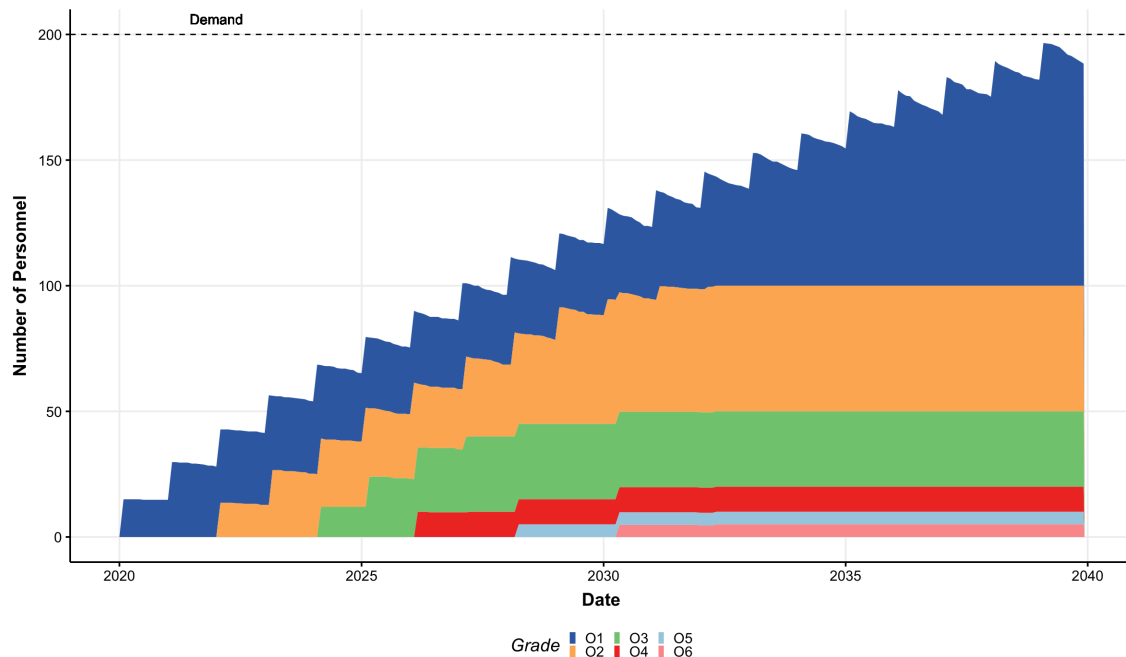


Figure 5.8. Exploratory Baseline Scenario Result – Supply by Level Stacked

5.2.2 Increased Wastage Scenario

In our second scenario, we adjusted wastage rates, as seen in Figure 5.2 of Section 5.1.2, and kept all other simulation inputs the same. Wastage rates were set based on an officer's LOS and rates applied annually. All officers with a LOS > 228 months are separated from the system by setting wastage to 100% (see Figure 5.2, row five). Scenario results, shown in Figure 5.9, reveal demand being satisfied for each level towards the end of the simulation window. We also saw LOS for each level stabilized. Increasing LOS indicates a lack of outflow from the level due to minimal promotions or wastage of personnel.

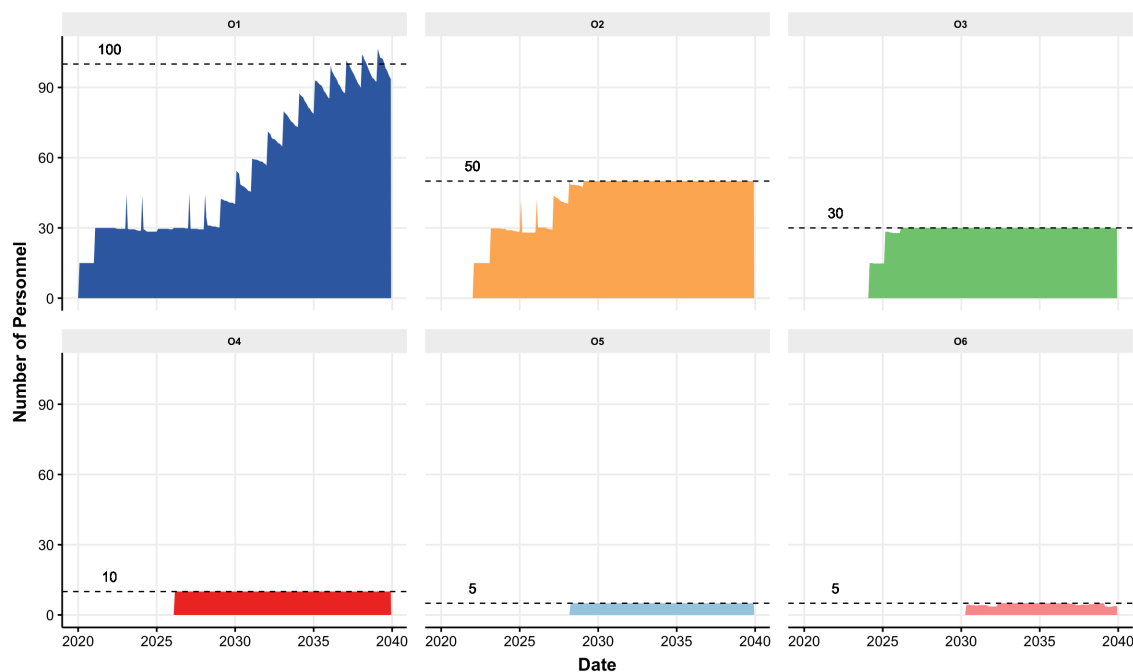


Figure 5.9. Increased Wastage Scenario Result – Supply by Level Line Graphs with Demand Lines.

5.2.3 Initial Personnel and Pull Promotions Scenario

In our third exploratory scenario, we built on the previous two and added initial personnel. We again used the pull promotions scheme. These 200 personnel fill the 200 positions at the start of the simulation. The initial personnel are of the appropriate level and posting to 100% match demand. Each initial officer's LOS, time in level, and time in posting values were randomly generated with appropriate entries given minimum time in level and time

in posting inputs. Figure 5.10 provides a screenshot of the initial personnel element from Athena Lite.

Initial Personnel ⓘ

# ⓘ	Workgroup ⓘ	Level ⓘ	Unit ⓘ	Platform Endorsement ⓘ	Length of Service ⓘ	Time in Level ⓘ	Time in Posting ⓘ
1	Prevention	O1	1_1	None	11	11	11
2	Prevention	O1	1_1	None	10	10	10
3	Prevention	O1	1_1	None	9	9	9
4	Prevention	O1	1_1	None	17	17	17
5	Prevention	O1	1_1	None	16	16	16
6	Prevention	O1	1_1	None	11	11	11
7	Prevention	O1	1_1	None	16	16	16
8	Prevention	O1	1_1	None	11	11	11
9	Prevention	O1	1_1	None	13	13	13
10	Prevention	O1	1_1	None	21	21	21

Figure 5.10. Athena Lite User Interface – Initial Personnel

Figure 5.11 displays simulation results of supply and demand for O1, O5, and O6 levels. The results show excess O1s throughout the simulation window, with a peak of 167 O1s in early 2029 before falling towards the requirement level near 2040. A gap of O5 and O6 personnel opens in 2035 and grows until supply of O5 and O6 officers falls to zero. This gap is caused by wastage rules that force insufficient numbers of officers to separate from the system.

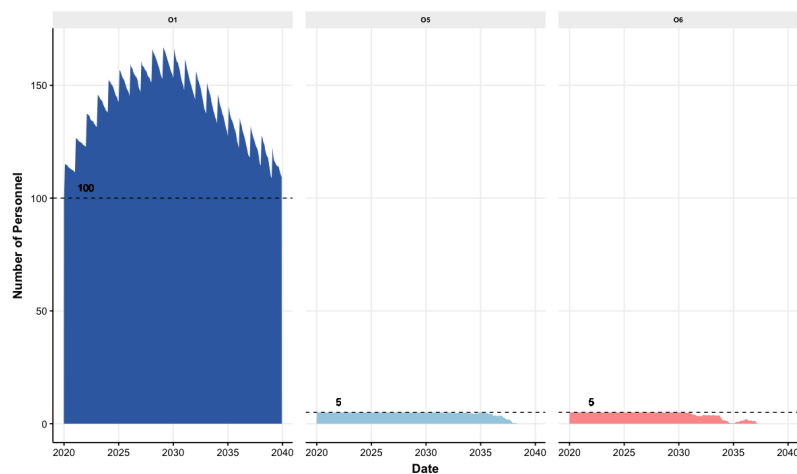


Figure 5.11. Initial Personnel Scenario Result – Supply by Level Line Graphs with Demand Lines.

In Figure 5.12, the average length of service for levels O4–O6 steadily increases. In Sept 2035, O6 average length of service drops off. The drop is due to those officers reaching a

length of service of 228 months and being separated. A similar drop occurs with O5 later in the simulation for the same reason. To create a more sustainable system, wastage rates may need to be increased to create near constant average length of service lines at each level.



Figure 5.12. Initial Personnel Scenario Result – Length of Service

5.2.4 Push Promotions Scenario

In this scenario, we investigated the push promotion scheme. The push promotion scheme determines the number of personnel to promote based on promotion percentages, and not based on supply and demand gaps. We used the promotion percentages as seen in Figure 5.13. In row one of the figure, we see promotions from the O1 level were defined to take place every 6 months. Push promotions scheme has been set in the promotion type column. Promotion percentage is specified in the final column at 99%. This means that 99% of eligible O1 personnel will be promoted to O2 every 6 months. O1 personnel must have completed at least two years at the O1 level (as defined in time in level element) before being eligible for promotion. We defined promotion percentages for each level using different time steps and rates.

Figure 5.14 provides us with supply results for each level. We see undersupply of personnel at the O1, O2, and O3 levels for most of the simulation period. The O4, O5, and O6 levels have consistent oversupply of personnel. In particular, supply at the O6 level is 18 times greater than demand at one point during the simulation. Ideally, supply and demand should roughly match as the simulation reaches steady state.

Promotion Properties

# ②	Workgroup ②	Level ②	Time Step ②	Promotion Type	Promotion Percentage
1	Prevention	O1	6 months	Push	99
2	Prevention	O2	6 months	Push	85
3	Prevention	O3	1 year	Push	80
4	Prevention	O4	1 month	Push	7
5	Prevention	O5	1 month	Push	5

Figure 5.13. Athena Lite User Interface – Promotion Properties

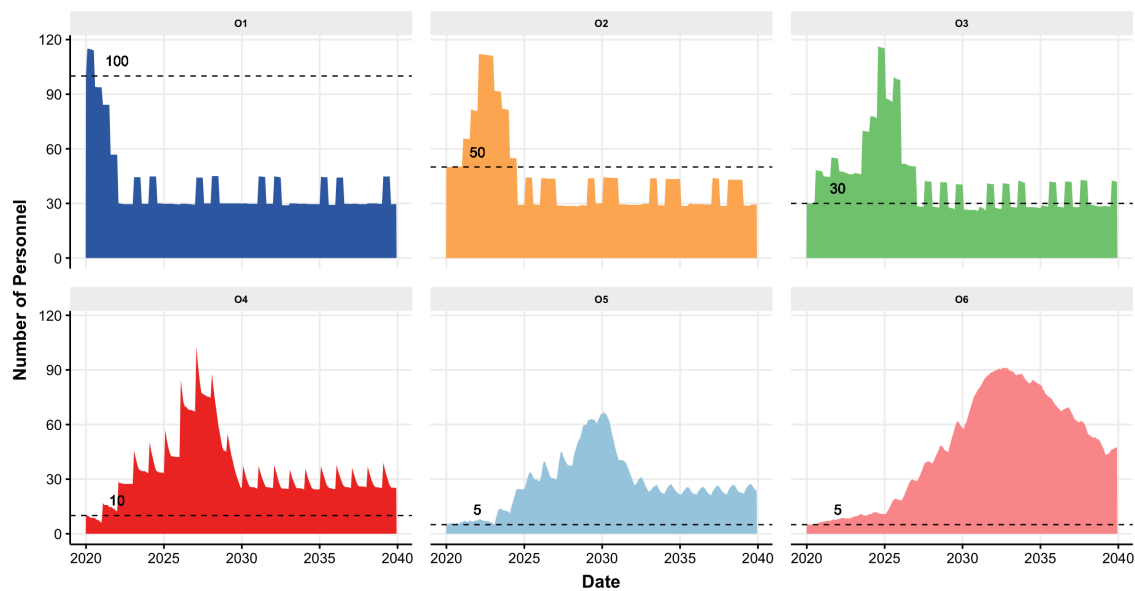


Figure 5.14. Push Promotions Scenario Result – Supply by Level Line Graphs with Demand Lines

Taking a look at the average length of service for each level in Figure 5.15, we see consistent values over time. Horizontal lines for length of service are desirable and indicate there is a balance between personnel entering and departing from the level.

There is roughly a 24-month gap between the O1, O2, and O3 lines due to the 24-month minimum time in level requirement. For example, this means that length of service for personnel at the O2 level must be greater than 24 months; personnel with less than 24 months of service cannot have promoted to O2 yet, due to the minimum time in level constraint.

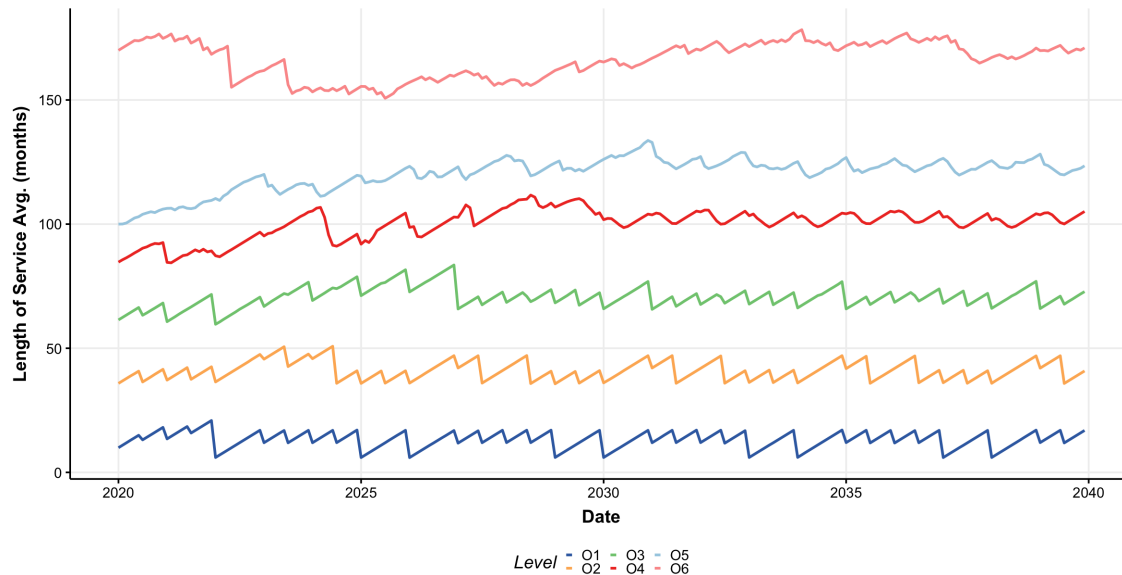


Figure 5.15. Push Promotions Scenario Result – Length of Service

5.2.5 Constrained Push Promotions Scenario

In our final scenario, we used the constrained push promotion scheme. This scheme calculates the desired number to promote from both push and pull promotion schemes and then implements the lower number of the two. For example, if push promotion scheme calculates five personnel for promotion and pull promotion scheme calculates ten personnel for promotion, then constrained push scheme will promote five personnel. Figure 5.16 displays the LOS for each rank over the simulation period. Figure 5.16 closely resembles Figure 5.12 and suggests that the number to promote under the pull promotion scheme is generally less than the push promotion scheme. As in the Initial Personnel and Pull Promotions Scenario, the LOS lines in Figure 5.16 are generally increasing until they plummet when personnel reach mandatory separation from the system.

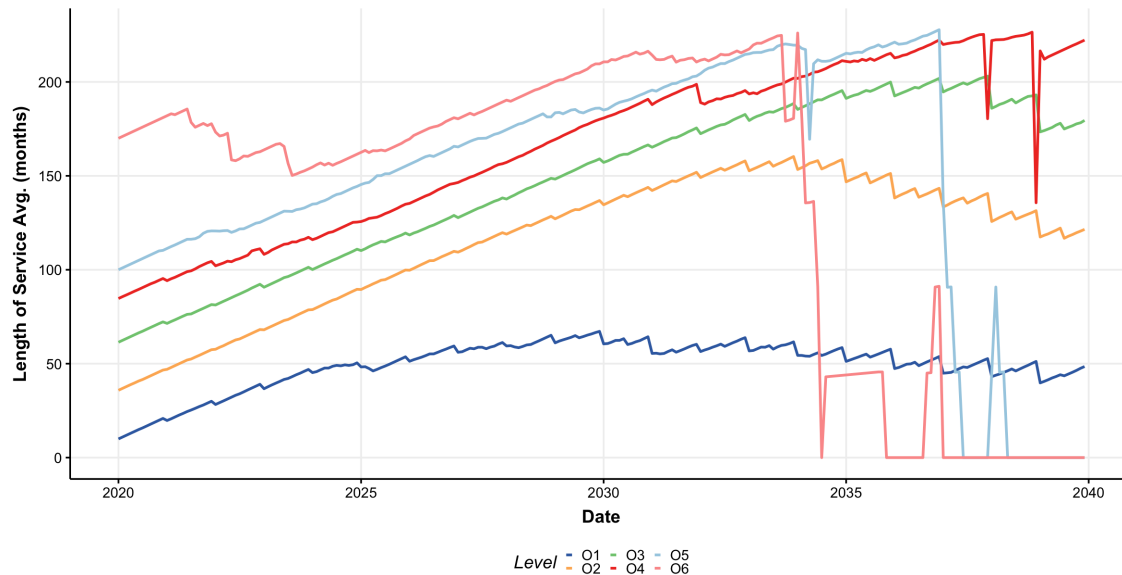


Figure 5.16. Constrained Push Promotions Scenario Result – Length of Service

5.2.6 Promotion Scheme Result Comparison

In this final section, we analyze the results of three scenarios with different promotion schemes to inform our future decisions about promotion schemes in the USCG simulation scenarios. Figures 5.17 and 5.18 display the results of the previous scenarios. Figure 5.17 illustrates the supply and demand at each level, with color used to represent the promotion schemes.

There is a minimal difference in supply between the pull and constrained push promotion schemes. Both scenarios result in surplus personnel at the O1 level and undersupply at the O5 and O6 levels. However, the push promotion scheme is distinctive, as it leads to undersupply at the O1 and O2 levels and oversupply at the higher levels. Ideally, we aim to minimize both over- and undersupply.

In the pull and constrained push promotion scenarios, the accumulation of O1 personnel is likely due to a low rate of promotions. Personnel enter the O1 level at a faster rate than they advance through promotion or leave the system. These schemes do not promote junior personnel as demand at higher levels has been met. Consequently, there is a backlog

of personnel at the O1 level caused by the scheme selecting a low desired number of promotions. During the second half of the simulation window, higher-level personnel are not leaving the system quickly enough to maintain a steady LOS, as seen in Figure 5.18 by the increasing lines and discussed in Sections 5.2.3 and 5.2.5. The lack of regular departures from high level causes most O5 and O6 personnel to depart the system simultaneously, creating a supply and demand gap that lasts several years until new personnel are promoted to fill those positions. To reduce the gap, personnel are pulled up to higher levels by the scheme applying greater desired number of promotions, and in turn, gradually drawing down the oversupply at the O1 level.

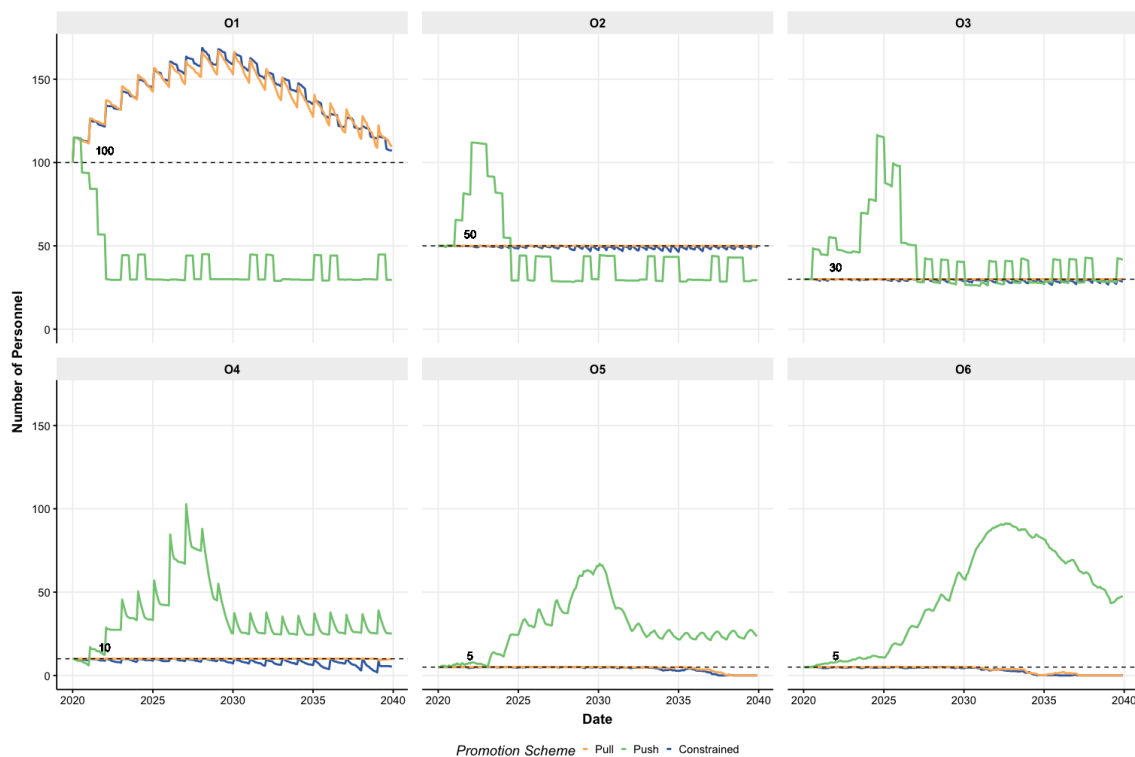


Figure 5.17. Promotion Schemes Comparison – Supply and Demand Over Time

In the push promotion scheme scenario, there is personnel oversupply at higher levels, particularly at O6. As long as there are eligible personnel, the push promotion scheme continues to move personnel up the level hierarchy and this results in excess O6 personnel. To address this issue, wastage rates could be increased or the minimum time in level

requirements could be increased. Raising the minimum time in level requirement would result in “older” O6 personnel that are wasted at greater rates.

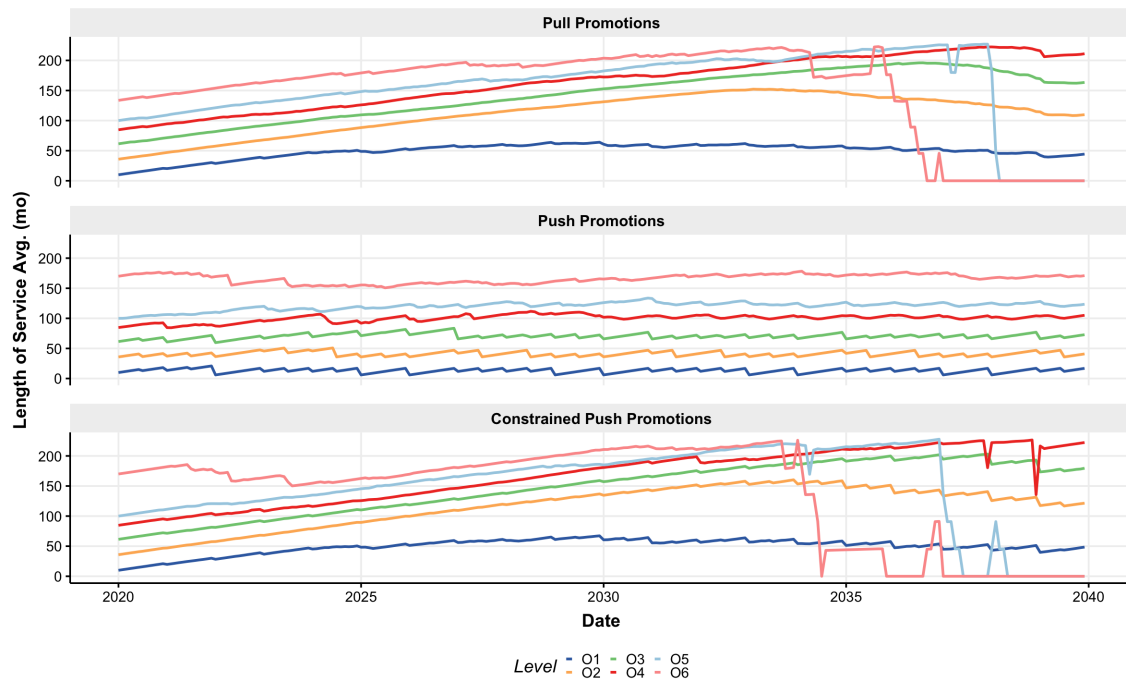


Figure 5.18. Promotion Schemes Comparison – Length of Service

The push scheme facilitates the promotion process and the flow of personnel supply independently of demand. This results in stable average length of service for personnel. The push scheme approach closely aligns with USCG policies which govern promotions from O1 and from O2. For these grades, promotions are dictated by a time-in-grade requirement, irrespective of the demand for the personnel.

These exploratory scenarios have served as a valuable opportunity for us to acquaint ourselves with the tool interface and gain a deeper understanding of the interplay between different simulation inputs and their resultant impacts. In the forthcoming chapter, we plan to employ these acquired skills to simulate the USCG Prevention workforce.

CHAPTER 6:

USCG Prevention Workforce Simulations and Results

In this chapter, we detail our process for developing scenarios to test the simulation capabilities of Athena Lite, while modeling the USCG Prevention workforce. We then proceed to investigate the results generated by Athena Lite simulations and conduct an in-depth analysis of these outcomes for meaningful insights.

We examine the diverse inputs we employed, and discuss the data analysis techniques that were utilized in our investigation. A critical assessment of the results derived from our simulations follows, allowing us to uncover patterns and trends that shed light on the intricate dynamics of the workforce. Moreover, our results also illuminate the strengths and weaknesses of Athena Lite as a simulation tool, offering valuable insights into its suitability and potential areas of improvement for addressing the USCG workforce modelling problem.

6.1 Scenario Development

This section discusses the scenario development process. We developed a series of scenarios based on the USCG Prevention workforce in order to test and refine the Athena Lite tool, as well as to navigate the complexities inherent in modeling. Given our background knowledge of the USCG workforce and the simulation logic, assumptions, and inputs of Athena Lite, these scenarios are the foundation of our simulation efforts. We encountered challenges, and while we managed to find potential solutions for some, others proved to be more resistant to resolution. We discuss these challenges and associated scenario development in this section.

6.1.1 USCG Workforce to Athena Lite

Modeling a complex system like the USCG workforce invariably has numerous challenges. Inevitably, some details and aspects of reality are lost as the real-world system is translated into a usable and efficient simulation model. In Figure 6.1, we provide an overview of the USCG workforce system and our simulation boundary. Each arrow in and out of the red simulation boundary box represents a different input we calculated from USCG data and defined in Athena Lite. For example, the arrow referring to officers leaving the system is

captured by wastage in the simulation tool. Based on data availability, simulation design, and research constraints, we made assumptions and tested different simulation inputs, in order to identify the best option to model the Prevention workforce. We refer to Figure 6.1 throughout the Chapter to highlight system dynamics.

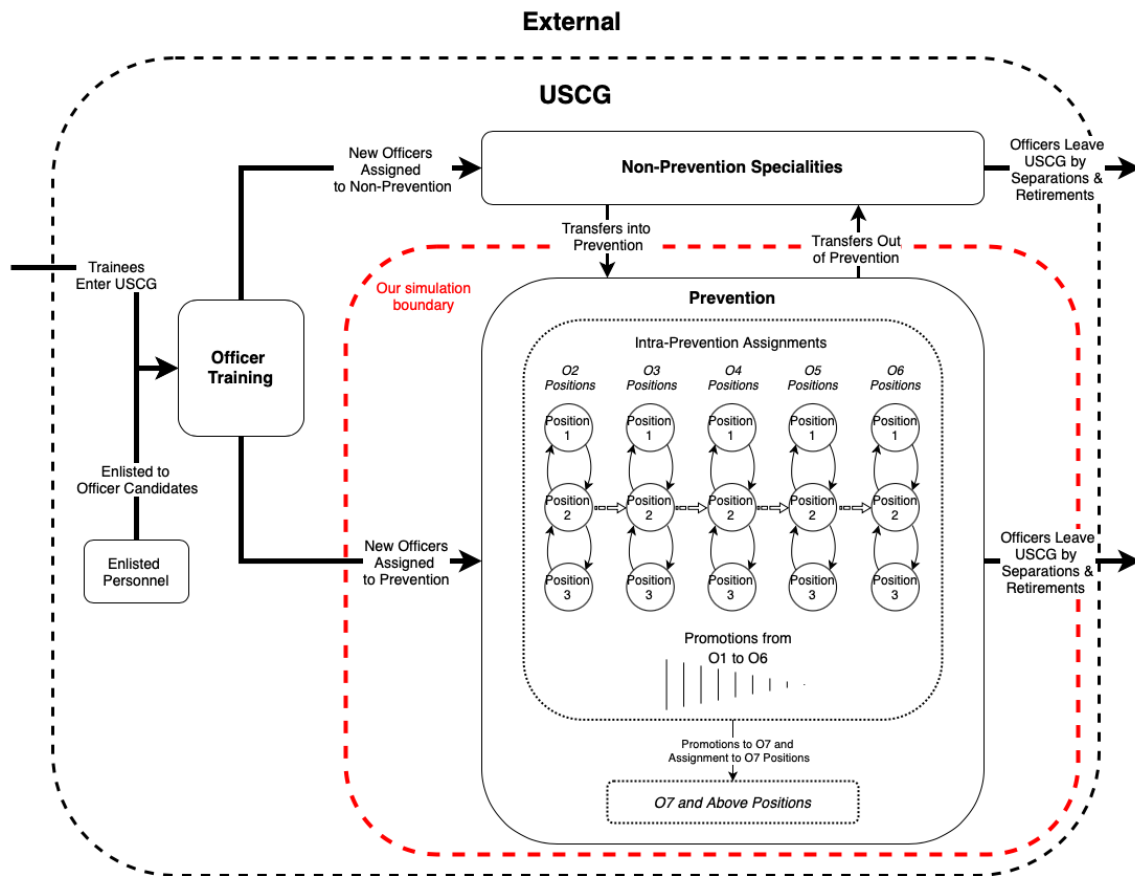


Figure 6.1. USCG Officer Workforce Diagram

6.1.2 Static Workgroup Assignment

The first challenge arose with workgroups. Athena Lite logic does not allow for personnel to transfer between workgroups or permit personnel to be allocated to a posting with a different workgroup. Initially, we attempted to establish each Prevention OSC as a separate workgroup to model OSC-specific behaviours, but this approach proved unfeasible due to the simulation's limitation on personnel movement between workgroups. To illustrate this issue, considering our discussion of OSC OAP-11J from Section 2.2.4, if we designated each OSC

as a unique workgroup, personnel would be assigned to the OAP-11 workgroup and would only qualify for allocation to postings within that specific workgroup. Consequently, these OAP-11 workgroup personnel would not be eligible for OAP-10J postings. This workgroup transfer issue necessitated that we consider the Prevention workforce as a whole entity, thereby overlooking specific OSC considerations.

An additional challenge arose from the workgroup limitation related to out-of-specialty assignments. Prevention officers are assigned to non-Prevention positions at different points in their career for education and greater experience (e.g., Graduate school as seen in four blocks of Figure 2.2). Following completion of a non-Prevention position, the officer is usually assigned back to a Prevention position. Given the simulation tool's limitation on workgroup transfers, we were unable to account for officers departing the Prevention field and then returning at a future assignment. We assumed the number of Prevention officers entering and leaving the system for out-of-specialty assignments is steady and does not significantly impact the overall supply of Prevention officers. This issue would likely have been resolved by modeling the entire USCG officer corps, though this is outside the scope of this work.

6.1.3 Misaligned Promotion Policy and Simulation Logic

Overall, the USCG's promotion policies do not fit nicely with the Athena Lite simulation logic. The first of two concerns is related to the USCG's up-or-out promotion system. As discussed in Section 2.2.3, the Coast Guard mandates separation for officers in ranks O1–O3 who are not selected for promotion (or continuation) at two consecutive promotion boards. Officers at O4 and above also face separation for non-selection, but generally not prior to 20 years of service. The Athena Lite promotion and wastage logic covered in Section 5.1 does not account for this promotion policy. To identify the best option for this issue, we tested two different methods of handling wastage in order to remove non-selected personnel from the model. The first scenario uses general Prevention wastage values provided by the USCG. General wastage values account for personnel who leave the Service due to non-selection for promotion, but they fail to apply the wastage at the appropriate grade within Athena Lite. The second scenario defines wastage values based on level to account for up-or-out promotion policies. The different sets of wastage values are discussed in more detail in Section 6.2.4.

Our second concern with promotion policies is the number and timing of promotions. In brief, the USCG and Athena Lite select and promote personnel with different logic. The USCG sets the number of officers to be promoted equal to the number of existing and anticipated vacancies in the promotion grade, less the number of officers already on the promotion list [27]. Then an opportunity of selection (OOS) percentage is set with the goal to maintain the promotion points metric within a desired range. The size of the promotion-eligible officers pool is the number to select divided by OOS. With these values set, a promotion selection board determines which officers are selected for promotion (i.e., implementing the OOS). Following selection for promotion, officers are promoted over time after meeting a minimum time in grade requirement or based on vacancies in the grade to be promoted into. All officers on the promotion list are eventually promoted.

This promotion process is in contrast to Athena Lite's promotion logic. The simulation logic determines the desired number to be promoted from one of three promotion schemes, applies a promotion percentage to the eligible pool of officers (i.e., those that meet min. time in level requirements) at specified times, and then promotes them. While the logic is different, particular issues arise when considering promotion to O4 and above.

Unlike promotions to O2 and O3, which take place after 18 and 30 months at the previous grade, respectively, promotions to O4 and above take place when a vacancy exists in the promotion grade. This generally means promotions take place monthly until a promotion list is cleared. For promotions to take place monthly in Athena Lite, the user must define monthly promotion events. At each monthly promotion event, the simulation logic applies the defined promotion percentage to the pool of personnel who meet the minimum time in level requirement until the desired number to promote is reached, and then the selected personnel are promoted. The pool of eligible officers is changing with each time step as new personnel meet the minimum time in level requirement and join the pool. However, the impact of this is lessened by eligible personnel with the longest time in level being considered first.

A significant problem arises concerning the appropriate promotion percentage to apply during monthly promotion events. While the desired number of officers to be promoted remains unaffected, the question of what percentage to apply to eligible officers on a monthly basis remains ambiguous, especially given that the USCG applies the promotion

percentage only once annually. To tackle this issue, we conducted three distinct scenarios focused on varying promotion configurations, aiming to determine the most suitable fit.

6.1.4 Allocation and Level Mismatch

Athena Lite allocates personnel to postings based on level, with the person and posting levels required to match. While the USCG strives to have a 100% match between position grade and the assigned officer's grade, this is not always possible. It is not uncommon for there to be a grade mismatch to ensure personnel are assigned to the most important positions and allow greatest decision space to manage the workforce. This limitation of Athena Lite presents issues for simulating the Prevention workforce (and likely other areas of the USCG workforce). The most junior positions in the Prevention field are at the O2 grade, however, O1–O3 officers are regularly assigned to these positions. There are no positions at the O1 grade in the Prevention field and O1 personnel are assigned to O2 positions as a matter of policy. When referring to number of personnel to meet O2 posting requirements, it should be noted that Athena Lite does not consider O1 personnel as candidates though the USCG does.

6.1.5 Data Availability

In shaping the scenarios, we also mitigated issues related to USCG data availability. These include a lack of available Prevention-specific (and other specialties) promotion selection rates. Additionally, the job requirements and achievements datasets only covered a very small portion of the simulation window which created issues when identifying Prevention-coded positions and Prevention officers throughout the simulation period. These data issues and their resolution are covered in later sections.

6.2 Simulation Initialization

Having familiarized ourselves with Athena Lite and mapping USCG workforce dynamics to Athena Lite features, we proceeded to employ this tool in tandem with USCG data to simulate the Prevention workforce. Our work, which builds upon the data preparation outlined in Section 4.2, involved readying the USCG-provided data to satisfy the requirements of 21 distinct input worksheets. We completed this data preparation and analysis using R, a statistical software [49]. These worksheets, subsequently imported into Athena Lite,

encapsulate the structure and data elements outlined in Sections 5.1.1 and 5.1.2. This section delves into the setup of each scenario and covers the intricate processes and analyses involved in defining element inputs recorded in these worksheets in order to initiate the simulation scenarios.

There are Athena Lite features not applicable to modeling the Prevention workforce and outside the scope of our research. We did not populate worksheets related to these features: personnel transitions, health factors, optimiser parameters, experience grades, mentor mentee availability, mentor mentee postings, resource availability, experience resource requirement, and experience allocation.

Besides the data presented in Chapter 4, we incorporated information from other sources related to promotions and competencies. To estimate promotion percentages for levels O2–O5 in the simulation, we utilized historical actual in-zone OOS rates from reference [25]. This supplementary data was necessary because other datasets do not capture promotion rate information. For calculating the level O1 promotion percentage input, we employed data from 2017–2022 promotion selection panel results [57]–[68]. Lastly, we referred to the USCG’s Competency Dictionary [69] to identify all Prevention competencies and OSCs for supply and demand calculations.

6.2.1 USCG Prevention Workforce Scenarios

We devised simulation scenarios with the aim of achieving the most realistic alignment and outcomes with respect to the USCG Prevention workforce. An overview of the USCG Prevention scenario simulation inputs is provided in Table 6.1. We tested different methods to overcome modeling challenges discussed in Section 6.1. These efforts are encapsulated by the inputs of the six scenarios developed, which are summarized Table 6.2. In scenarios A.1 and A.2, we compared the impact of general and level-specific wastage inputs. In scenario A.2, our objective was to model the up-or-out promotion system. Our second set of scenarios, B.1–B.4, tested the impact of four different promotion schemes. We did not implement dynamic changes to the model over the simulation period (e.g., use year one simulation results to make input changes for year two). Input values not found in the Sections below are included in Appendix B.

Table 6.1. USCG Workforce Simulation Inputs Summary

Data Element	Input
Workgroup Structure	“Prevention.”
Level Structure	Officer Grades O1–O6.
Unit Structure	Prevention-coded positions.
Initial Personnel	Personnel assigned to Prevention positions on January 2017.
Wastage	Wastage rates applied based on length of service. Rates are annual. See Table 6.2 for scenario-specific inputs.
Promotions	See Table 6.2 for scenario-specific inputs.
Time in Level	Minimum time in level set for each level based on USCG policy for applicable grade. Maximum time in level requirements not used.
Time in Posting	12–48 months for all postings.
Personnel Inflow	Number of inflows and schedule calculated from USCG data, and set constant throughout simulation period. Initial length of service value is calculated from USCG data and varies over the simulation period.
Personnel Outflow	Number of outflows and schedule for promotions to O7 based on USCG data.
Personnel Requirements	Prevention positions from the Personnel Allowance List (PAL) used, with changes over the simulation period as changes occur in the PAL data.
Simulation Configuration	1 January 2017–30 November 2022 simulation period with 30 replications.

Note: Inputs for wastage, promotions, and outflow are constant over the entire simulation period.

Table 6.2. USCG Workforce Scenario-Specific Inputs

Input	Scenarios					
	A.1	A.2	B.1	B.2	B.3	B.4
Wastage						
General Wastage. <i>See Table B.3 for percentages.</i>	✓		✓		✓	✓
Level-Specific Wastage. <i>See Table B.4 for percentages.</i>		✓		✓		
Promotions						
Promotion Configuration: Set 1	✓	✓				
Set 2			✓	✓		
Set 3					✓	
Set 4						✓

Table 6.3. Promotion Configuration Sets

Promotion Set	Promotion From Level	Time Step	Promotion Scheme	Promotion Percentage (%)
1	O1	1 Month	Push	99
	O2	1 Month	Push	85
	O3	1 Month	Pull	71
	O4	1 Month	Pull	65
	O5	1 Month	Pull	57
2	O1	1 Month	Push	99
	O2	1 Month	Push	85
	O3	1 Month	Push	71
	O4	1 Month	Push	65
	O5	1 Month	Push	57
3	O1	1 Month	Push	8.25
	O2	1 Month	Push	7.08
	O3	1 Month	Pull	5.92
	O4	1 Month	Pull	5.42
	O5	1 Month	Pull	4.75
4	O1	6 Months	Push	49.5
	O2	1 Year	Push	85.0
	O3	1 Month	Pull	5.92
	O4	1 Month	Pull	5.42
	O5	1 Month	Pull	4.75

6.2.2 Structures

In these simulation scenarios, we defined Prevention as the sole workgroup.

As with our exploratory scenarios, we established the officer grades, O1–O6, as the level structure.

We utilized a merged list of unit names from the initial personnel and personnel requirements elements to define the simulation unit structure. This ensured all unit names in the scenario were captured in the unit structure element. Subsequently, unique unit names associated with each Prevention position were exported to populate the unit structure.

6.2.3 Initial Personnel

To ensure an accurate representation of officers within the system at the commencement of our simulation, we populated the initial personnel element with officers who were serving at the start of our simulation period (i.e., 1 January 2017). Each row of the initial personnel element represented a unique individual and included details such as the officer's rank, assigned unit, length of service, time in current level, and time in present posting. The entries in the level column aligned with the level structure, and unit names corresponded to the unit structure.

There is a minor discrepancy in snapshot dates between the two datasets we used to determine initial personnel. Employee data was captured on 9 January 2017 while PAL data was captured on 1 January 2017. This difference may have resulted in differences between the position assignment of personnel and actual positions, however, we considered this a minor issue given that the gap is only one week.

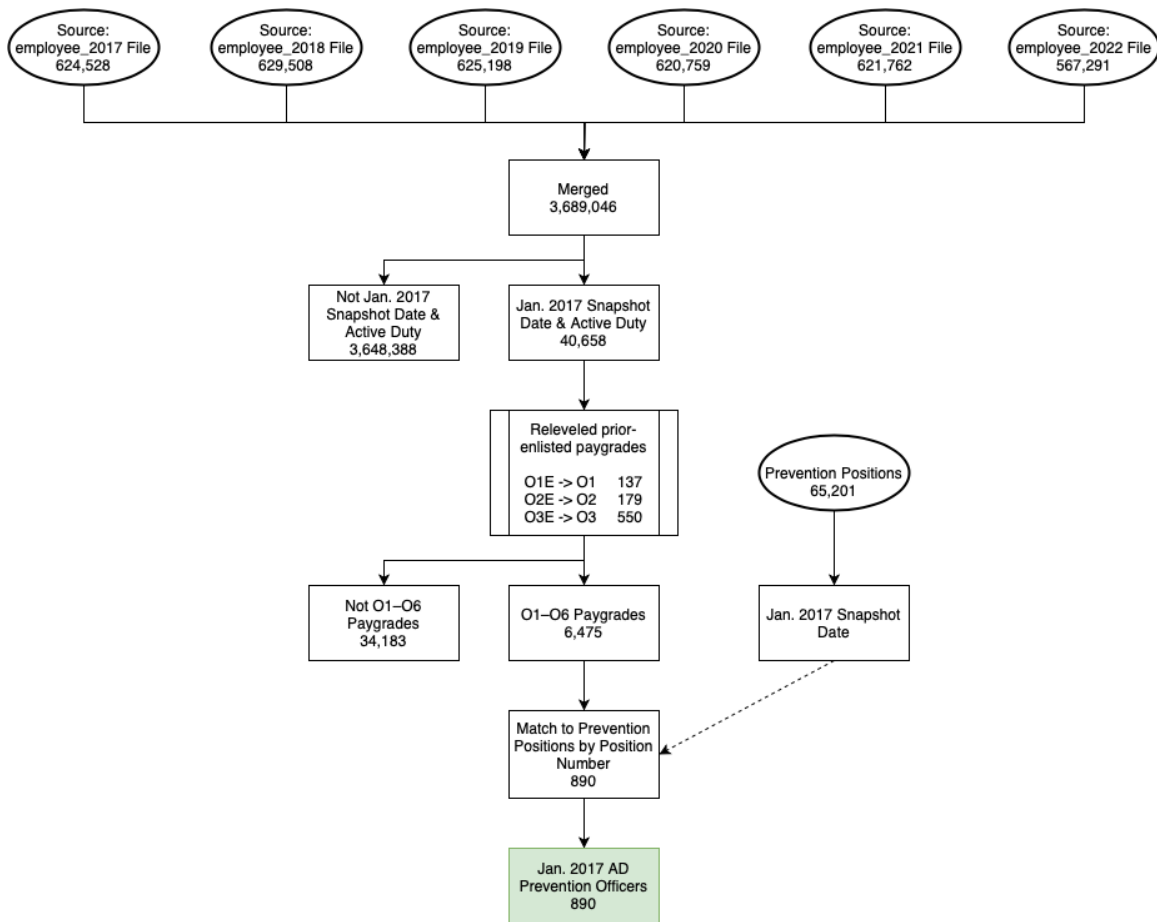


Figure 6.2. Initial Personnel Data Preparation Flowchart

To identify Prevention personnel serving in January 2017, we completed the data preparation steps laid out in Figure 6.2. In the Figure, the number of observations is recorded at each step of the process. This began with merging the six employee files and filtering to the January 2017 snapshot date, active duty (includes personnel in extended active duty and active standby reserve statuses), and O1–O6 officers. The 6,475 officers making up this group were matched by position number to Prevention-coded positions from the Prevention positions dataset (See Section 6.2.8 for Prevention positions details). In the process, all officers bearing prior-enlisted paygrade designations were re-coded to the corresponding grade (e.g., O1E -> O1, O2E -> O2). We did not include prior-enlisted officer paygrades as the designation is not hierarchical in the level structure. Subsequently, to derive the length of service, time in rank, and time in posting for each officer, we calculated the intervals between the snapshot date and certain fields in the employee data: active duty base date, date

of rank, and position entry date. Consequently, we obtained a list of 890 active duty officers in grades O1–O6 serving in a Prevention position on January 2017, which initialized the initial personnel element.

6.2.4 Wastage Properties

The wastage element defines the number and timing of personnel departing the Prevention workforce through attrition by wastage percentages. As pointed out by Mortimer [6], [11] and Bartholomew [45], wastage percentages align with hazard rates calculated from survival analysis. A hazard rate represents the rate of an event occurring at a particular time, conditional on survival up to that point in time. For example, a hazard rate could denote the rate at which an individual might be expected to pass away at the age of 70, assuming they have survived until that age. In our case, we were interested in the departure of personnel from the Prevention workforce either due to transfer to another area of the USCG or separation/retirement from the Service.

To define the wastage percentage within the wastage properties element, we tested two sets of hazard rates derived from USCG data to identify the more realistic option. Initially in Scenario A.1, we established wastage percentages in Athena Lite using values provided by [46], where Prevention officers were identified using Prevention OSCs. These wastage percentages apply to personnel based on length of service and regardless of level (e.g., Both an O1 officer and an O3 officer with five years of service have the same wastage probability). See Table B.3 in Appendix B for Scenario A.1 wastage values.

Next, our aim was to understand the rate at which Prevention officers leave the Service in relation to their length of service and grade, in order to account for the up-or-out promotion system. As discussed in Section 2.2.3, the Coast Guard mandates separation for officers in ranks O1–O3 who are not selected for promotion or continuation at two consecutive promotion boards. Officers at O4 and above also face separation for non-selection, but generally not prior to 20 years of service. While CG-1B2 provided wastage rates for Prevention personnel [46], these rates were not directly applicable for addressing the up-or-out promotion issue. Athena Lite does not track personnel who are not selected for promotion through the simulation. Consequently, individuals not selected for promotion twice would remain in the simulated workforce unless separated due to wastage.

To address this challenge, we leveraged the insight that officers not selected for promotion after two boards would have longer lengths of service compared to those who were selected. We computed the average hazard rate for each rank based on six years of employee data, covering service duration from 0 to 40 years. Using a similar approach to [46], we divided this range into 40 bins, each representing a year of service (e.g., 0–0.99 years of service, 1–1.99 years of service). By filtering the employee dataset to include officers assigned to Prevention-coded positions, we allocated each officer to the appropriate years-in-service bin based on the interval between their active duty entry date and the snapshot date. For each bin and officer, we determined whether the officer remained in service one year after the snapshot date. To calculate the hazard rate for each year bin, we divided the number of officers lost over one year by the total number of officers at the beginning of the period. To account for short-term fluctuations, we averaged the wastage rate over 36 months. These computed hazard rates formed the basis for determining level-specific wastage values that account for up-or-out promotion dynamics.

To compel those personnel twice not selected for promotion to exit the system, we set wastage at 100% for later years in service. The year cut-off to apply 100% wastage was set at two years following when promotion should have taken place if not passed over for promotion for each grade, informed by promotion point ranges [12] and [25]. The challenge with this approach is the potential for inaccuracies when modeling prior-enlisted personnel in the simulation. While most officers' lengths of service correspond to the duration of their time as an officer, prior-enlisted officers have longer lengths of service, reflecting their initial service as enlisted members. Some prior-enlisted officers may have lengths of service that we defined to 100% wastage. This configuration may artificially suppress the supply of personnel as more simulated personnel are forced out than would depart the workforce in reality. A more accurate approach to handle promotion, in the context of USCG personnel, though not an Athena Lite feature at this time, would be to define wastage percentages based on time in level in addition to length of service.

Appendix B, Table B.4 displays the wastage percentages defined for Scenario A.2. We assumed wastage percentages for Prevention officers did not change over the six years of our research and, as such, applied both sets of wastage percentages for the entire duration of the simulation period.

6.2.5 Promotion Properties and Probabilities

Like real-world officers, personnel in the simulation promote and progress up through the workforce. To model this in Athena Lite, we defined the promotion event time step, promotion scheme from each level, and level promotion percentages. We grouped combinations of these parameters into four different promotion configurations that we tested across our scenarios. The specific scenarios and promotion configurations are detailed in Tables 6.2 and 6.3. We used promotion configuration Set 1 in Scenarios A.1 and A.2, Set 2 in Scenarios B.1 and B.2, Set 3 in Scenario B.3, and Set 4 in Scenario B.4. Set 1 and its parameters, which summarize all aspects of the utilized promotion inputs, form the foundation for Sets 2–4.

There is a subtle difference in terminology between USCG and Athena Lite with regards to promotions. The USCG uses the term “opportunity of selection” OOS when referring to the percentage of officers to be promoted and it references the grade to be promoted *into* [12]. On the other hand, Athena Lite defines promotion percentages by the level an officer is promoted *from* [53]. For example, when the USCG refers to the O3 OOS percentage it is referencing officers being promoted into O3. In Athena Lite, this number would be called the O2 promotion percentage. In both cases, the value is in reference to the promotion of personnel from O2 to O3.

In Set 1, the push promotion scheme is used for promotions from levels O1–O2 and the pull scheme for promotions from O3–O5. USCG promotions from O1 and O2 take place after meeting time in grade requirements, regardless of vacancies in the system, which aligns with Athena’s push promotion scheme logic and monthly time steps. As discussed in Section 6.1.3, for promotions from O3–O5 levels, we defined monthly promotion events with the number of promotions based on vacancies, and used the push promotion scheme to do so. We note that the number of vacancies Athena Lite calculates is Prevention-specific, while the USCG calculates vacancies for a grade across the entire officer corps. Identical time step and promotion schemes were used in Set 3.

Additionally in Set 1, we defined the promotion percentages the simulation uses to determine which eligible officers are promoted. Unfortunately, data on Prevention-specific promotion rates were not available for use. Instead, we assumed promotion percentages for Prevention officers were equivalent to percentages for all officers of the same rank. We also assumed

promotion rates were constant over the simulation period (i.e., 2017–2022). We used three different promotion percentage values in our four sets with these values based on data derived from USCG sources. To determine the promotion percentages for levels O2–O5 in Athena Lite, we calculated the average actual in-zone opportunity of selection from promotion years (PYs) 2017–2022 for grades O3–O6, found in the PY 2023 Officer Corps Accession Plan [27]. To ascertain the promotion percentage for level O1, we consulted PY17–PY22 LTJG selection board results [57]–[68] and calculated the average in-zone OOS over the six year period to be 99%. In Sets 1 and 2, we used these calculated promotion percentages directly. For Sets 3 and 4, we attempted to overcome challenges between USCG promotions and Athena Lite logic by dividing the USCG OOS values by the number of time steps in a year.

The frequency of USCG promotions generally determined when promotion events should take place in the simulation. The USCG promotes officers every month, as determined by meeting a time in grade requirement (O1 and O2) or as vacancies open (O3 and above). We defined this dynamic in Sets 1–3 as monthly time steps, allowing Athena Lite to promote personnel each month of the simulation period. In Set 4, we used level-specific time steps. USCG promotions from O1 to O2 take place twice a year, and as such we defined the time step for the O1 level as six months. For the same reason, we defined the O2 level time step as one year. For levels O3–O5, we used monthly time steps in conjunction with the pull promotion scheme.

6.2.6 Time in Level

The time in level element sets the minimum (and maximum) time an officer must serve before being eligible for promotion to the next level. In our scenarios, we used officer grades as the level structure. As such, USCG time in grade is equivalent to Athena Lite’s time in level. Based on Service policy [12], we defined minimum time in level for each level as seen in Figure 6.4. We do not use the maximum time in level feature as it is not realistic for USCG workforce policies.

It is important to note the difference between USCG’s and simulation’s definition and timing of an officer eligible for promotion. In the USCG, it is not uncommon for a delay of 6–12 months between becoming eligible, being selected, and completing a promotion. Athena

Lite does not account for this delay—once an officer has met the minimum time in level requirement in Athena Lite, they are eligible for promotion and, if selected, are immediately promoted.

Table 6.4. Minimum Time in Level Inputs for USCG Scenarios

Level	Min. Time in Level (mos)
O1	18
O2	30
O3	36
O4	48
O5	48

6.2.7 Time in Posting

In our model system, officers are cyclically reassigned to various postings, with the duration of each posting being determined by user-defined “time in posting” inputs. Both the minimum and maximum time periods that a person can spend in a posting, prior to promotion or reassignment, are customizable to each posting.

In our simulation, the time in posting input was set to a minimum of 12 months and a maximum of 48 months, an approximation of USCG assignment and transfer practices. This decision was based on the computations in Section 4.3.3 and background provided in Section 2.2.2. Typically, the USCG tends to relocate personnel during the summer months, and after a certain period of service in a position. In instances where new personnel join a unit outside of this summer transfer window, the USCG adjusts their tour length accordingly to align their departure date with the regular transfer window. It is worth noting that promotions do not lead to personnel transfers outside of these annual summer transfer windows.

In contrast, our Athena Lite model triggers personnel transfers when an officer is either promoted or when they reach the maximum time allowed in a posting, irrespective of the current time in the simulation. The simulation tool does not have a feature to concentrate when transfers take place (e.g., summer months).

6.2.8 Personnel Requirement

The demand for personnel in our model was defined in the personnel requirement element, which relied on the number of Prevention positions required at each level within each unit for every time step of the simulation. To derive these numbers, we began by identifying Prevention positions from the PAL and job requirements files as seen in Section 4.2's Figure 4.5 data preparation diagram.

Once the Prevention positions (depicted by the green box in the diagram) were identified, for each snapshot date we counted the number of Prevention positions at every level across all units. As seen in Table B.8 of Appendix B, these values were used as input into the personnel requirement element. The number of and characteristics of our defined simulation postings vary over the simulation period, as found in the data. For example, from USCG data, there are 207 Prevention positions at the O4 grade in March 2022 and this increases to 214 positions in April 2022. The values we defined in personnel requirements include these position fluctuations. We imputed the April 2018 snapshot as no values for the month were included in the data file. We assumed the April personnel requirements match those in March 2018.

In the absence of an available list indicating priority among USCG positions, all posting requirements were assigned the same priority level. It is important to note that this is a modeling assumption necessary due to a lack of available data. Therefore, the priority of positions is likely different in actual USCG assignment processes.

6.2.9 Personnel Inflow

In our simulation, personnel entries into the system are governed by parameters set in the personnel inflow element. We detailed the workgroup, level, and length of service of each officer entering the system.

In the real-world Coast Guard workforce, officers are commissioned into the Service and then dispersed across various specialties, with a subset assigned to the Prevention workforce. This process is depicted in Section 6.1, Figure 6.1, where arrows from the Officer Training component lead into different specialties. However, there is no specific data available on the number of personnel directly entering the Prevention workforce from accession sources.

Further complicating the scenario is the fact that some officers enter the Prevention workforce from other Coast Guard specialties, such as following an initial tour with an afloat unit, and they may enter at O2 or O3 grades.

To define the number and timing of inflows into the simulated Prevention workforce, we calculated the number of real-world officers newly assigned to a Prevention position for every month of the simulation period. It is general USCG practice that only O3 and below personnel join Prevention for the first time, so we assumed only personnel at levels O1–O3 could flow into the simulated Prevention workforce. The number of personnel inflows includes new accessions joining the Prevention specialty directly from officer training. Additionally, we calculated the average length of service for those officers entering Prevention. We made the assumption that the number of accessions and the timing of these accessions occurred regularly throughout the simulation period. The initial length of service values vary throughout the simulation period.

It is worth noting that officers within the Prevention workforce tend to rotate in and out of Prevention positions throughout their careers. In our model, officers who were not in a Prevention position as of January 2017 were not considered part of the system. Our model does not account for the fluctuating movement of personnel into and out of Prevention, and for simplicity, we assumed that the rates of officers moving in and out were equal.

6.2.10 Personnel Outflow

In our simulation model, we considered all personnel exiting from the system to be governed by the previously discussed wastage percentages, except for O6 personnel promoted to O7. We accounted for those personnel promoted to flag officer (i.e., O7) in the simulation by defining values in the outflow element.

As per Section 4.3.5, we found that, on average, from January 2017 to November 2022, 1.17 Prevention officers left the USCG Prevention workforce each year via promotion to O7. In our simulation, we assumed that one Prevention officer is promoted to O7 each July. This annual outflow at the O6 level was then incorporated into our model in the personnel outflow element. Athena Lite does not permit fractional outflows to be defined.

6.2.11 Simulation Configuration

The last component shaping our scenarios was the simulation configuration, which remained consistent across all scenarios. Our simulation period of the Prevention workforce spanned from 1 January 2017 to 30 November 2022. This specific time frame was chosen to align with the dates covered in the available USCG data.

For statistical robustness and to account for variability, we conducted 30 Monte Carlo trials. We configured the simulation to report results on a monthly basis and activated the output averaging feature to provide more stable and representative results.

6.3 Scenario Results

In previous sections, we presented different scenarios and their corresponding inputs. Now, we delve into the results obtained from each USCG Prevention workforce scenario. The simulation results from Athena Lite were imported into R for analysis and visualization. To understand how the Athena Lite results compared to real-world data and over what time frame, we included actual USCG Prevention workforce data. We expected to see simulation results that aligned closely with real-world data towards the beginning of the simulation period, before diverging as simulation time progressed.

To enable a systematic evaluation and comparison of simulation performance across different scenarios, we utilized mean absolute percentage error (MAPE) as a quantitative measure. The MAPE allowed us to discern and compare the accuracy of the simulations by quantifying the average absolute percentage difference between the simulated results and the actual values. The MAPE of our simulation results was calculated as

$$\text{MAPE} = \frac{1}{n} \sum_{i=1}^n \left| \frac{Y_i - \hat{Y}_i}{Y_i} \right| \times 100\%, \quad (6.1)$$

where n is the total number of months in the simulation period, Y_i represents the actual values from USCG Prevention workforce data, and $\hat{Y}_i$ represents the predicted values from Athena Lite simulation results.

6.3.1 Scenario A.1

In Scenario A.1, we utilized general wastage rates that were applied uniformly to all levels. However, this scenario did not account for the USCG's up-or-out promotion policy. The simulation results for this scenario are presented in Figures 6.3, 6.4, and 6.5.

Figure 6.3 compares the supply and demand for each level using data from both the Athena Lite simulation results and the USCG workforce data for the same time period. The Athena Lite values represent the average supply across all 30 replications. At the O1 and O2 levels, we observe a reasonable fit between the simulated supply (depicted by the blue line) and the actual workforce supply numbers (depicted by the green line). The slopes of the two lines are similar, although there are slight differences in timing.

However, at the O3 level, we observe more divergent behavior. The actual supply at the O3 grade decreases from 2017 to 2022, while the simulated supply steadily increases from 375 to over 600 personnel by the end of the simulation period. The increase in simulated supply at the O3 level indicates that there are insufficient numbers of personnel leaving the level either due to wastage or promotion. One of the likely reasons for this disparity between the simulated and actual supply is the absence of personnel departing the simulated system who, in reality, are separated from the Service for failing to be promoted. As mentioned in Section 6.1.3, Athena Lite does not have a built-in feature to account for the USCG's up-or-out promotion system. To address this issue, we tested a different method in Scenario A.2.

In Scenario A.1, promotions into O4–O6 levels were determined by the pull promotion scheme, which only promotes personnel if there is a vacancy in a posting. While there is a very close match between the simulated number of personnel and the required number of personnel to fill postings, the number of simulated personnel remains relatively stable compared to fluctuations in the actual number of personnel. The difference between the simulated and actual supply for levels O4–O6 is minimal, with a maximum gap of 20 personnel for O4 and O5 and three personnel for O6. It is important to note that the USCG also tries to match actual supply with requirements, therefore there is a link between USCG supply level and requirement level.



Figure 6.3. Scenario A.1 – Supply and Requirements Over Time with Simulation Results and USCG Data

From the data presented in Table 6.5, it is evident that the simulation accuracy demonstrates satisfactory performance in 2017, with a MAPE of 7.6% across all levels. The model exhibits an error rate of under 10% for all levels except O1 in 2017. However, as the time horizon extends to later years, the simulation’s accuracy deteriorates significantly. The error percentage steadily increases from 7.6% in 2017 to 31.1% in 2022, the final year of the simulation.

Table 6.5. Scenario A.1 Model Accuracy (%)

Year	Level						All Levels
	O1	O2	O3	O4	O5	O6	
2017	16.90	3.19	8.05	7.31	5.57	4.65	7.61
2018	29.41	13.93	16.34	3.92	9.00	3.83	12.74
2019	11.24	35.55	29.02	0.67	12.06	6.95	15.91
2020	4.80	36.20	46.02	2.60	14.12	3.67	17.90
2021	12.57	31.52	75.82	5.19	9.53	3.11	22.96
2022	39.94	16.36	108.28	3.12	14.20	4.75	31.11
All Years	18.85	22.88	46.39	3.81	10.70	4.49	17.90

Each entry in the table represents the MAPE calculation corresponding to the specific Year and Level combination.

Furthermore, when comparing the model’s performance across different levels, interesting insights emerge. The simulation performs well on O4 and O6 levels, with a MAPE of less than 5% averaged across all years. On the other hand, the O3 level has the highest level of inaccuracy, with a significant MAPE of 46% averaged across all years and particularly poor performance with a 108% error in 2022.

It is crucial to consider that the simulation only covers 11 months of 2022, and if it were to model the full 12 months as it does for earlier years, the error percentage would likely be higher. These findings emphasize the need for further analysis and improvements in the simulation to enhance accuracy, particularly for the O3 level.

Average LOS is a crucial personnel attribute to analyze as the Coast Guard utilizes it for benchmarking promotion timing [27]. In Figure 6.4, we calculated average LOS for each level based on the Scenario A.1 results. The LOS values remain relatively stable over the simulation period for levels O3–O6. However, levels O1 and O2 exhibit greater variability in LOS. Notably, there is a decline in the average LOS at the O1 level around mid-2018. This decline coincides with an influx of approximately 30 personnel around the same time (seen on the blue line of level O1 in Figure 6.3). These new personnel have lower LOS values, thereby bringing down the average LOS for the O1 level.

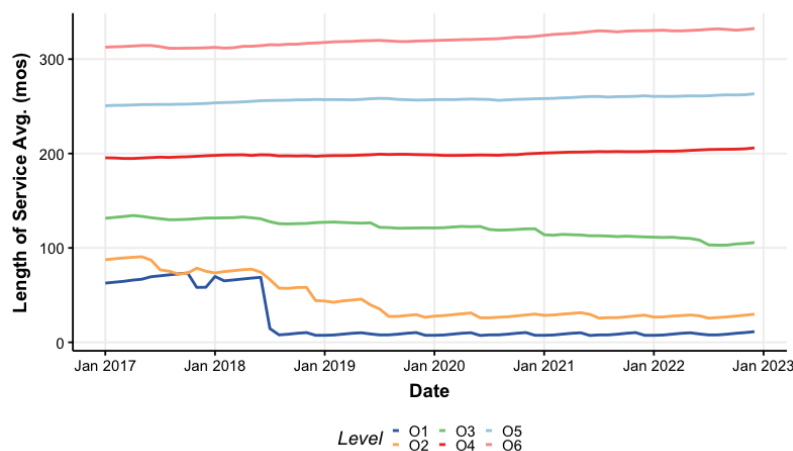


Figure 6.4. Scenario A.1 – Simulation Results Length of Service

We conducted a comparison between the simulated average LOS output and the USCG data for the same time period, as shown in Figure 6.5. The blue lines of Figure 6.5 match the

level-specific LOS lines from Figure 6.4. By comparing the average LOS, we were able to identify the points where the simulation behavior deviates from the actual dynamics of the USCG system.

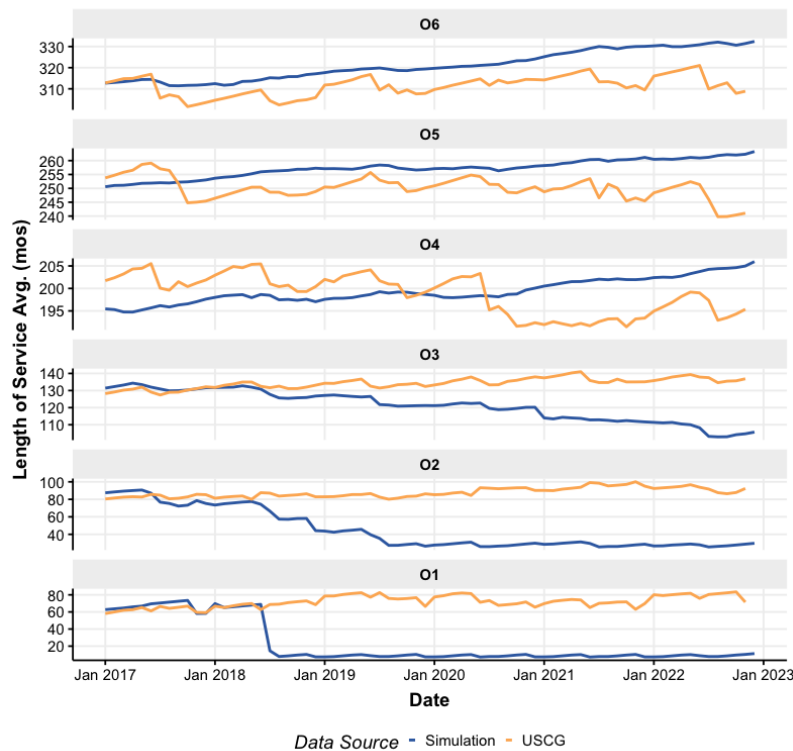


Figure 6.5. Scenario A.1 – Simulation Results and USCG Data Length of Service Comparison

In the simulation, the drop in average LOS for levels O1 and O2, observed around mid-2018, is specific to the simulation and not reflected in the USCG data. Furthermore, the simulated average LOS for level O3 diverges from the actual LOS starting around mid-2018 and continues to decrease throughout the remaining simulation period.

Regarding levels O4–O6, the difference between the simulated and actual LOS remains relatively consistent and relatively small, ranging between 10-20 months. However, the simulation LOS lacks the seasonality observed in the actual LOS lines. The USCG LOS lines exhibit an annual peak during early summer, followed by a decline in late summer, and a steady increase leading into the next summer. This seasonality aligns with the Service’s

assignment transfer season when numerous senior personnel separate or retire, resulting in fluctuations in personnel numbers and a decrease in the average LOS.

In summary, the results from Scenario A.1 indicate that the simulation achieved a satisfactory level of alignment between the simulated and actual supply and average LOS. However, there was a notable issue with the unrealistic growth in the supply of O3 personnel, which needed to be addressed in Scenario A.2 to improve the accuracy of the simulation.

6.3.2 Scenario A.2

Scenario A.2 was developed to address concerns raised in Scenario A.1 and tackle the impact of the up-or-out promotion policies on workforce behavior within the USCG. By incorporating the effects of personnel separations due to promotion failures through wastage rates, this scenario aimed to improve the accuracy of the simulation.

Figure 6.6 provides simulation results related to supply and requirements, and includes actual workforce data.

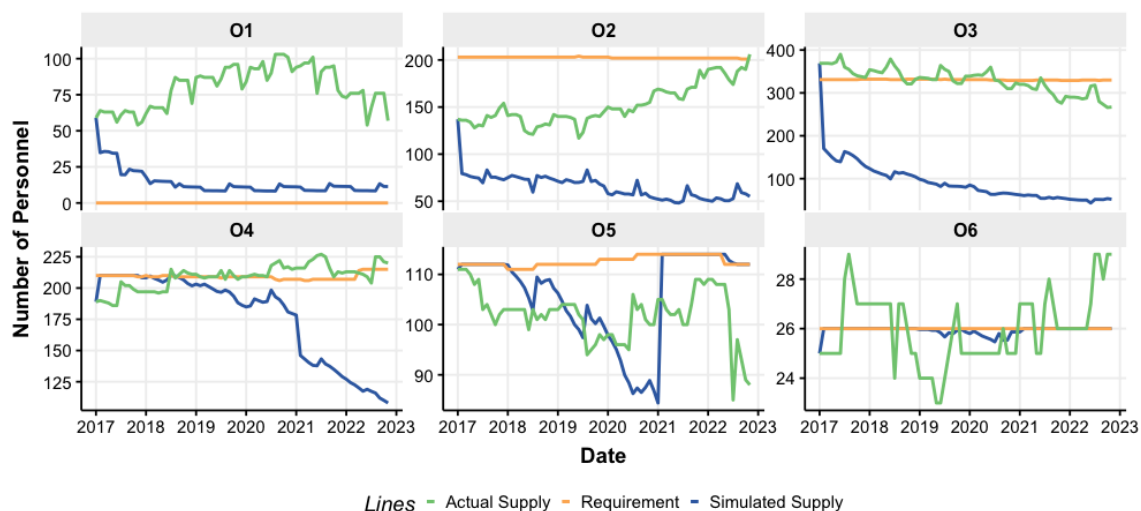


Figure 6.6. Scenario A.2 – Supply and Requirements Over Time with Simulation Results and USCG Data

Overall, we see a very poor match of simulated supply to the required number of personnel (depicted by the yellow line) as well as to actual supply of personnel from USCG data. The

simulated level of supply is significantly less than the requirement and actual supply across most levels.

This simulation result leads us to conclude a greater number of personnel departed the simulation than would in actuality. Additionally, the wastage rates used in this scenario are a poor substitute for the up-or-out promotion policy. As noted in Section 6.2.4, using wastage rates is an imprecise solution to address workforce promotion and separation dynamics. Forcing simulated personnel with longer lengths of service to depart the Coast Guard resulted in more personnel departing the system than appear to be departing in reality.

This scenario has a MAPE of 39.8% averaged across the entire simulation period and all levels. We provide all error percentages and additional results in Appendix C, Section C.1.

6.3.3 Scenario B.1

The primary goal of Scenarios B.1 and B.2 was to identify an optimal promotion configuration within the simulation that closely matched the dynamics of the USCG Prevention workforce. In Scenario A.1, we observed a lack of fluctuation in the simulated supply of personnel and sought to address this issue in Scenario B.1. In this scenario, we implemented the push promotion scheme for all levels and maintained the same wastage rates as in Scenario A.1, which did not account for the up-or-out promotion policy. Notably, this configuration differed from Scenarios A.1 and A.2, which employed a combination of push and pull promotion schemes.

As with the two previous scenarios, we first look at the simulated supply levels, actual supply levels, and requirement over the simulation period. Supply levels at O1 and O2 are identical to those seen in Figure 6.3 as the promotion simulation inputs for those levels are identical. At levels O3–O6, we see wildly different simulation supply than actual supply levels. In all four levels, there are dramatic increases and decreases in the simulated number of personnel. For example, immediately after simulation start in very early 2017, the level of O3 supply drops with a corresponding rise in the level at O4. This large cohort of simulated officers continues to make its way through the levels over time, leading to dramatic changes in O4–O6 supply levels later in the simulation period. The reason for the immediate promotion of a large number of simulated personnel from O3 to O4 is due to how Athena Lite determines promotion eligible personnel. Personnel are eligible for promotion once they have met the

minimum time in level requirement. Among the group of 369 simulated officers making up the initial personnel input at O3, 349 of them meet or exceed the minimum time in level requirement. This group of initial personnel are immediately eligible for promotion to O4 and the simulation promotes a large number of them based on the defined promotion percentage.

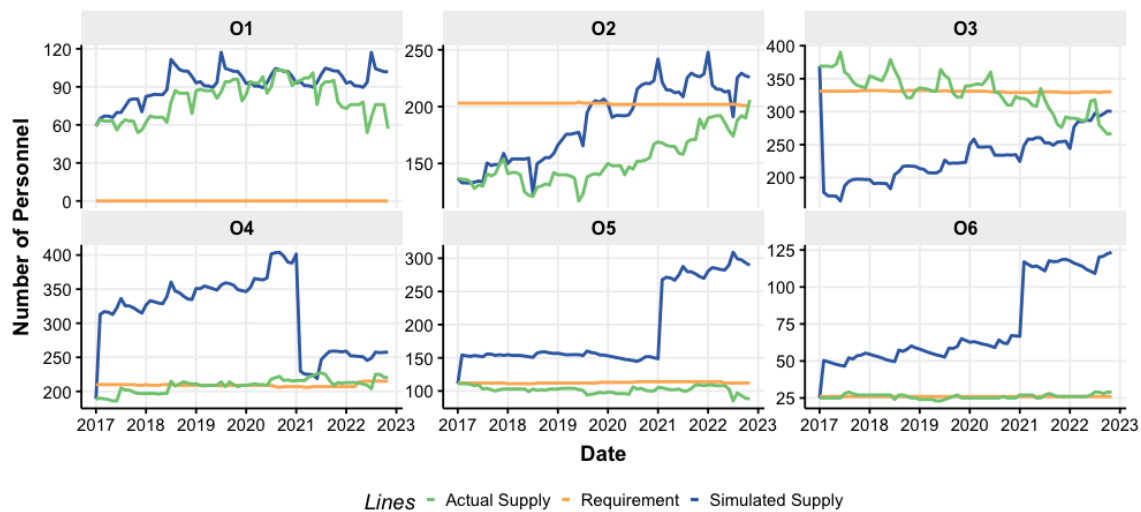


Figure 6.7. Scenario B.1 – Supply and Requirements Over Time with Simulation Results and USCG Data

This scenario had a MAPE of 66%, the worst error percentage of the four scenarios we considered. See Appendix C, Section C.2 for additional plots and error information.

6.3.4 Scenario B.2

In Scenario B.2, we aimed to address the disparities between simulated and actual supply levels by combining the push promotion scheme for all levels with the level-specific wastage rates observed in Scenario A.2. The simulation results, displaying the supply levels of both simulated and USCG Prevention personnel, are presented in Figure 6.8. However, these results reveal inconsistencies between the simulated supply numbers and the actual Prevention workforce. This discrepancy can be attributed to the same underlying issue discussed in Scenario A.2—the wastage percentages assigned to each level, intended to account for the up-or-out promotion system, are higher than what is observed in reality.

Notably, there are significant fluctuations in the number of simulated personnel at the O1-O3 levels immediately after the simulation begins, and supply remains consistently low for the remainder of the simulation period. This suggests that either the minimum time in level or the wastage settings are not aligned with the characteristics of the officers in the initial personnel cohort. Additionally, the large number of promotions from O4 to O5 and from O5 to O6 in January 2021 can be attributed to the minimum time in level input. With the minimum time in level set at 48 months for O4 and O5 levels, a substantial number of promotions occur exactly 48 months from the start of the simulation. As the push promotion scheme used here resulted in unrealistic and large numbers of personnel being promoted, we return to mixed promotion schemes in the next scenario. For further analysis, including length of service plots and error calculations, refer to Appendix C, Section C.3.

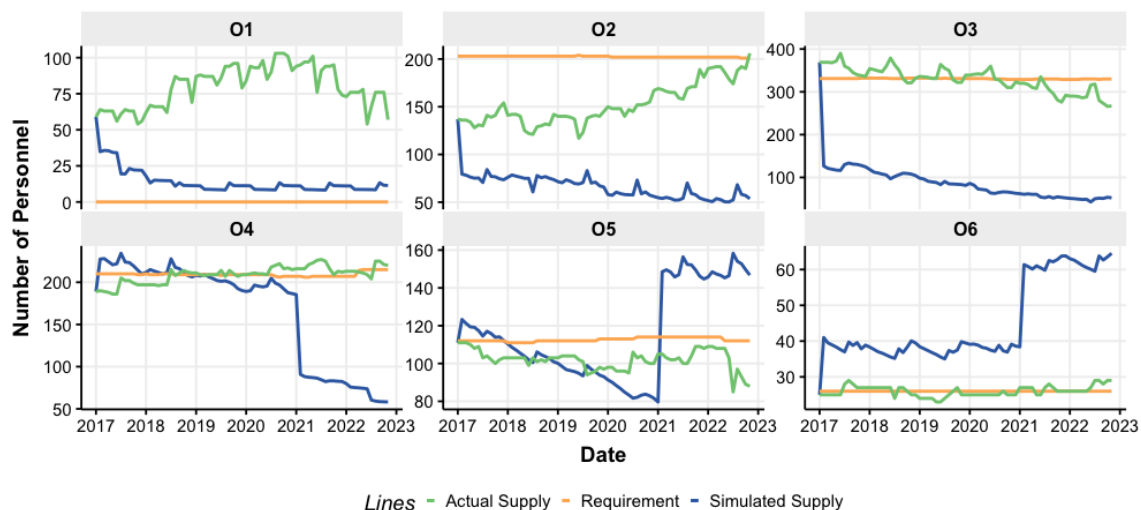


Figure 6.8. Scenario B.2 – Supply and Requirements Over Time with Simulation Results and USCG Data

6.3.5 Scenario B.3

In Scenario B.3, we observed results that are nearly identical to those in Scenario A.1. The only difference in inputs between these two scenarios is the promotion percentage applied at each monthly promotion event. Scenario B.3 utilized promotion configuration Set 3, where the promotion percentage is determined as the ratio of officers selected (OOS) to the number of monthly time steps (i.e., 12). In contrast, Scenario A.1 used a promotion

percentage derived directly from historic OOS data. The resulting MAPE values for both scenarios are close, further highlighting the similarity in their outcomes. Scenario A.1 yields a MAPE of 17.90, while Scenario B.3 has a MAPE of 18.40.

From these findings, we conclude that promotion percentage has minimal impact in these scenarios, while the promotion scheme and wastage rates have more significant effects. This emphasizes the importance of considering promotion configuration and wastage factors when simulating and analyzing the USCG Prevention workforce. In the subsequent scenario, we explore the influence of different promotion time steps. For further examination of length of service plots and error calculations, please refer to Appendix C, Section C.4.

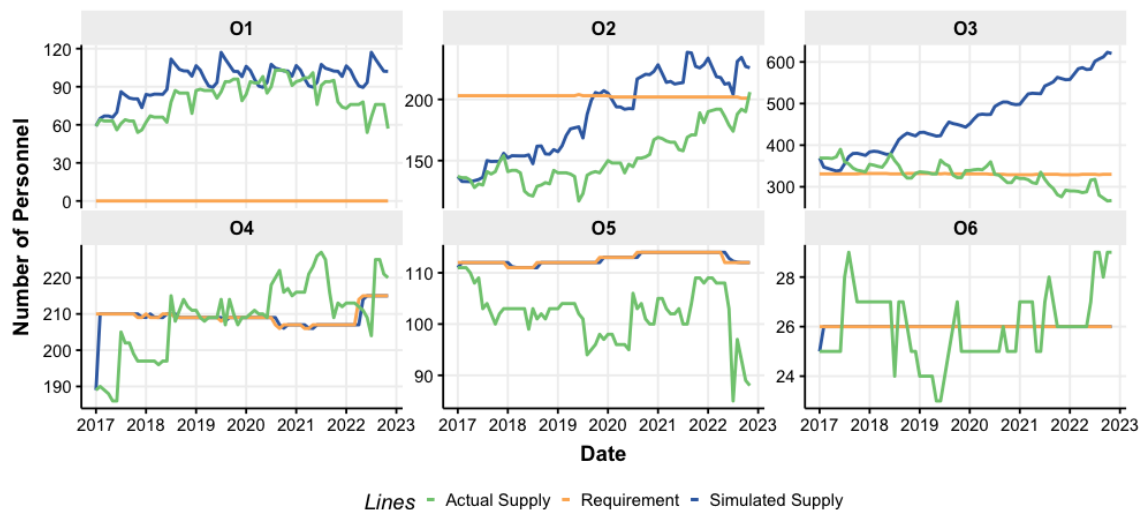


Figure 6.9. Scenario B.3 – Supply and Requirements Over Time with Simulation Results and USCG Data

6.3.6 Scenario B.4

In our final scenario, we focused on fine-tuning the time step promotion setting within the simulation. Promotions from O1 and O2 were scheduled to occur at the same frequency as USCG promotion boards meet, while promotions from O3 to O5 were defined to place at monthly time steps. Additionally, we incorporated promotion percentages for each level based on the number of USCG promotion events in a year. For instance, at the O1 grade, there were two promotion events per year, with a promotion percentage of 49% applied at

each event (calculated as $99\%/2 = 49.5\%$).

The results of Scenario B.4 were comparable to those of Scenarios A.1 and B.3. Figure 6.10 displays supply levels, and it reveals unrealistic growth at the O3 level. Supply for O4–O6 levels met the requirements but deviated from the USCG supply line. The only difference in setup between Scenario B.3 and Scenario B.4 was the promotion event time step and promotion percentages. These adjustments had minimal impact on the overall behavior of the simulation. The most noticeable change was the shape of the supply lines at the O1, O2, and O3 levels. In Scenario B.4, the lines were smooth and exhibited regular jumps corresponding to the annual promotion event, while Scenario B.3 showed more variability and smaller changes over time due to the monthly promotion events. Comparing the simulated supply lines with the USCG supply line, we noted that the monthly time step more closely resembled the USCG supply pattern than the annual time step.



Figure 6.10. Scenario B.4 – Supply and Requirements Over Time with Simulation Results and USCG Data

Figures 6.5, C.4 and C.5 show the error percentage of Scenarios A.1, B.3, and B.4 are comparable and under 20%. As expected, the error increases over time, as the simulation gets further from its starting point pegged with real-world data in the initial personnel element. Performance across levels is also insightful. We see fair performance, with an average MAPE < 5%, for O4 and O6 levels. The minimal error at the O6 level is partly due

to the small number of personnel being modeled.

It is important to note that although there is a relatively small MAPE between actual and simulated supply at O4–O6 levels, Figures 6.3, 6.9, and 6.10 illustrate the standard deviation of actual supply is much greater than simulated supply. This suggests the simulation is over fitting to the requirement. While USCG’s goal is also to meet the requirement, the actual supply levels are more variable and the result of policy constraints on its ability to do so. Therefore, the MAPE does not fully capture the performance of the simulation.

In conclusion, the simulation results from the different scenarios provide valuable insights into the performance and accuracy of the USCG Prevention workforce simulation model in Athena Lite. Scenario A.1 demonstrated a reasonable match between simulated and actual supply and average LOS, but encountered challenges in capturing the dynamics of promotions and departures at the O3 level. Scenario A.2 attempted to address these concerns by incorporating a workaround for the up-or-out promotion policy, but it resulted in worse performance compared to the actual workforce behavior. Scenarios B.1–B.4 further explored different promotion configurations, with B.1 and B.2 utilizing the push promotion scheme for all levels. In Scenarios B.3 and B.4, we specifically tested the impact of different time steps and promotion percentages. These findings underscore the importance of accurately modeling the promotion policies and their influence on the workforce dynamics. It is evident that ongoing refinement of the model is necessary to improve accuracy and provide a robust tool for workforce planning and decision-making within the USCG Prevention workforce.

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CHAPTER 7: Conclusion

In this final chapter, we review our objectives, highlight key findings and results, discuss model performance, and recommend areas for future work.

7.1 Summary

The motivation for this work arose from the imperative for USCG workforce planners to have access to advanced and efficient tools that can effectively evaluate the impact of proposed policy changes on the military workforce. Our objective in this research was to assess the compatibility of the Athena Lite tool for simulating the USCG Prevention workforce and its potential as a decision support tool. To accomplish this, we followed a comprehensive workforce analysis workflow. We began by gathering, cleaning, and preparing the data for analysis. We conducted detailed exploratory data analysis, employing summary statistics and creating informative visualizations to gain insights and address any data challenges. In the next phase, we delved into the Athena Lite tool, conducting tests using a fictional workforce to comprehend the tool's limitations and constraints. We then applied our workforce knowledge and tool experiences to USCG data. Through the development and execution of six scenarios with inputs based on USCG data, we gained a deeper understanding of the Prevention workforce and evaluated the performance of the simulation tool. Finally, we compared the simulation results with real-world data to assess the practicality and accuracy of the model.

We discovered that Athena Lite possesses significant potential as a powerful simulation tool for the Coast Guard, but further research and refinement are necessary to ensure its operational effectiveness. Despite challenges in adequately tuning the numerous simulation features to reliably model the Prevention workforce, this study contributes valuable insights and lays the groundwork for future improvements in workforce planning within the USCG.

7.2 Findings and Model Performance

In assessing the performance and accuracy of the simulation model in capturing the dynamics of the USCG Prevention workforce, it is crucial to acknowledge the inherent challenges associated with simulating such a complex workforce. While Athena Lite considers various factors like promotion processes, wastage rates, transfer processes, and unique unit or position restrictions, it has limitations in capturing the many workforce behaviors specific to the Coast Guard Prevention workforce.

The reliability of our results was impacted by obstacles related to data availability and usability. Discrepancies in snapshot dates, undefined data fields, and data entry errors introduced inconsistencies and limitations in the information we used for analysis. The monthly snapshot format added complexity and required significant effort to derive the necessary inputs for Athena Lite.

Our data analysis revealed a steady supply of personnel to meet Prevention mission demands. However, we acknowledge that there are underlying factors and long-term stressors that were not fully captured in our work, such as experience gaps and retention challenges in the Coast Guard. These factors require attention and analysis to ensure the long-term sustainability and effectiveness of the Prevention workforce in meeting future demands.

The USCG Prevention workforce operates within a unique set of circumstances and organizational dynamics, which were not fully accounted for in our scenarios or not possible to model within the simulation tool. The complexities of career progression, assignment policies, and the interplay between different ranks and specializations within the Prevention workforce present challenges in accurately representing the dynamics of promotions, transfers, separations, and other workforce behaviors. Focusing on the Prevention workforce, which operates as part of a larger workforce, added additional complexities. The simulation tool's ability to capture all these intricacies while remaining accessible and user-friendly is a complex, but important requirement.

Despite the potential value of the Athena Lite simulation tool, our findings indicate the current tool and our scenarios fall short in accurately representing the Prevention workforce's behavior. Unrealistic growth in personnel numbers, dramatic fluctuations in promotions, and high mean absolute percentage errors demonstrate the difficulty in accurately modeling the

workforce dynamics. The discrepancies observed in the simulation results indicate that our models are not effectively capturing the complexities of the USCG Prevention workforce. More work is necessary to determine if aspects of the workforce could be modeled in alternative ways. While the tool showed better performance at the start of the simulation period, its accuracy significantly decreased over longer time horizons. This indicates a need for further refinement and improvements to enhance the model's long-term forecasting capabilities.

The high mean absolute percentage error of 18% in our best scenario result highlights potentially limited utility, at this stage, of the simulation tool for effective workforce planning. With such a margin of error, the model's outputs may not provide reliable insights or serve as a capable decision-making tool for workforce planners without further development and work.

7.3 Recommendations and Areas of Refinement

To improve the performance and accuracy of the simulation tool and our scenarios, further research and development efforts are needed. This should involve refining the modeling assumptions and algorithms to better align with the specific behaviors and policies of the USCG Prevention workforce. Additionally, incorporating more detailed data and considering additional factors such as individual career paths, training programs, and specific workgroup dynamics could enhance the tool's fidelity and reliability. We provide a short list of areas that could be improved and further developed to enhance the tool's usefulness for workforce modeling efforts.

- Addressing the modeling of the up-or-out promotion system: A recurring challenge in our work was finding an appropriate method to model the up-or-out promotion system. The addition of a feature to allow the user to define wastage by time in level would eliminate the challenges in capturing this workforce dynamic. Wastage defined by time in level could accommodate prior-enlisted personnel and others with uncommon lengths of service.
- Refining the timing and logic of Athena Lite promotions to USCG promotions: Currently, the timing and logic of USCG promotions are not readily modeled in Athena Lite. Further development and work are needed to better align the promotion

schemes and time stepping of Athena Lite promotions with the USCG promotion system.

- Incorporating dynamic adjustments for time in postings: Transfers between positions in the Coast Guard generally take place each summer and any personnel who transfer outside this summer window have their tour lengths adjusted to realign with the summer cycle. The current simulation logic allows for a person to transfer at any time between the minimum and maximum time in posting inputs. Adding a feature to adjust posting lengths based on the summer transfer window or other constraint would result in more accurate supply numbers.
- Allowing for restrictions on immediate reassignment to the same posting: Athena Lite permits personnel who depart a posting after having reached the maximum allowable time in posting to be immediately reassigned to the same posting. A feature that enables the user to determine if immediate reassignment is allowed for an individual posting would improve the modeling of units and positions where this behavior is not permitted (e.g., arduous duty stations, Commanding Officer positions).
- Enabling the modeling of more detailed behavior with workgroup changes: One of the original project sponsor requests was to model each Prevention officer specialty code to understand more detailed behaviour of the Prevention workforce. In Chapter 2, we covered these training and career progression dynamics in detail. However, the simulation tool does not allow for personnel to transfer between workgroups. The ability to model transfers between workgroups would provide a more detailed understanding of the Prevention workforce. Although this capability exists in Athena Lite's companion software, Athena Pro, incorporating it into Athena Lite could enhance the accuracy of USCG workforce modeling.
- Integrating statutory caps on number of officers and grade distribution: The USCG officer workforce must remain under caps on the number of officers and grade distribution of those officers as laid out in [26]. Athena Lite is not able to enforce these caps on the simulated workforce, which may be a necessary feature as the Service adapts to recent changes in the maximum number of officers allowed.

It is worth noting that these features may already be available in Athena Lite's companion software, Athena Pro, and further research and exploration of the tool's capabilities may provide insights on the most appropriate Athena Lite use cases. Continued refinement and

development of Athena Lite could significantly enhance its value in modeling and analyzing the USCG Prevention workforce, as well as other workforce communities within the USCG.

There are a number of features we did not explore or use in this research. Some of these, such as platform transitions, were not appropriate for the Prevention workforce. Others, like optimization and health factors, were outside the scope of our research. Further work should be undertaken to understand the associated simulation logic and these features' appropriateness to simulating the USCG workforce. For example, further study of the platform transitions feature may prove worthwhile in simulating the USCG's small boat and shipboard workforces.

In our scenarios, we applied constant promotion percentages at each level. This approach treats all officers of the same level with the identical probability of being promoted. More research should be undertaken to understand if promotion percentages vary with time in level. It may be the case that promotion percentages vary based on time in level for some groups of officers, such as officers selected for continuation or those above zone. The results of this work could allow a workforce planner to more accurately simulate promotions in Athena Lite.

We recommend future work to address data limitations that posed constraints on our work and exploration of tool features. Ill-defined data fields required assumptions as to their meaning, which a data dictionary would alleviate. The absence of Prevention-specific promotion percentages necessitated numerous assumptions and impacted the quality of our results. We were unable to test the optimization features of the tool because of the lack of a prioritized position list. These data-related issues highlight the importance of comprehensive and accurate data for effective utilization of the simulation tool and underscore the need for improved data management practices in future workforce analysis efforts.

7.4 Conclusion

In conclusion, our work on understanding the dynamics of the USCG Prevention workforce and simulating scenarios using Athena Lite has provided valuable insights and identified areas for improvement. The challenges and limitations encountered highlight the complexities involved in military workforce planning and the use of simulation tools for decision-making purposes.

While our scenarios and analysis offer a starting point, there is a clear need for continued research and improvements to enhance the accuracy, performance, and practicality of the simulation models and tool in capturing the unique behaviors and dynamics of the Prevention workforce. These include addressing challenges related to modeling the up-or-out promotion system, refining the timing and logic of promotions, incorporating dynamic adjustments for time in postings, and enabling more detailed modeling of workgroup changes.

Furthermore, alongside simulation, leveraging data analysis to inform decision-making and forecast the future health of the Prevention workforce should be prioritized. The availability and analysis of vast human resources data can provide valuable insights for workforce planning efforts within the USCG.

The challenges encountered in our research serve as a reminder of the complexities involved in military workforce planning and the need for robust and tailored tools to support decision-making processes. While Athena Lite offers capabilities that can be useful, further research and development are necessary to fully leverage its potential and provide accurate and actionable insights for workforce planning within the USCG.

In summary, our work contributes to the understanding of the USCG Prevention workforce and the capabilities of Athena Lite as a simulation tool. It emphasizes the need for ongoing research, collaboration, and refinement to improve the accuracy and practicality of the tool and simulation model, ultimately supporting effective workforce planning and decision-making within the USCG.

APPENDIX A: Summary Statistics

Table A.1. USCG Data Summary Statistics

Name		Count	Mean	Standard Deviation	Median	Min.	Max.	
Prevention Personnel (Jan. 2017–Nov. 2022)								
Monthly Total by Grade	All	71	898.27	16.77	896	867	931	
	O1	71	79.96	14.33	81	54	103	
	O2	71	152.24	21.45	145	117	206	
	O3	71	328.89	28.74	331	266	390	
	O4	71	209.17	10.01	210	186	227	
	O5	71	102.01	5.32	103	85	111	
	O6	71	26.00	1.44	26	23	29	
January 2017 Snapshot Date	Length of Service (mos)	890	152.67	84.66	149	0	472	
	Time in Position (mos)	890	16.77	10.76	17	0	62	
	O1	59	8.37	4.78	8	0	16	
	O2	137	14.96	8.90	14	0	37	
	Time in Grade (mos)	O3	369	40.64	25.80	43	0	127
	O4	189	39.70	26.34	37	3	127	
	O5	111	30.27	21.35	28	1	78	
	O6	25	44.28	28.87	30	6	102	
Monthly Inflow of O1–O3 Officers		71	8.51	11.15	3	0	51	
Prevention Positions (Jan. 2017–Nov. 2022)								
Monthly Total by Grade	All	71	880.97	2.06	881	877	886	
	O1	NA	NA	NA	NA	NA	NA	
	O2	71	202.49	0.61	203	201	204	
	O3	71	330.62	1.03	331	329	332	
	O4	71	209.24	2.34	209	206	215	
	O5	71	112.62	1.02	112	111	114	
	O6	71	26.00	0.00	26	26	26	

Statistics calculated from [21], [22], [47], [48]. See Sections 4.3 and 6.2 for details.

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APPENDIX B: USCG Simulation Model Inputs

All the necessary inputs for the USCG simulation model have been compiled and included in Appendix B for convenience. Please note that some inputs may be repeated from Chapter 6 for clarity and ease of reference. See Section 6.2 for calculation details.

Table B.1. USCG Workforce Scenario-Specific Inputs

Input	Scenarios					
	A.1	A.2	B.1	B.2	B.3	B.4
Wastage						
General Wastage. <i>See Table B.3 for percentages.</i>	✓		✓		✓	✓
Level-Specific Wastage. <i>See Table B.4 for percentages.</i>		✓		✓		
Promotions						
Promotion Configuration:						
Set 1	✓	✓				
Set 2			✓	✓		
Set 3					✓	
Set 4						✓

See Table B.5 for details of Promotion Configuration Sets.

Table B.2. All Scenarios – Portion of Initial Personnel Input

Workgroup	Level	Unit	Length of Service (mos)	Time in Level (mos)	Time in Posting (mos)
Prevention	O5	36597	246	62	29
Prevention	O5	7517	290	15	6
Prevention	O5	9100	234	40	5
Prevention	O3	7725	243	20	29
Prevention	O5	8269	435	39	29
Prevention	O5	46014	285	16	17
Prevention	O4	45412	223	99	16
Prevention	O3	8369	280	68	19
Prevention	O5	8252	472	50	29

Table B.3. General Wastage. Adapted from [46].

Length of Service (mos)	Wastage (%)	Length of Service (mos)	Wastage (%)
0-11	0.00	252-263	16.42
12-23	0.22	264-275	17.02
24-35	0.00	276-287	16.32
36-47	0.00	288-299	14.69
48-59	0.00	300-311	15.00
60-71	2.99	312-323	16.08
72-83	1.98	324-335	25.88
84-95	1.68	336-347	19.66
96-107	1.74	348-359	18.15
108-119	1.66	360-371	31.76
120-131	1.31	372-383	21.07
132-143	2.03	384-395	25.51
144-155	1.36	396-407	18.37
156-167	0.94	408-419	27.37
168-179	0.55	420-431	9.05
180-191	0.25	432-443	39.60
192-203	0.30	444-455	35.71
204-215	0.16	456-467	38.24
216-227	0.89	468-479	31.58
228-239	1.51	480-491	0.00
240-251	23.56	492-503	50.00
		504	100.00

Table B.4. Level-Specific Wastage

Length of Service (mos)	Level-Specific Wastage Percentage (%)					
	O1	O2	O3	O4	O5	O6
0-12	6.29	0.00	6.78	1.69	0.00	0.00
13-24	10.58	11.05	0.00	0.00	0.00	0.00
25-36	4.30	12.80	0.00	0.00	0.00	0.00
37-48	7.34	10.54	0.00	8.47	0.00	0.00
49-60	100.00	26.28	24.52	0.00	0.00	0.00
61-72	100.00	19.79	21.01	0.00	0.00	0.00
73-84	100.00	100.00	11.91	0.00	0.00	0.00
85-96	100.00	100.00	18.75	6.78	0.00	0.00
97-108	100.00	100.00	15.57	0.00	0.00	0.00
109-120	100.00	100.00	13.39	10.17	0.00	0.00
121-132	100.00	100.00	22.13	8.03	0.00	0.00
133-144	100.00	100.00	20.36	9.73	0.00	0.00
145-156	100.00	100.00	100.00	4.80	8.47	0.00
157-168	100.00	100.00	100.00	10.38	1.69	0.00
169-180	100.00	100.00	100.00	7.48	18.64	0.00
181-192	100.00	100.00	100.00	12.84	0.00	0.00
193-204	100.00	100.00	100.00	8.39	8.77	0.00
205-216	100.00	100.00	100.00	14.77	12.89	0.00
217-228	100.00	100.00	100.00	12.32	18.33	0.00
229-240	100.00	100.00	100.00	43.38	25.99	0.00
241-252	100.00	100.00	100.00	100.00	26.84	1.69
253-264	100.00	100.00	100.00	100.00	41.17	17.51
265-276	100.00	100.00	100.00	100.00	32.52	2.26
277-288	100.00	100.00	100.00	100.00	100.00	5.08
289-300	100.00	100.00	100.00	100.00	100.00	26.90
301-312	100.00	100.00	100.00	100.00	100.00	21.78
313-324	100.00	100.00	100.00	100.00	100.00	43.83
325-336	100.00	100.00	100.00	100.00	100.00	37.23
337-348	100.00	100.00	100.00	100.00	100.00	19.32
349-360	100.00	100.00	100.00	100.00	100.00	28.64
361-504	100.00	100.00	100.00	100.00	100.00	100.00

Table B.5. Promotion Configuration Sets

Promotion Set	Promotion From Level	Time Step	Promotion Scheme	Promotion Percentage (%)
1	O1	1 Month	Push	99
	O2	1 Month	Push	85
	O3	1 Month	Pull	71
	O4	1 Month	Pull	65
	O5	1 Month	Pull	57
2	O1	1 Month	Push	99
	O2	1 Month	Push	85
	O3	1 Month	Push	71
	O4	1 Month	Push	65
	O5	1 Month	Push	57
3	O1	1 Month	Push	8.25
	O2	1 Month	Push	7.08
	O3	1 Month	Pull	5.92
	O4	1 Month	Pull	5.42
	O5	1 Month	Pull	4.75
4	O1	6 Months	Push	49.5
	O2	1 Year	Push	85.0
	O3	1 Month	Pull	5.92
	O4	1 Month	Pull	5.42
	O5	1 Month	Pull	4.75

Table B.6. All Scenarios – Minimum Time in Level Input

Level	Min. Time in Level (mos)
O1	18
O2	30
O3	36
O4	48
O5	48

Table B.7. All Scenarios – Portion of Time in Posting Input

Workgroup	Level	Unit	Minimum Time in Posting (mos)	Standard Time in Posting (mos)	Maximum Time in Posting (mos)
Prevention	O1	543	12	36	48
Prevention	O2	543	12	36	48
Prevention	O3	543	12	36	48
Prevention	O4	543	12	36	48
Prevention	O5	543	12	36	48
Prevention	O6	543	12	36	48
Prevention	O1	594	12	36	48
Prevention	O2	594	12	36	48
Prevention	O3	594	12	36	48

Table B.8. All Scenarios – Portion of Personnel Requirement Input

Workgroup	Level	Unit	Time	Priority 1 Req.
Prevention	O2	543	0-70	9
Prevention	O2	594	0-25	1
Prevention	O2	594	49-55	1
Prevention	O2	670	0-70	3
Prevention	O2	6271	5-70	18
Prevention	O2	6271	0-4	11
Prevention	O2	6282	0-28	1
Prevention	O2	7103	0-70	11
Prevention	O2	7184	0-70	6

Table B.9. All Scenarios – One Year Portion of Personnel Inflow Input

Workgroup	Level	Initial Length of Service (mos)	Time	Number of Personnel
Prevention	O1	69	0	6
Prevention	O1	15	1	2
Prevention	O1	70	4	4
Prevention	O2	39	4	1
Prevention	O3	102	4	4
Prevention	O1	68	5	24
Prevention	O2	45	5	4
Prevention	O3	134	5	9
Prevention	O1	70	6	5
Prevention	O2	48	6	17
Prevention	O3	121	6	9
Prevention	O1	6	7	5
Prevention	O2	49	7	3
Prevention	O3	142	7	1
Prevention	O1	49	8	1
Prevention	O2	64	8	1
Prevention	O3	99	8	1
Prevention	O1	84	11	18
Prevention	O1	69	12	6

Table B.10. All Scenarios – Personnel Outflow Input

Workgroup	Level	Time	Number of Personnel	Description
Prevention	O6	6	1	Promotion_to_RDML
Prevention	O6	18	1	Promotion_to_RDML
Prevention	O6	30	1	Promotion_to_RDML
Prevention	O6	42	1	Promotion_to_RDML
Prevention	O6	54	1	Promotion_to_RDML
Prevention	O6	66	1	Promotion_to_RDML

APPENDIX C: Additional Results of USCG Scenarios

C.1 Scenario A.2

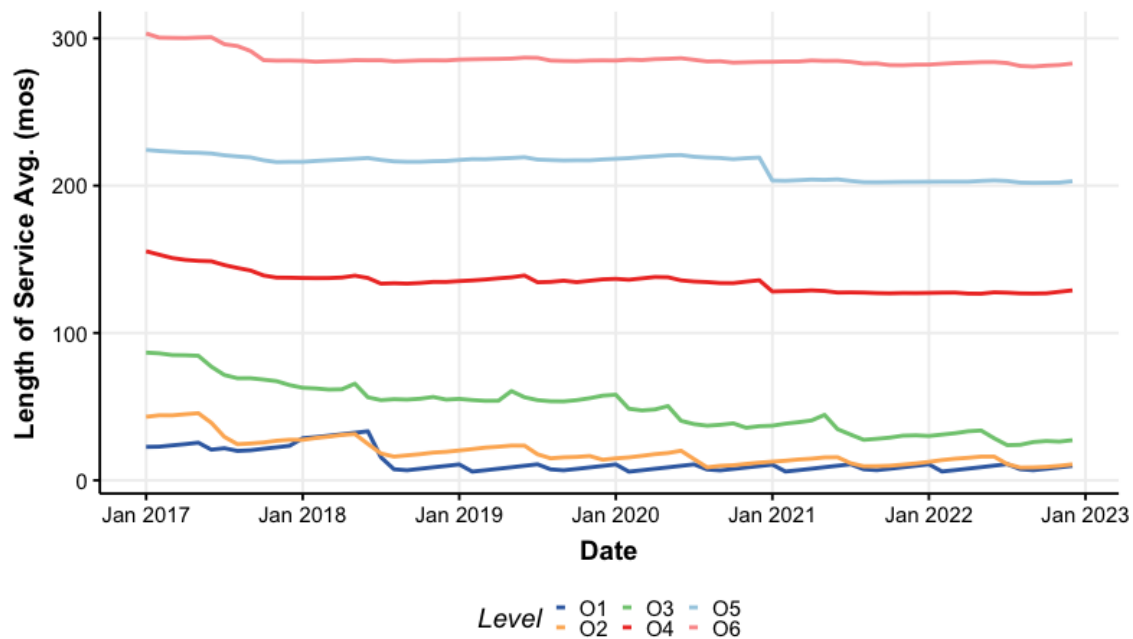


Figure C.1. Scenario A.2 – Simulation Results Length of Service

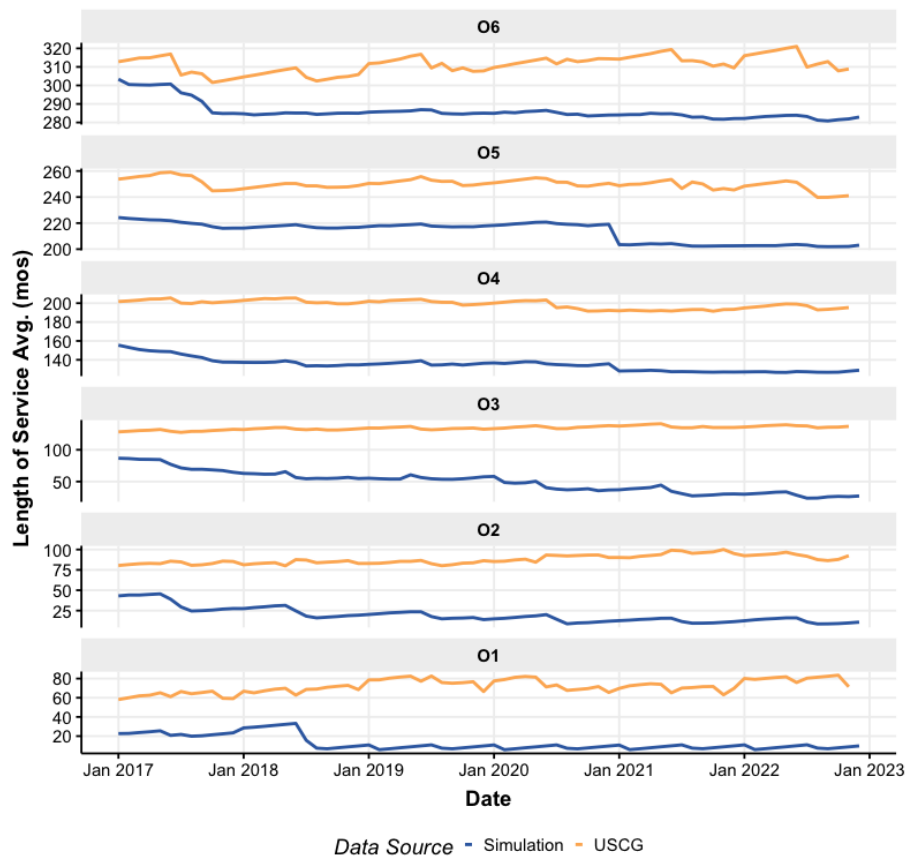


Figure C.2. Scenario A.2 – Simulation Results and USCG Data Length of Service Comparison

Table C.1. Scenario A.2 Model Accuracy (%)

Year	Level						All Levels
	O1	O2	O3	O4	O5	O6	
2017	50.07	41.18	53.28	7.28	5.57	4.65	27.00
2018	80.70	44.44	67.74	3.98	5.88	3.83	34.43
2019	88.75	47.56	74.22	5.96	3.75	6.67	37.82
2020	89.51	61.07	79.15	11.99	8.93	2.79	42.24
2021	88.66	68.59	81.23	35.08	10.45	3.15	47.86
2022	85.79	71.05	82.34	45.22	14.22	4.75	50.56
All Years	80.51	55.43	72.86	17.87	8.05	4.30	39.80

Each entry in the table represents the MAPE calculation corresponding to the specific Year and Level combination.

C.2 Scenario B.1

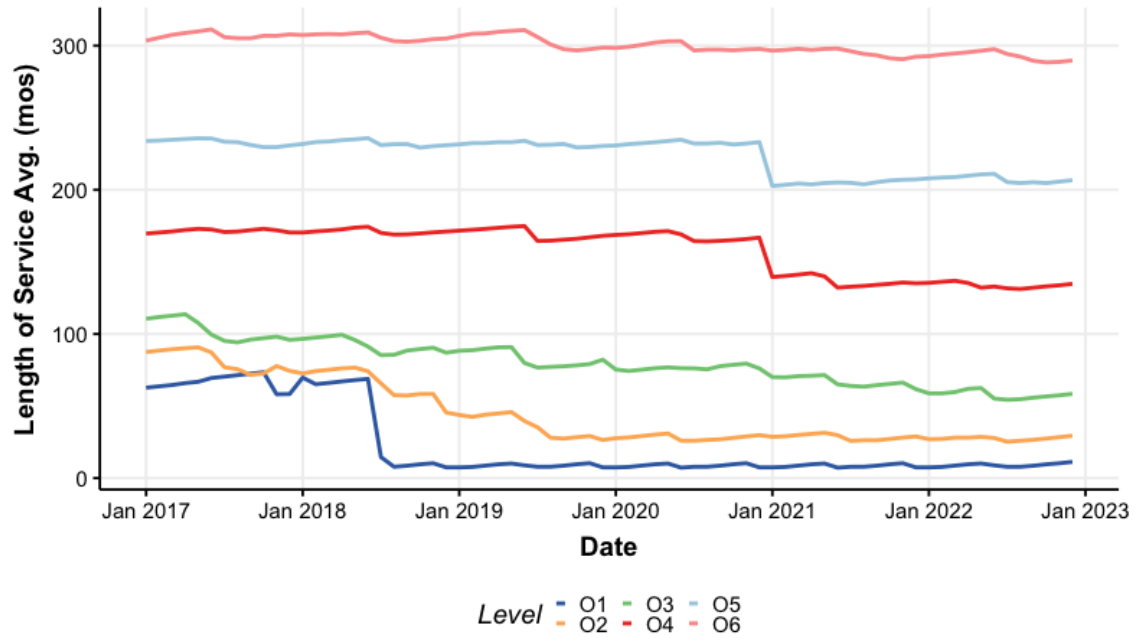


Figure C.3. Scenario B.1 – Simulation Results Length of Service

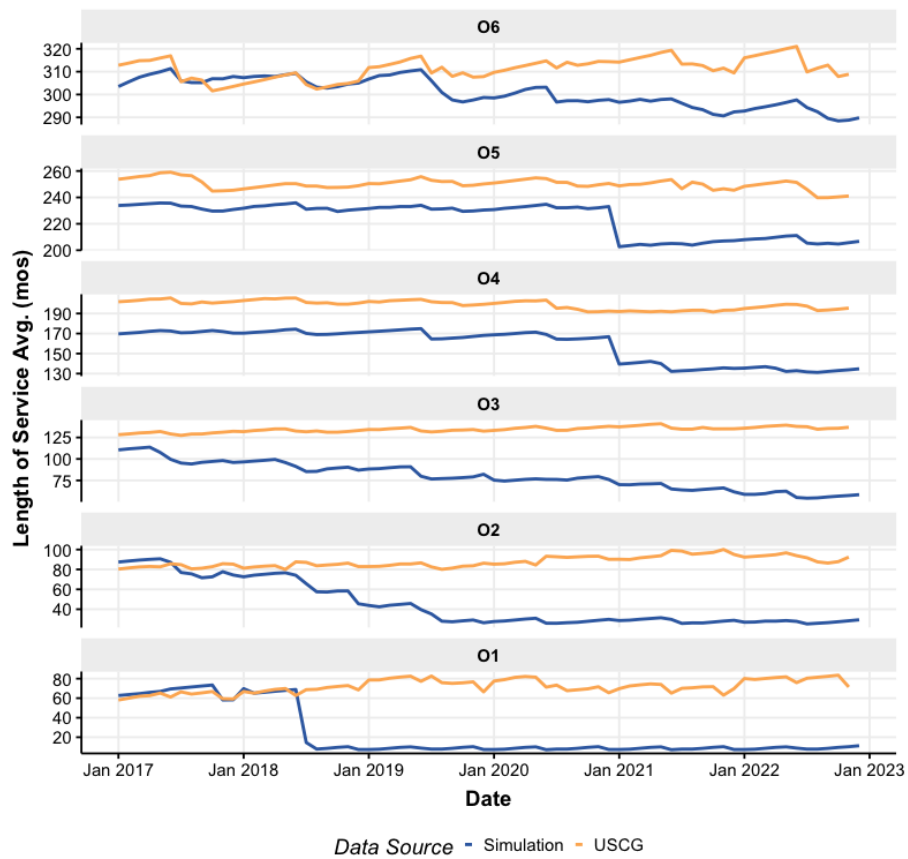


Figure C.4. Scenario B.1 – Simulation Results and USCG Data Length of Service Comparison

Table C.2. Scenario B.1 Model Accuracy (%)

Year	Level						All Levels
	O1	O2	O3	O4	O5	O6	
2017	16.89	3.12	44.23	59.33	41.74	83.75	41.51
2018	29.32	13.85	41.36	65.32	51.55	107.59	51.50
2019	11.29	35.58	35.76	68.32	55.69	135.44	57.01
2020	4.72	36.15	27.29	76.91	50.27	149.82	57.53
2021	12.74	31.28	17.37	17.52	153.61	321.96	92.41
2022	40.10	16.51	7.00	17.93	194.42	326.42	100.40
All Years	18.88	22.83	29.14	51.35	89.76	185.54	66.30

Each entry in the table represents the MAPE calculation corresponding to the specific Year and Level combination.

C.3 Scenario B.2

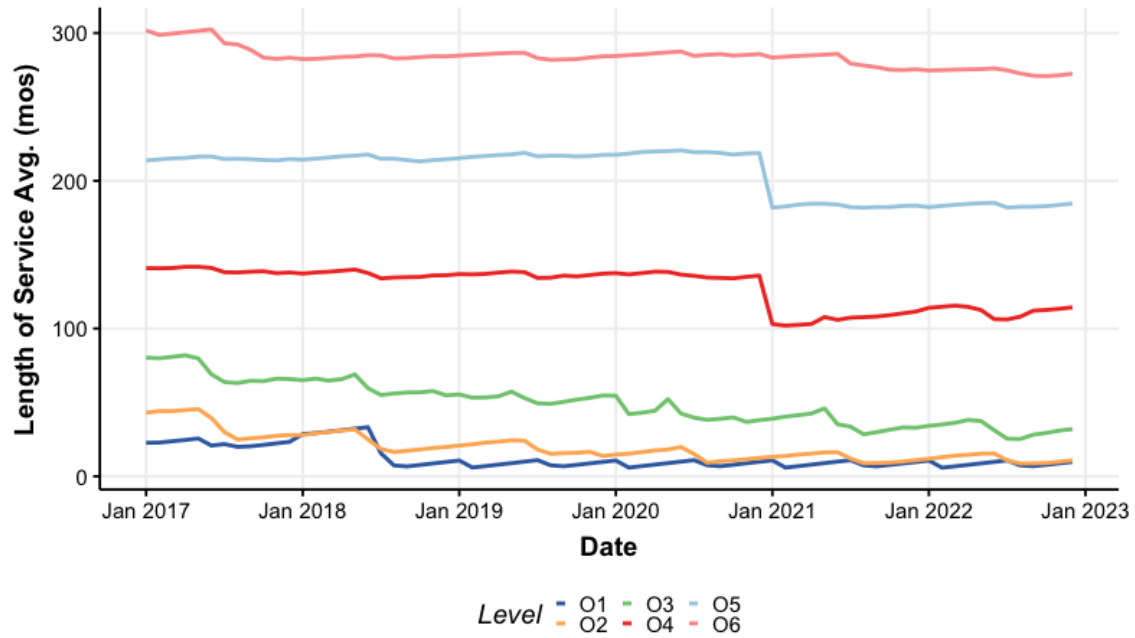


Figure C.5. Scenario B.2 – Simulation Results Length of Service

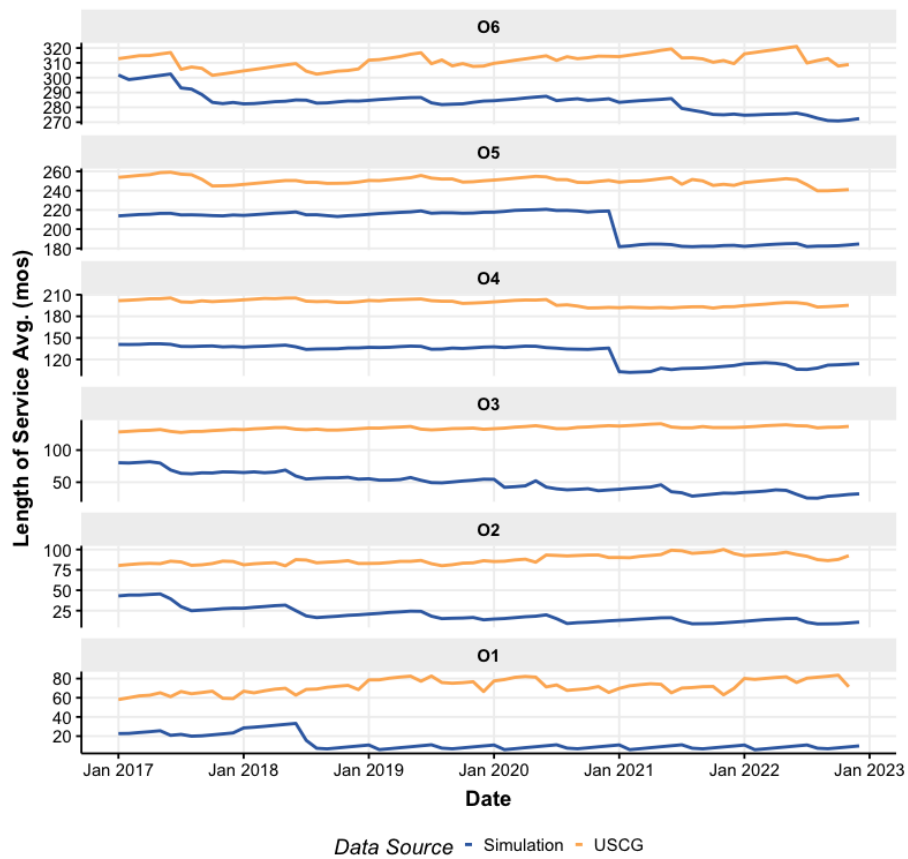


Figure C.6. Scenario B.2 – Simulation Results and USCG Data Length of Service Comparison

Table C.3. Scenario B.2 Model Accuracy (%)

Year	Level						All Levels
	O1	O2	O3	O4	O5	O6	
2017	50.23	40.81	59.51	13.24	9.89	43.33	36.17
2018	80.78	43.72	68.87	5.38	3.15	42.36	40.71
2019	88.60	47.81	73.90	3.88	5.09	52.69	45.33
2020	89.35	60.39	79.11	9.29	14.35	52.44	50.82
2021	88.82	66.95	81.53	57.06	41.86	125.89	77.02
2022	85.78	71.20	82.54	68.27	51.20	127.51	81.09
All Years	80.52	54.92	74.13	25.60	20.50	73.28	54.80

Each entry in the table represents the MAPE calculation corresponding to the specific Year and Level combination.

C.4 Scenario B.3

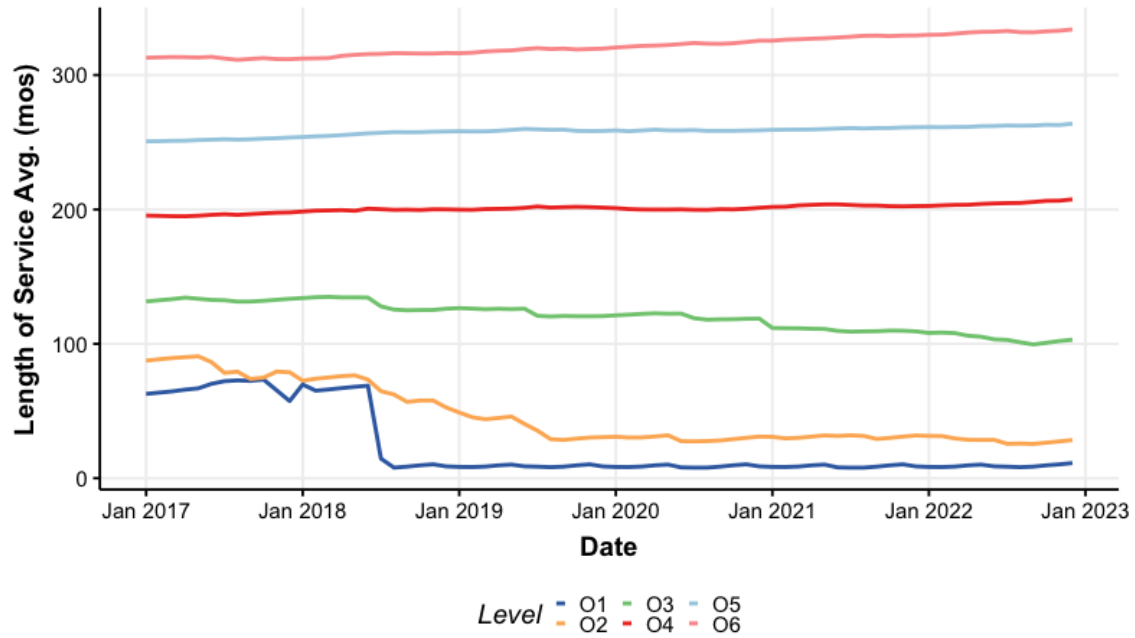


Figure C.7. Scenario B.3 – Simulation Results Length of Service

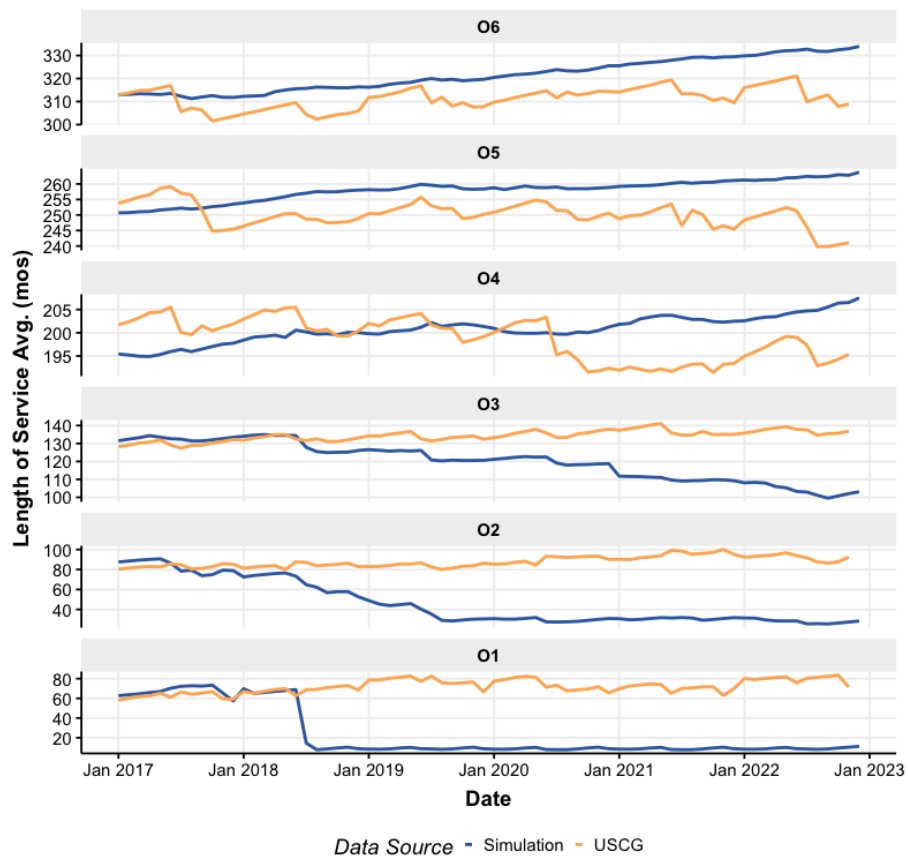


Figure C.8. Scenario B.3 – Simulation Results and USCG Data Length of Service Comparison

Table C.4. Scenario B.3 Model Accuracy (%)

Year	Level						All Levels
	O1	O2	O3	O4	O5	O6	
2017	20.94	3.21	7.83	7.31	5.57	4.65	8.25
2018	29.65	17.04	15.91	3.93	9.00	3.83	13.23
2019	14.81	33.95	29.85	0.67	12.06	6.95	16.38
2020	7.63	36.71	45.89	2.60	14.12	3.67	18.44
2021	14.53	31.89	75.55	5.20	9.53	3.11	23.30
2022	44.83	17.59	107.20	3.12	14.23	4.75	31.95
All Years	21.74	23.48	46.19	3.82	10.70	4.49	18.40

Each entry in the table represents the MAPE calculation corresponding to the specific Year and Level combination.

C.5 Scenario B.4

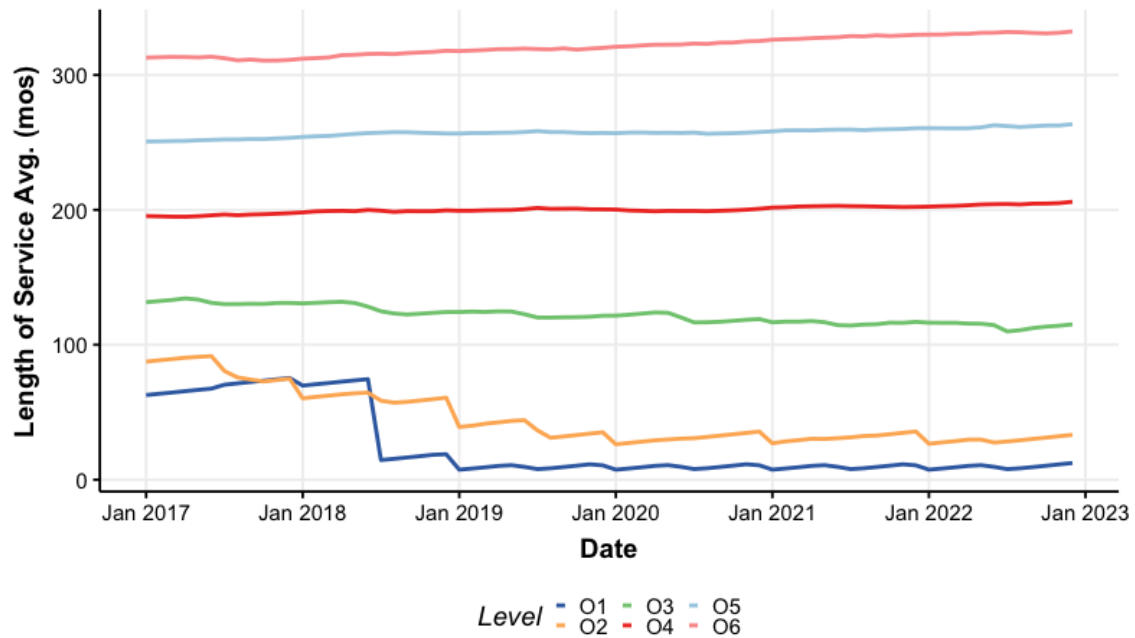


Figure C.9. Scenario B.4 – Simulation Results Length of Service

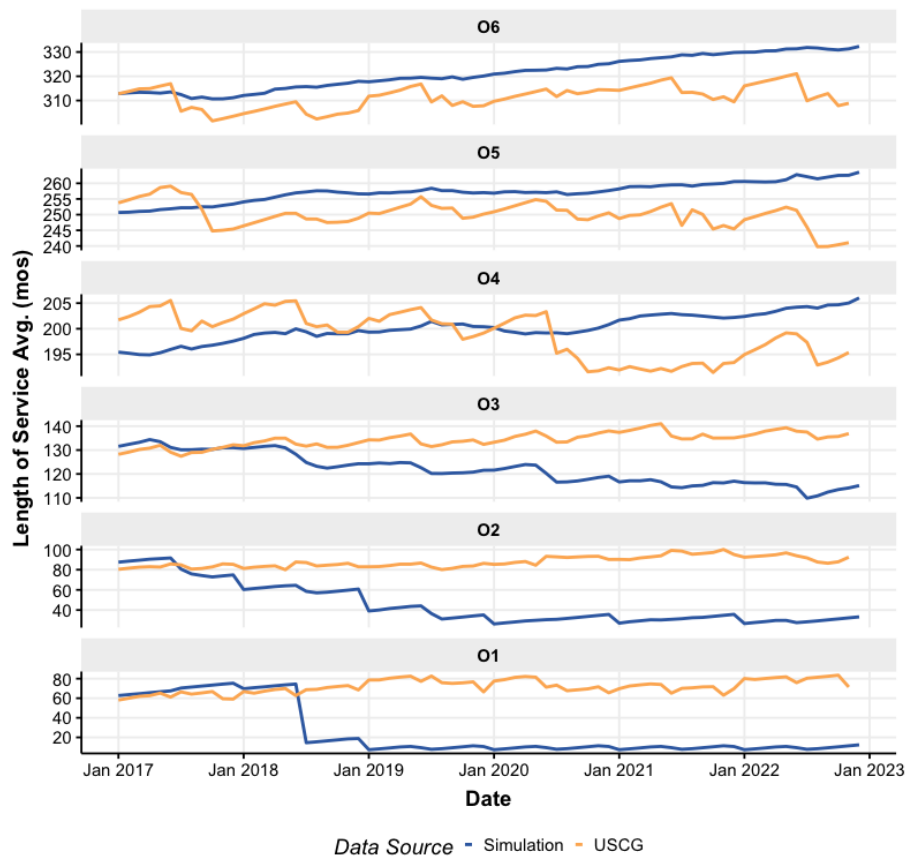


Figure C.10. Scenario B.4 – Simulation Results and USCG Data Length of Service Comparison

Table C.5. Scenario B.4 Model Accuracy (%)

Year	Level						All Levels
	O1	O2	O3	O4	O5	O6	
2017	22.03	12.22	4.39	7.31	5.57	4.65	9.36
2018	36.76	28.73	10.19	3.93	9.03	3.83	15.41
2019	20.71	40.81	25.10	0.67	12.06	6.95	17.72
2020	13.21	41.11	41.00	2.60	14.12	3.67	19.28
2021	20.24	43.17	65.94	5.20	9.53	3.11	24.53
2022	50.83	26.48	98.44	3.12	14.20	4.75	32.97
All Years	26.96	32.16	40.03	3.82	10.70	4.49	19.70

Each entry in the table represents the MAPE calculation corresponding to the specific Year and Level combination.

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