



ACQUISITION RESEARCH PROGRAM SPONSORED REPORT SERIES

Employing Markov Models to Forecast the End Strength of the US Navy Supply Corps Financial Management (3111) Community

June 2022

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Prepared for the Naval Postgraduate School, Monterey, CA 93943

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ABSTRACT

The Navy Supply Corps has a wide array of Subspecialties (SSP) and Additional Qualification Designations (AQD) that define an officer's skillset/experience and billet requirements. Current planning by the Supply Corps' Office of Personnel (OP) assumes identical retention rates across all SSP/AQD combinations. This strategy may lead to unanticipated effects when changes to policy occur.

Our research applies the Markov model to manpower data obtained from OP to analyze the current and forecasted end strength of the Supply Corps' Financial Management (FM) community. This research addresses the following questions: 1) What are the forecasted end strengths for Navy Supply Corps Officers with FM experience and qualifications? 2) Does the FM community's current billet structure create enough FM officers to achieve OP's inventory goal of 2.5 times the number of qualified FM officers per FM billet at the O5-O6 level?

We find that if the Supply Corps' FM community continues along its current manpower trajectory, OP will likely never achieve its inventory goal for the community. However, our models provide multiple ways through which OP can achieve its O5-O6 inventory goals over time.



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LIST OF ACRONYMS AND ABBREVIATIONS

AKC	acquisition coded critical—financial management
AQD	additional qualification designator
AWF	acquisition workforce
BFM	business financial management
BtB	back to basics
BUS-FM	business financial management
BUPERS	Bureau of Naval Personnel
DASN-P	Deputy Assistant Secretary of the Navy (Procurement)
DAU	Defense Acquisition University
DAWIA	Defense Acquisition Workforce Improvement Act
DOD	Department of Defense
FM	financial management
FY	fiscal year
LDO	limited duty officer
MBA	Master of Business Administration
NAVSUP	Naval Supply Systems Command
NPC	Naval Personnel Command
NPS	Naval Postgraduate School
NROTC	Navy Reserve Officer Training Corps
OCM	Officer Community Manager
OP	Office of Personnel
OPNAV	Office of the Chief of Naval Operations
POCR	probationary officer continuation and re-designation
SC	Supply Corps
SCM	supply chain management
SSP	subspecialty code
USD A&S	Under Secretary of Defense for Acquisition and Sustainment
USNA	United States Naval Academy



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I. INTRODUCTION

A. PURPOSE

The purpose of this MBA project is to develop a Markov model to forecast the end strength for Navy Supply Corps officers with experience in the Business and Financial Management (FM) community. The Markov model will also be used to analyze continuation rates and make recommendations to the Supply Corps' Office of Personnel (OP) to achieve end strength goals. We seek to answer two primary questions:

1. What are the forecasted end strengths for Navy Supply Corps officers with FM experience and qualifications?
2. Does the FM community's current billet structure create enough FM officers to achieve OP's inventory goal of 2.5 times the number of qualified FM officers per FM billet at the O5-O6 level?

B. BACKGROUND

The United States Navy Supply Corps (SC) has designated FM as a complementary line of operation because it is a valued skillset (Office of Supply Corps Personnel, 2010). According to OP, the SC is responsible for filling 37 percent of the Navy's FM billets (Office of Supply Corps Personnel, 2010). Ensuring the SC produces FM officers with the correct skillsets, associated subspecialty codes (SSPs) and additional qualification designators (AQDs) to fill critically coded billets requires an understanding of the training, education, and experience pipelines of the financial management competency. Currently, OP lacks clarity on the effectiveness of its training and education pipeline in filling these critical billets. An analysis is necessary to determine if the current pipelines and billet structures are adequate for the needs of an increasingly dynamic SC.

The SC uses AQDs to define an officer's experience. AQDs are added to an officer's record following certain "coded" tours or upon obtaining a professional certification. The FM AQDs require more time in coded billets to earn the highest level of



certification. While other professional certification AQDs require four years of experience, FM requires six years.

C. SCOPE AND METHODOLOGY

The goal of this MBA project is to develop a Markov model to forecast future inventory levels of SC officers with FM qualifications. Current manpower planning by OP assumes identical retention rates across all SSP and AQD combinations. The scope of this research is limited to Navy Supply Corps officers within the FM community—specifically, those with 3110/3111/3112/3113 SSPs and AK1/2/3 AQDs, between the ranks of Ensign (O1) and Captain (O6). We use data from OP to identify all coded FM billets at the O5 and O6 levels, and to determine current and historic inventory levels.

D. CONCLUSION AND RECOMMENDATIONS

If the Supply Corps' FM community continues along its current manpower trajectory, taking into consideration historical accession, promotion, and attrition rates, by 2031 the community will achieve an end strength of 297 SC officers. With current inventory at 296, we observe that the FM community is operating in a near steady state. The SC has averaged 32 annual accessions into the 3111 community over the past ten years. If this trend continues, the FM community is highly unlikely to reach OP's goal of 2.5 3111QR-qualified O6s for every 3111 O6 billet. To achieve this goal, we recommend implementing a hybrid approach of adding new entry-level billets while also increasing the number of follow-on tour opportunities for officers with 3111S and 3110P codes. This approach is most likely to create a training pipeline for the 3111 community that culminates in a steady state inventory that achieves OP's inventory goal.

E. ORGANIZATION OF STUDY

The introduction chapter summarizes the purpose, background, scope and methodology, and conclusion/recommendations of this MBA project. Chapter II provides background on the SC community, including an in-depth look at the SC's FM community. Chapter III examines the evolution of the Markov model and reviews literature on military and civilian studies. Chapter IV illustrates the data and methodology used to develop the



Markov models. Chapter V demonstrates various ways to employ Markov models to reach a desired end state for the FM community. Chapter VI discusses our conclusion, recommendations, and considerations for future research studies to be conducted.



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II. BACKGROUND

A. SUPPLY CORPS CAREER DEVELOPMENT

As SC officers progress throughout their careers, success is often based on a combination of job performance, reputation, tour quality, and developed skillsets. These skills can be earned through job rotations, qualifications, assignments, or education (Office of Supply Corps Personnel, 2011). Job rotations are valuable because they allow SC officers to become experts in one or more core competencies, ultimately providing SC officers with a broader view of how logistics impact operations across many levels of the Department of Defense (DOD). Qualifications are professional achievements that may take the form of SSPs or AQDs and are earned through experience, education, and formal training within the acquisition community. By varying assignments, SC officers can either diversify their skillsets or become experts in a chosen skillset. Significant experience in one or more of the SC's core competency areas is often a prerequisite to filling senior logistics management positions.

1. Career Stages

From the ranks of O1 through O3, junior SC officers develop an understanding of how they support the Navy and DOD at the tactical level (Office of Supply Corps Personnel, 2011). This is achieved through an officer's first operational tour, whether as a division officer or a department head across various platforms, including the expeditionary community. Following this tour, a SC officer rotates to an experience tour ashore. This is normally a general shore duty billet or an internship. At this stage, a SC officer develops supply-related experience in the form of SSPs and AQDs and begins learning the basics behind one or more of the SC's major core competencies (Office of Supply Corps Personnel, 2011). Following a successful shore duty tour, a SC officer completes a second operational tour to develop additional proficiency at the tactical or developmental level. After completion of a second operational tour, postgraduate education is strongly recommended, preferably within one of the SC's core competency areas.



From the ranks of Lieutenant Commander (O4) to Commander (O5), Supply Corps officers utilize their postgraduate and junior officer experience to become logistics professionals and fill key leadership positions within the community (Office of Supply Corps Personnel, 2011). Any SSPs or AQDs earned as a junior officer are beneficial at this stage, as an officer continues to build upon existing knowledge within a certain competency. Figure 1 shows important milestones through a traditional SC career path.

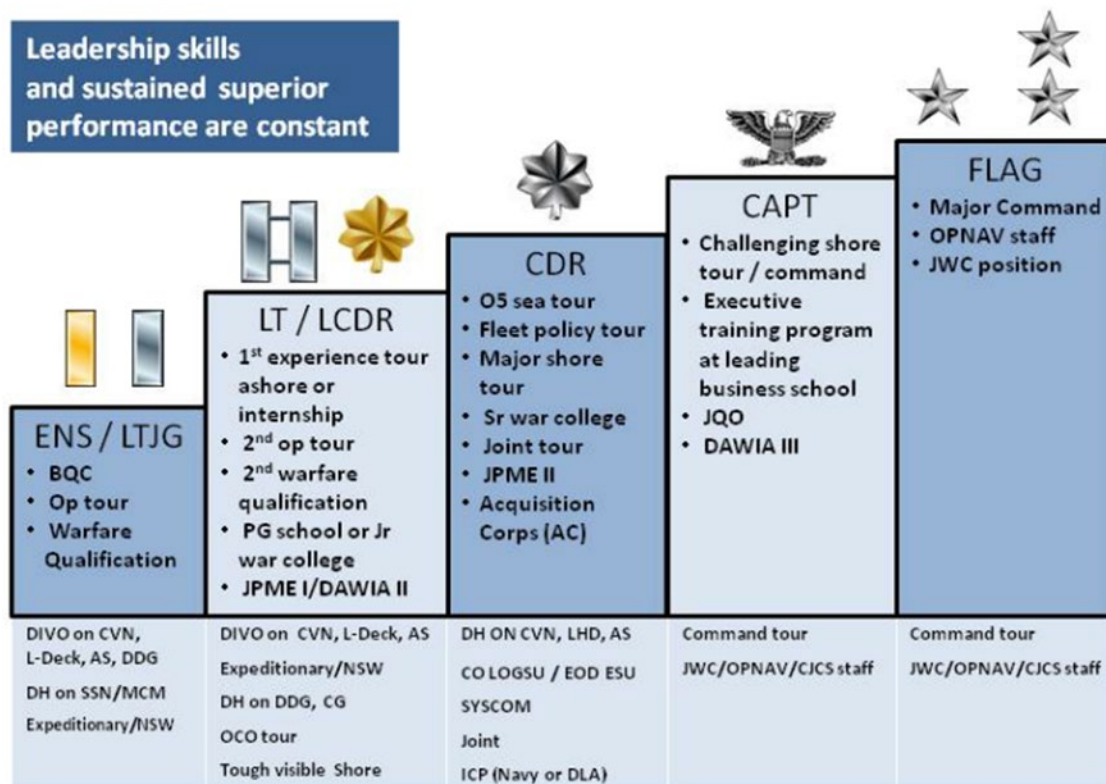


Figure 1. Career Milestones. Source: Office of Supply Corps Personnel (2011).

2. Education Timeline

The Supply Corps prides itself on providing its officers with the education necessary to achieve the professional growth required for the community to excel. The Supply Corps Office of Personnel's (OP) *It's Your Career Playbook* breaks down an officer's general education timeline as follows: "basic technical development and

leadership; advanced technical proficiency and leadership; and senior officer development and leadership” (Office of Supply Corps Personnel, 2011, p.10). Commissioned Navy SC officers attend Navy Supply Corps School (NSCS) before their first operational assignment. Although NSCS does not offer any SSPs or AQDs, the Supply Corps officer Basic Qualification Course prepares SC officers for their initial fleet (operational) assignments.

Postgraduate opportunities are also made available to SC officers. According to Supply Corps OP’s *It’s Your Education* playbook, officers are selected for postgraduate education programs via an administrative screening board (Office of Supply Corps Personnel, 2021a). If selected, SC officers are afforded the opportunity to attend a nationally ranked U.S. business school (810/811 program), Naval Postgraduate School (NPS), Naval War College, or other intermediate service colleges. Once accepted into a nationally ranked program, 810 program selectees enter a full-time Master of Business Administration (MBA) program, and upon graduation are awarded a 1301P subspecialty code for supply chain management (SCM). Candidates selected for the 811 program for petroleum management attend the University of Kansas Graduate School of Business to earn an MBA, a certificate in petroleum management, and a 1307P (fuels) subspecialty code. Candidates selected for NPS are eligible to participate in several MBA programs offered through the Department of Defense Management. NPS differs from the 810/811 programs because a candidate is eligible to study curriculums outside of SCM and petroleum management. Table 1 shows the various SC curriculums available at NPS.



Table 1. Curriculums Available to SC Officers at NPS. Source: Office of Supply Corps Personnel (2021a).

Curriculum title	Number	Length	Convening dates	Min APC	Subspecialty code
Operations Research -Logistics Analysis	361	27m	Winter/ Summer	325	3212P
Acquisition & Contract Mgmt	815	18m	Winter/ Summer	345	1306P
Supply Chain Mgmt	819	18m	Winter/ Summer	345	1302P
Financial Mgmt	837	18m	Winter/ Summer	345	3110P
Information Mgmt	870	18m	Summer	345	1309P

The FM curriculum (837) is an 18-month program that convenes twice per calendar year. Supply Corps officers who successfully complete this program earn a 3110P subspecialty upon graduating.

B. FINANCIAL MANAGEMENT COMMUNITY

Supply Corps OP's *It's Your Experience* playbook explains that SC officers with FM expertise are vital to the community because of their ability to align financial and physical resources with the Navy's goals (Office of Supply Corps Personnel, 2011). The financial management community manages appropriated and working capital funds and disperses into three interrelated sub-functional areas. These disciplines include business financial management (BFM), financial management (FM), and comptroller (Office of Supply Corps Personnel, 2011).

Supply Corps officers assigned to BFM billets act as key business advisors to Navy Program Managers, specifically within the realm of cost analysis and financial management. Within the sub-functional area of FM, SC officers support multiple comptroller functions, including budget formulation, funds management, and funds execution. Lastly, within the sub-functional area of comptroller, SC officers are responsible



for “maintain[ing] cognizance over all financial planning, programming, budgeting, accounting, allocation, control, and execution of resources and funds for DOD organizations” (Office of Supply Corps Personnel, 2011, p. 9). Currently, there are 127 coded FM billets throughout the SC, ranging from Lieutenant Junior Grade (O2) to Captain (O6). Figure 2 shows the current breakdown of all coded financial management billets by rank.

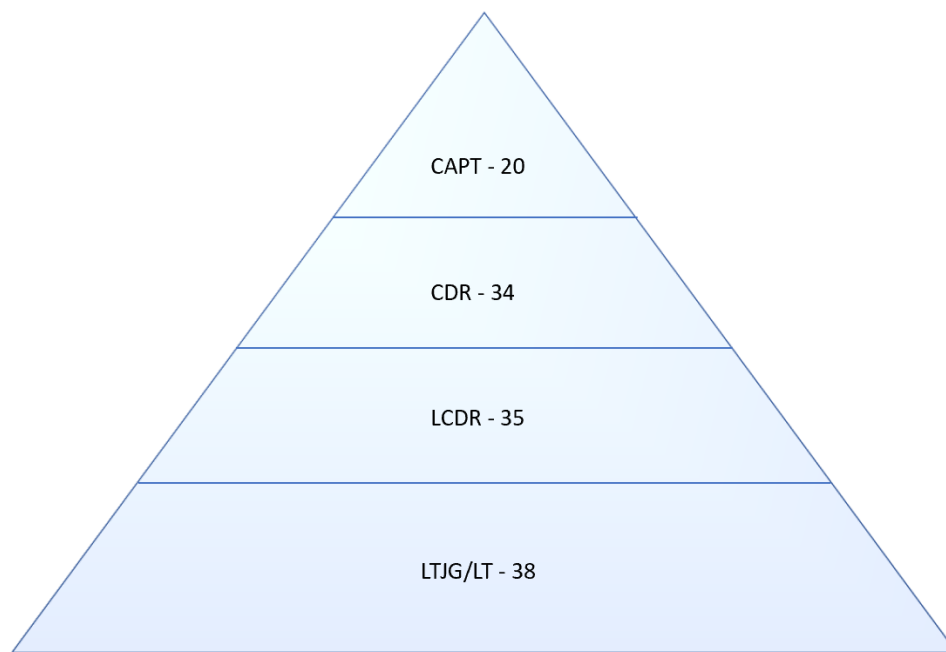


Figure 2. Supply Corps FM Billets by Rank

1. Subspecialty Codes/Additional Qualification Designators

The Navy Supply Corps emphasizes that its junior officers earn SSPs and AQDs whenever possible. SSPs reflect professional disciplines acquired through formal education, functional training, and experience and are aligned with the SC’s principal competencies (Office of Supply Corps Personnel, 2021b). SC officers can earn SSPs through three channels: the SC’s internship program, postgraduate education, or serving in a coded billet. Additionally, Supply Corps officers serving in general billets who believe they have obtained sufficient experience in a subspecialty may submit a request for “non-coded experience credit” to the Officer Community Manager (OCM) for consideration. For

example, officers requesting non-coded experience credit for FM may submit a request for a 3110/3111 subspecialty code. The OCM forwards the request to OPNAV N8 for review and approval, as OPNAV N8 is considered the subject matter expert and adjudicator for all officers requesting this subspecialty (United States Navy Personnel Command, 2022). The SSPs that pertain to the FM community include: 3110 (Financial Management—Advanced Defense Focus [Executive MBA]); 3111 (Financial Manager); 3112 (Comptroller); and 3113 (Financial Management—Energy). Table 2 shows the full list of SSPs available for SC officers.

Table 2. Subspecialty Codes for Supply Corps officers in *It's Your Record Playbook*. Source: Office of Supply Corps Personnel (2021b).

1301—Supply Acquisition, Distribution Management
1302—Supply Inventory/Supply Chain Management
1304—Transportation Logistics Management
1306—Acquisition and Contract Management
1307—Petroleum Management
1309—Logistics Information Technology
2000—National Security Studies (War College)
3000—Resource Management and Analysis—General
3110/1/2/3—Financial Management
3121/2—Logistics and Transportation Management
3210/1/2/3—Operations Research Analysis
4000—General Applied Disciplines
6511—Requirements Management

In addition to the numbered SSPs shown in Table 2, a suffix (letter) is added to a subspecialty code to represent a specific level of qualification. The most commonly seen subspecialty codes in the SC include S, R, T, P, and Q:

- S Code: earned by an officer who completes at least 18 consecutive months in a subspecialty coded billet.



- R Code: earned by an officer who completes a second tour of at least 18 consecutive months in a coded billet within the same line of operations. For example, if a SC officer completes a 24-month FM internship, that officer earns a 3111S subspecialty. If that same officer transfers to another billet that is also coded 3111S, that officer earns a 3111R subspecialty upon completing a minimum of 18 consecutive months in that billet. An officer with an “R” code is considered to have “proven significant experience” within a subspecialty.
- T Code: added to the record of an officer who has not yet graduated but is in a training pipeline.
- P Code: earned by an officer after graduating with a master’s degree in an approved Navy-specific subspecialty. When possible, a SC officer’s next billet following the completion of a master’s degree program is a “payback” or “follow-on tour,” where an officer is assigned to a coded billet that matches a subspecialty code earned in graduate school.
- Q Code: added to an officer’s record after earning a master’s degree in an approved Navy-specific subspecialty and serving in an 18-month follow-on tour in a billet coded for that subspecialty. For example, a SC officer who currently attends NPS in the 837 curriculum is assigned a 3110T subspecialty code. Upon graduating, that officer’s subspecialty code transitions from a 3110T to a 3110P. Following graduation, if that officer is assigned to a coded 3111 billet and serves a minimum of 18 consecutive months in that billet, that officer’s subspecialty suffix transitions from a 3110P to a 3111Q.

2. Defense Acquisition Workforce Improvement Act (DAWIA)

The Defense Acquisition Workforce Improvement Act, passed into law in 1990, directs the Department of Defense to create education and training criteria for all members of the acquisition workforce. Within the FM community, personnel can obtain three levels



of certification. Critical FM billets often require certain levels of qualification. For SC officers in the FM community, completion of these three levels of certification is designated by the AK1, AK2, and AK3 AQDs, respectively.

According to Defense Acquisition University (DAU), level one (I) certification in the FM career field currently requires “a minimum of two years of acquisition experience in a budgeting, financial, or earned value management position,” in addition to completing one online acquisition class and five functional training courses through the DAU website (Defense Acquisition University, n.d.). Figure 3 shows a detailed breakdown of all requirements needed to obtain FM Level I certification.

Core Certification Standards (required for DAWIA certification)	
Acquisition Training	ACQ 1010 Fundamentals of Systems Acquisition Management
Functional Training	● BCF 110 Fundamentals of Business Financial Management
	● BCF 130 Fundamentals of Cost Analysis
	● EVM 101 Fundamentals of Earned Value Management
	● CLB 014 Acquisition Reporting Concepts and Policy Requirements
	● CLM 003 Overview of Acquisition Ethics
Education	Formal education not required for certification
Experience	2 years of acquisition experience in Budgeting, Financial and/or Earned Value Management

Figure 3. Core Certification Standards for Business Financial Management Level I. Adapted from Defense Acquisition University (n.d.)

Level two (II) certification in the FM career field requires “a minimum of four years of acquisition experience in a budgeting, financial, or earned value management position” (Defense Acquisition University, n.d.). Additionally, level II candidates must complete two acquisition training courses, including one in-person course, as well as seven functional training courses, four of which are to be completed on the DAU website, with the remaining three to be conducted in-person. Figure 4 shows a detailed breakdown of all requirements needed to obtain FM Level II certification.

Core Certification Standards (required for DAWIA certification)	
Acquisition Training	● The virtual or "V" version of a course noted by the "V" after the course number in the course ID is acceptable in lieu of the (R) version of a course. ● ACQ 2020 Intermediate Systems Acquisition, Part A ● ACQ 2030 Intermediate Systems Acquisition, Part B (R)
Functional Training	● Functional Training Identified at Level 1 as well as: ● BCF 221 Intermediate Financial Management Concepts ● BCF 225 Acquisition Business Management Application (R) ● BCF 275 Applied Business Analysis Techniques (R) ● CLB 037 The Defense Working Capital Fund (DWCF) ● CLC 011 Contracting for the Rest of Us ● PMT 0170 Risk Management ● AND choose one of the following three (3) course options listed below: ● ACQ 3700 Acquisition Law (R) ● EVM 202 Intermediate Earned Value Management (R) ● EVM 263 Principles of Schedule Management (R)
Education	Formal education not required for certification
Experience	4 years of acquisition experience in Budgeting, Financial and/or Earned Value Management

Figure 4. Core Certification Standards for Business Financial Management Level II. Adapted from Defense Acquisition University (n.d.)

Lastly, level three (III) certification in the FM career field requires “a minimum of six years of acquisition experience in a budgeting, financial, or earned value management position” (Defense Acquisition University, n.d.). Additionally, level III candidates must complete three functional training courses, including one in-person training. Figure 5 shows a breakdown of all requirements needed to obtain FM Level III certification.

Core Certification Standards (required for DAWIA certification)	
Acquisition Training	● The virtual or "V" version of a course noted by the "V" after the course number in the course ID is acceptable in lieu of the (R) version of a course. ● Acquisition Training identified at Level II must have been completed
Functional Training	● Functional Training identified at Level II must have been completed ● BCF 301 Business, Cost Estimating, and Financial Management Workshop (R) ● CLB 036 Foreign Military Sales ● CLM 031 Improved Statement of Work
Education	Formal education not required for certification
Experience	6 years of acquisition experience in Budgeting, Financial and/or Earned Value Management

Figure 5. Core Certification Standards for Business Financial Management Level III. Adapted from Defense Acquisition University (n.d.)

3. Acquisition Reform—Back to Basics

After a thorough review of the Acquisition Corps’ competencies and certification standards, The Undersecretary of Defense for Acquisition and Sustainment (USD A&S) is implementing a new “certification framework structure” to replace DAWIA’s existing multi-level certification standard (Weatherington, 2021). In September 2020, USD A&S



initiated the phased implementation of the “Back to Basics (BtB) 21st Century Acquisition Workforce (AWF) talent management framework” (OP Monthly, Jan 2022). Since September 2020, OSD-led career field task forces have been assembled to streamline DAU training curriculums, develop new certification standards, and provide guidance on grandfathering existing certifications. To date, the FM community has begun re-baselining, to include a review of manpower and billeting, military career path, and military promotion board impacts.

Under BtB, the FM certification process transitions to a two-level certification standard, Practitioner and Advanced. A practitioner certification requires four years of acquisition experience in the financial management career field. Advanced certification requires six years of experience in advanced financial management positions. Figure 6 lists the new certification criteria for the Business Financial Management pipeline. Figure 7 shows the anticipated new training courses for the BUS-FM pipeline.

Element	Business - Financial Management
Structure	Practitioner and Advanced
Education	Not required (Hiring agencies determine Occupational Series which may have requirements)
Training	Acquisition Common Competencies, Business Common Competencies, Acquisition Financial Management Competencies
Experience	Practitioner: At least 4 years of relevant acquisition experience in financial management Advanced: At least of 6 years in an advanced acquisition financial management position within an ACAT I/II program office or Business System Category I, PEO, or Service/Component/Headquarters/equivalent level.
Assessment	No comprehensive exam - Assessment included in training.
Validation	Practitioner: Services/Components validate relevant acquisition experience according to Services processes Advanced: Service/Components verify and validate 6 years relevant acquisition experience in an advanced acquisition financial management position within an ACAT I/II program office or Business System Category I, PEO, or Service/Component/Headquarters/ equivalent level according to Services processes.
Currency	80 hours Continuous Learning every 2 years – with an acquisition and/or leadership focus. CL guidelines: >50 hours of course work pertaining to Acquisition, >20 hours of leadership training

Figure 6. Business Financial Management Certification Elements—Back to Basics. Source: Weatherington (2021).



Business Financial Management	
Practitioner	Advanced
ACQ 1010 Fundamentals of Systems Acquisition Management	BFM 3000 Advanced Acquisition Financial Management
BUS 1100 Business Essentials	BFM 4000 Executive Financial Management
BFM 1000 Fundamentals of Acquisition Financial Management	
BFM 2000 Applied Acquisition Financial Management	

Figure 7. BUS-FM Proposed Training Courses Source: Weatherington (2021).

During this shift to BtB, the DAWIA level I, II, and III certification experience, education, and training standards remain in place. The long-term impact of these changes on both the civilian and military workforce is unknown. New information continues to be released by the Deputy Assistant Secretary of the Navy for procurement and acquisition (DASN-P) during this transition period (Office of Supply Corps Personnel, 2022).

C. SUPPLY CORPS ACCESSIONS

The Navy has two distinct organizations responsible for human resources and accessions planning: the NAVSUP Office of Personnel (PERS 4412) within Navy Personnel Command (NPC) and the Bureau of Naval Personnel 3 (BUPERS-3). The PERS 4412 team assigns officers to billets and sets policies that govern the distribution and placement of its officers (Carnal & Tobias, 2015). Within BUPERS-3, the Supply Corps Community Manager's role is to "cover planning for accessions, promotions, advancements, retention, lateral transfer, training and force shaping for community health so the Navy has the necessary personnel with the correct skill sets and at the right pay grade" (Carnal & Tobias, 2015, Part B).

Capped by Congress, annual accessions into the SC are derived from the Navy's need to fill first and second operational tour requirements, as OP is committed to filling 100% of its operational billets across all ranks. According to Reel (2019), the SC community receives officers from five unique sources:

- Officer Candidate School (OCS)
- Probationary Officer Continuation and Re-designation (POCR) boards



- Limited Duty Officer (LDO) boards
- United States Naval Academy (USNA); and
- Navy Reserve Officer Training Corps (NROTC) (Reel, 2019, p. 53)

1. Officer Candidate School

OCS is responsible for about 66% of the SC's annual accessions. Supply Corps leadership conducts a quarterly review of all OCS applicants. These senior officers are ultimately responsible for selecting top candidates based on a combination of factors, including "grade point average, Officer Aptitude Rating, work experience, and minimum academic qualifications for Naval Postgraduate School" (Reel, 2019, para. 2). All board selectees attend OCS in Newport, Rhode Island for 12 weeks. Upon completion of OCS, they commission as Navy Supply Corps officers.

2. Probationary Officer Continuations and Redesignation Boards

According to Reel (2019), the POCR boards represent the second-highest contributor for SC accessions, with approximately 33% of SC accessions coming through these boards, respectively. The POCR board serves as a re-designation board, which provides an avenue for officers in other Navy communities to be re-assigned to another community in the Navy (i.e., the Supply Corps). POCR board eligibility is for junior officers only. Officers with more than six years of commissioned service are not eligible to apply (Reel, 2019).

3. LDO Boards/USNA/NROTC

These three sources provide the fewest number of accessions to the SC. The LDO board may select six to eight officers annually to transition to the SC. According to Reel (2019), selected LDOs have five years to transition from LDO status to the 3100 designator (active-duty Supply Corps). The Naval Academy and NROTC each have their own internal selection processes, respectively, for deciding which students receive a direct commission into the SC (Reel, 2019).



4. CHAPTER SUMMARY

This chapter discusses a SC officer's career development timeline and examines the financial management community in terms of its sub-functional areas, responsibilities, and total FM billets by rank. We define SSPs and AQDs that are pertinent to the FM community, provide a breakdown of DAWIA's three-level certification standard, and discuss the new Back to Basics certification structure that DoD plans to transition to in 2022. Lastly, we explore the channels through which the Supply Corps receives its annual accessions.



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III. LITERATURE REVIEW

A. OVERVIEW

A review of applicable studies found several that apply Markov models to military manpower research, but none that specifically address the SC's FM community. Our project is designed to address that issue. Military and civilian applications of the Markov model for manpower scenarios are grounded primarily in works by Bartholomew (1971), Kalamatianou (1987), and Sales (1971). In addition to these studies, our work follows a methodology similar to Irby, Higgins, and Tinsley (2021), who performed their analysis on SC officers within the contracting and acquisition subspecialty.

B. EVOLUTION OF MARKOV MODELS

One method for modeling how people transition within a manpower system is to employ models based on Markov chains (Bartholomew et al., 1991). There are two features of the manpower planning model: aggregates and factors of uncertainty. Bartholomew et al. (1991) explain aggregates as manpower planning tools that aid in predicting the number of personnel needed at a given state at a given point in time. There are a variety of Markov models, including "Markov chains, hidden Markov models, Markov decision processes, and partially observable Markov decision processes" (Chauhan, 2021, para. 7). All of these models are used to find the probabilities of different states and the transitions between those states. Additionally, Markov models can recognize patterns in data and make predictions. In our study, we use a Markov model to forecast the inventory of officers in the SC FM community.

C. MARKOV MODEL—MILITARY STUDIES

One military-specific study applies Markov models to the Navy Nurse Corps, with an emphasis on surge planning in wartime (Rai, 2019). Other studies have utilized Markov models to forecast manning and continuation rates for the Selective Marine Corps Reserves (Erhardt, 2012), Navy healthcare administrators (Josiah, 2014), and Marine Corps Reserve officers (Licari, 2013).



As previously mentioned, our study expands upon research conducted by Irby, Higgins, and Tinsley (2021). Their study focuses solely on acquisition and contracting SSPs within the SC, leaving a research gap that we address within the SC's financial management community. Irby et al. (2021) develop a transition matrix that identifies all SC officers with contracting experience between 2016 to 2020, to determine the probability of those officers transitioning from one qualification state to the next. The variables used in their study are unique identifiers that allow them to track and identify officers through the system by rank and SSP. They apply their model to forecast the progression and development of SC contracting officers over a ten-year period (Irby et al., 2021).

Additionally, their model identifies five ways an officer can transition in the system: “by staying at current rank, staying at current rank and qualifying (earning a Q or R suffix), promoting to the next rank, promoting to the next rank and qualifying, or attrite from the system” (Irby et al., 2021, p.21). Their research reveals that the current accession numbers used by the SC “are not sufficient to attain NAVSUP OP’s planning factor of 2.5 qualified O6 1306QR officers for every O6 1306 billet” (Irby et al., 2021, p. 3). Irby et al. (2021) recommend policy changes to NAVSUP OP to address these manpower issues, including the need to increase the number of experience tours and the rate at which contracting officers qualify.

D. MARKOV MODEL—CIVILIAN STUDIES

Civilian research utilizing Markov model manpower scenarios includes a statistical approach to manpower planning (Bartholomew, 1971), manpower planning models (Forbes, Morgan, Rowntree, 1975), and mathematical aspects of manpower study (Vajda, 1975).

In a study of strategic human resource management, Belhaj and Tkiouat (2013) employ a Markov model to address concerns about the future behavior of human resources employees. They do this by incorporating subsystems for employees that contain the same grade in the same family. The family and grade combination are determined by the total level of experience and education for each employee, respectively. Their proposed Markov model is created because of the “reality of staff development,” which asserts that the direction an employee takes is within a “family of grades.” The five families contained in the study are



administer, editors, technicians, technician assistants, and administrative agents. The four grades, or levels, are listed as first through fourth.

The results of Belhaj and Tkouat's model validate the notion that promotion possibilities are limited within an organization for those employees who start their careers as administrative agents. Though it is possible for an employee to transition from an administrative agent to an administer, the probability of an employee doing so is low. Their research shows that by placing employees within their "normal family" instead of one "whole family," the employees are more likely to evolve within their own family to the next higher grade. In our study, we use historical SC FM officer data and construct a transition matrix that displays promotions, attritions, and accessions within the 3111 community. Like the Belhaj and Tkouat study, the SC includes various subspecialty areas (i.e., contracting, supply chain, financial management), which represent the SC's core competencies, or "families." Our research focuses solely on the family that represents the SC's FM community.

Lastly, Zahakis and Maret (1980) present an industrial application of Markov chains in their manpower supply planning study of a chemical company. In their study, the team aims to forecast "manpower needs and resources, given multiple company objectives" (Zahakis and Maret, 1980). These objectives include organization history, people skills inventory, promotions, and policies regarding firings and retirement. They find that employees flowing through several states (i.e., skill, position level, years of service) can be predicted using Markov models. Employing this methodology for the FM community allows us to predict the flow of SC FM officers through various states such as rank, experience, and qualifications, and allows us to predict whether the SC FM community's current inventory level and billet structure can achieve OP's O5-O6 inventory goals.

E. CHAPTER SUMMARY

This chapter introduces the Markov model as an efficient manpower tool that allows researchers to pinpoint important characteristics of a specific manpower system to induce future dynamics. Additionally, we review relevant, existing literature on civilian and military applications of the Markov model to demonstrate its utility across various fields of study.



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IV. DATA AND METHODOLOGY

A. INTRODUCTION

This chapter presents the data and methodology used in the development of a model to forecast the end strength of Supply Corps officers with financial management subspecialty codes. We discuss how the data is obtained, what variables are used, and how the data is incorporated into our model.

B. DATA

To conduct our research, we obtain data from NAVSUP OP that shows the total inventory of Navy SC officers who have earned a SSP or AQD between January 2003 and May 2021. To focus on recent trends, we place a higher weight on data collected between 2016 to 2020. The data provides snapshots showing an individual's rank, SSPs, and AQDs, and is anonymized by assigning a unique identifier to each individual. The identifier is used to track individuals through the system. From this, we extract only the observations of individuals with financial management SSPs (3110, 3111, 3112, and 3113) and import that data to Microsoft Excel. We further sort these observations by rank (O1 through O6) and year. Because we seek to determine whether the FM community's existing billet structure creates enough FM officers with significant experience at the O5-O6 level, we also partition officers with an S or P suffix (O3-O6), or those with "experience," from officers with a Q or R suffix (O3QR-O6QR), or those with "significant experience." Figure 8 shows the total observations of 3111-qualified SC officers by rank and state from 2011-2020.



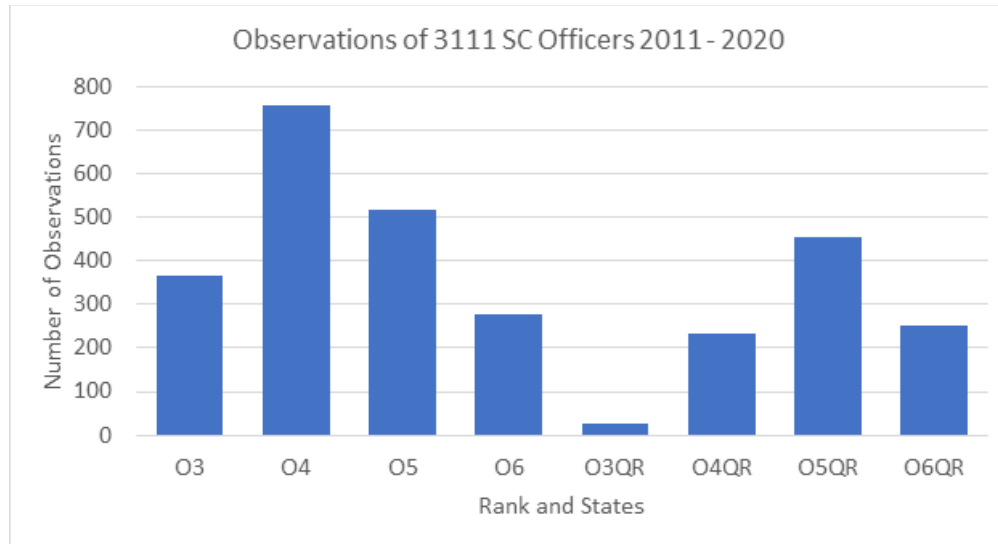


Figure 8. Total Observations of 3111-Qualified SC Officers

C. MARKOV MODEL THEORY

Markov models are stochastic models that describe the behavior of a system. They can be especially useful for manpower planning because they can predict the end strength of a system, like SC officers with a 3111 SSP. As stated by Bartholomew et al. (1991), statistical modeling is useful for manpower planning problems because manpower planning is concerned with aggregates and forecasting “the right numbers in the right places at the right time” (p. 1). Secondly, manpower planning contains elements of social and economic uncertainty, which can be aided by statistics.

Markov models have three basic assumptions. As Sales (1971) states, the first assumption is that the system contains a finite number of states, and those states are all-encompassing. For a manpower model, the states can be differentiators like rank or qualifications (O3, O4, O5, O6, etc.). Our research utilizes nine states: O3 through O6 who have FM experience as designated by a S or P suffix, O3 through O6 who have significant FM experience as designated by a Q or R suffix, and attrite. The attrite state is for any officer who leaves the service or promotes to flag officer (O7). We build our Markov model by calculating the probability of moving between states, such as the probability that an individual promotes from O3 to O4. Movements between states are called transitions. Each transition probability is denoted as p_{ij} where i is the state at time n and j is the state at time

$n+1$. For our model, p_{34} represents the probability that a 3111-qualified O3 during year n promotes to O4 by $n+1$, and p_{44QR} represents the probability that a 3111-qualified O4 at time n gains a Q or R suffix by time $n+1$.

The second assumption of Markov models is that the probability of transitioning, or moving, between states depends only on the current state (Bartholomew, 1971). To illustrate using a manpower example, the probability that an O3 transitions to O4 depends only on that individual being an O3 at present.

The last assumption is that transition probabilities do not change over time (Bartholomew et al., 1991). Put another way, the probability that an O3 transitions to O4 at time = 0 is the same probability that an O3 transitions to O4 at time = t . In Chapter II, we mention that the DAWIA three-level training standard is being replaced by the new Back to Basics initiative. Because the amount of time needed to qualify under the B2B system (4 years to achieve practitioner certification, 6 years to achieve advanced certification) closely parallels the time requirements under DAWIA's standard (4 years to achieve Level II certification, 6 years to achieve Level III certification), our model assumes that transition rates will remain the same following this change process.

D. VISUAL MODEL

Figure 9 is an illustration of our Markov model. Each state in Figure 9 can also transition to attrition, but we remove that from the graphic for visual ease.



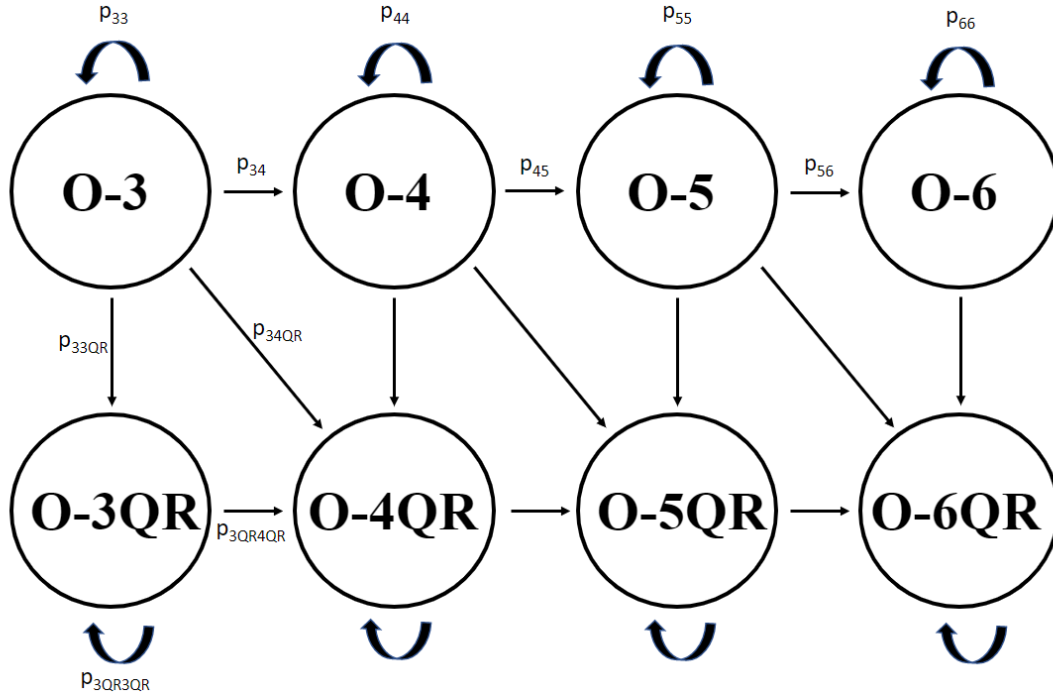


Figure 9. Conceptual Model of States and Flows with Q and R Suffixes

E. TRANSITION MATRIX

Before we can model the end state of a system, we must create a transition matrix to calculate the value for each transition probability, p_{ij} . Table 3 shows, in aggregate, the number of accessions, promotions, qualifications, and attritions within the SC's FM community from 2016 to 2020. After validating the totals in Table 3, we use the aggregated data to create our transition matrix, or P-matrix, as shown in Table 4. To calculate each transition probability, we divide the number of officers in each state by the total inventory of that flow. For our model, there are 124 observations of O3s who remain O3s during a fiscal year. Those 124 observations are divided by the 209 observations of officers who began each respective fiscal year as an O3 to arrive at a transition probability of .59. In other words, there is a 59% probability that an O3 at the beginning of a fiscal year will continue as an O3 at the end of a fiscal year. That same O3 also has a 2% probability of transitioning to the O3QR state during that fiscal year.

Table 3. SC Officers from FY16-FY20

Flows	O3	O4	O5	O6	O3QR	O4QR	O5QR	O6QR	Attrite	Total
O3	124	54			5	4			22	209
O4		319	34			30	4		29	416
O5			227	19			14	0	28	288
O6				122				3	32	157
O3QR					8	5			3	16
O4QR						88	33		10	131
O5QR							197	22	32	251
O6QR								121	18	139

Table 4. Transition (P) Matrix for 3111 Qualified SC Officers

Flows	O3	O4	O5	O6	O3QR	O4QR	O5QR	O6QR	Attrite
O3	0.59	0.26			0.02	0.02			0.11
O4		0.77	0.08			0.07	0.01		0.07
O5			0.79	0.07			0.05	0.00	0.10
O6				0.78				0.02	0.20
O3QR					0.50	0.31			0.19
O4QR						0.67	0.25		0.08
O5QR							0.78	0.09	0.13
O6QR								0.87	0.13

F. BARTHOLOMEW'S INVENTORY EQUATION

With the development of the transition matrix, we use two inventory models to predict the future end strength of SC Officers with a 3111 SSP. Both models rely on Bartholomew's inventory equation.

$$\mathbf{n}(t) = \mathbf{n}(t-1)\mathbf{P} + \mathbf{R}(t)\mathbf{r}$$

Bartholomew et al. (1991) and Licari (2013) define the elements of the equation.

- $\mathbf{n}(t)$ is the expected inventory at time t . Our model uses one-year time increments.
- $\mathbf{n}(t-1)$ is the inventory at the beginning of the time stamp.
- $\mathbf{P}$ is the transition matrix.

- $R(t)$ is total accessions, or total recruitment. In our model, this is the total number of officers who earn a new 3111 SSP/AQD each year.
- $\mathbf{r}$ is the recruitment vector. This is the probability that a new accession will be allocated into a specific state. For example, if $\mathbf{r} = (.75, .25, 0)$ then the system has three states. Seventy-five percent of recruits will enter the system in state one, 25 percent will enter in state two, and none will enter in state three.

G. INVENTORY MODELS

The first model we use is a fixed recruiting model, which is used to determine the total end strength in future years, assuming a fixed number of accessions. Using SC officers as our example, if OP knows the average number of SC officers who attain a 3111 SSP each year, that number can be set as the fixed recruitment number, R . The fixed recruitment number can then be applied to an accession vector ($\mathbf{r}$) to predict future end strength. An accession vector, also known as a recruitment vector, is “the proportion of new accessions that flow into the various states” (Irby et al., 2021, p.27). A second useful model is the fixed inventory model. In this model, the desired end strength is fixed, and the model is used to calculate the minimum number of accessions required. In other words, if OP wants an inventory of 50 SC O6s who have a 3111 SSP in five years, the model estimates the number of accessions needed to achieve that goal.

H. CHAPTER SUMMARY

This chapter describes the basic theory behind Markov models, explains how Markov models can be utilized in manpower planning, and shows how a data set can be used to create a fixed inventory or fixed recruitment model for SC Officers with a 3111 SSP.



V. EMPLOYMENT OF MODELS

A. OVERVIEW

This chapter demonstrates how manpower planners can utilize fixed recruitment, fixed inventory, and steady state inventory Markov models to answer various manpower-related questions pertaining to the FM community. We analyze the relationships between accession rates, transition rates, and end strength goals to gauge how each relationship affects FM inventory forecasts. Although not all uses of Markov models in this chapter offer feasible solutions to the SC's 3111 O6QR community, we purposefully demonstrate the employment of each type of model to show how manpower planners have options when deciding which model works best for a specific data set to reach a desired end state. Each Markov model discussed in this chapter is employed for the combined 3111 community, including both 3111SP- and 3111QR-qualified officers.

B. FIXED RECRUITMENT

The SC's FM community has a target end strength of 50 3111 O6QR-qualified officers. This is derived from OP's inventory goal across all subspecialties to maintain 2.5 to 3 times the number of officers per billet at both the O5 and O6 levels (Office of Supply Corps Personnel, 2022a). Additionally, OP's detailing rule is to fill all O6 FM billets with experts only (3111QR). This rule relaxes slightly for O5 billets, which can be filled by officers with either expertise (3111QR) or experience (3111SP), thus broadening the pool of eligible candidates. For our calculations, we utilize a 2.5 planning factor to determine health. Currently, there are 34 O5 billets and 20 O6 billets in the SC's FM community. Table 5 shows OP's inventory goal based on the current number of 3111 billets.

Table 5. NAVSUP OP Inventory Goal Based on Current Number of 3111 Billets.

Rank	Number of Billets	Planning Factor	OP Inventory Goal
O-5	34	2.5	85
O-6	20	2.5	50



With OP's target end strength goal in mind, we determine the current accessions (R) value for our fixed recruitment model by calculating average accessions into the 3111 community from FY11 to FY20. Fiscal year 2021 is not included because we received our data set from OP mid-FY21, rendering that year's data set incomplete. We calculate an R value of 32, meaning that, on average over the past ten years, 32 SC officers entered the 3111 community annually through completion of FM internships, MBAs in Financial Management from NPS, or experience through general FM coded billets. The annual number of 3110P and 3111S billet opportunities is 48, which is the number of internship billets (21), coded billets (17), and MBA positions at NPS (10) combined. Considering that each officer enters a billet at different times throughout the year and that it takes 18 months to earn a 3111 subspecialty in a coded billet, an accessions (R) value of 32 accessions per year appears to be a reasonable estimate.

Employing our fixed recruitment model, we forecast a 3111 SC inventory of 297 officers by year 2031. Of these 297 officers, we forecast an inventory of 55 O5s and 24 O6s with experience (3111S or 3110P code), meaning that they have completed one tour in a 3111-coded billet. Additionally, we forecast an inventory of 47 O5s and 37 O6s with significant FM experience (3111Q or 3111R), meaning that they have completed two or more tours in a 3111-coded billet. Table 6 shows the FM community's inventory forecast. This forecast is broken down by SC officers with FM experience only (O3-O6) and SC officers with significant FM experience (O3QR-O6QR). Table 7 shows the forecasted inventory of 3111 officers in 2031 based on the SC's current fixed recruitment number (R=32).



Table 6. Fixed Recruitment Inventory Forecast for 3111 Community.

		O3	O4	O5	O6	O3QR	O4QR	O5QR	O6QR	E/S	E/S QR
2021	n(0)	34	75	53	26	2	26	46	34	188	108
2022	n(1)	34.17225	74.89671	53.50411	25.30035	2.113397	24.95002	46.75075	34.42581	187.8734	108.24
2023	n(2)	34.27444	74.86201	53.89301	24.78993	2.174216	24.27597	47.09899	34.84891	187.8194	108.3981
2024	n(3)	34.33508	74.8618	54.1967	24.41895	2.207071	23.84164	47.22109	35.238	187.8125	108.5078
2025	n(4)	34.37105	74.87731	54.43605	24.15071	2.224949	23.56129	47.22227	35.58031	187.8351	108.5888
2026	n(5)	34.39239	74.89849	54.62597	23.95806	2.234748	23.38035	47.16435	35.87327	187.8749	108.6527
2027	n(6)	34.40506	74.92025	54.7774	23.82089	2.240159	23.2638	47.08275	36.11953	187.9236	108.7062
2028	n(7)	34.41257	74.94021	54.89853	23.72429	2.243167	23.18902	46.99692	36.32413	187.9756	108.7532
2029	n(8)	34.41703	74.95746	54.99564	23.65721	2.244851	23.1413	46.91679	36.49287	188.0273	108.7958
2030	n(9)	34.41967	74.97184	55.07359	23.6115	2.245799	23.1111	46.84677	36.63145	188.0766	108.8351
2031	n(10)	34.42124	74.98354	55.1362	23.58111	2.246337	23.0922	46.78814	36.74508	188.1221	108.8718
Steady-State	n*	34.42353	75.02632	55.39023	23.56891	2.247059	23.06691	46.59646	37.33318	188.409	109.2436

Table 7. Forecasted Inventory of 3111 Officers in 2031 (Fixed Recruitment).

Rank	3111SP	3111QR	Total Inventory
O-5	55	47	102
O-6	-	37	37

Our model shows that if the FM community maintains a fixed recruitment rate of 32 accessions per year, by 2031 OP will exceed its inventory goal of 85 O5s with FM expertise or experience, with a total O5 inventory of 102. However, OP will fail to achieve its inventory goal of 50 O6s with significant FM expertise at the O6 level, as our model forecasts that only 37 FM officers with significant expertise will remain in SC inventory by 2031.

Next, we demonstrate how to adjust R in the fixed recruiting model to achieve a desired end state. In this example, we know that OP's desired end state for 3111 O6QR-qualified SC officers is 50. Table 8 shows the inventory forecast of our model when R increases from 32 to 81.

Table 8. Fixed Recruitment Inventory Forecast for 3111 Community.

		O3	O4	O5	O6	O3QR	O4QR	O5QR	O6QR	E/S	E/S QR
2021	n(0)	34	75	53	26	2	26	46	34	188	108
2022	n(1)	55.6	88.1	62.1	27.8	2.6	26.2	48.0	34.9	233.5	111.6
2023	n(2)	68.4	103.7	70.3	29.7	3.4	27.8	50.1	35.9	272.1	117.2
2024	n(3)	76.0	118.9	78.1	31.8	4.1	30.6	52.8	36.9	304.8	124.4
2025	n(4)	80.6	132.6	85.4	33.9	4.6	33.9	56.1	38.2	332.5	132.7
2026	n(5)	83.2	144.3	92.3	36.0	5.0	37.3	60.0	39.5	355.9	141.9
2027	n(6)	84.8	153.9	98.8	38.1	5.2	40.7	64.4	41.1	375.6	151.4
2028	n(7)	85.8	161.7	104.6	40.2	5.4	43.7	69.1	42.9	392.3	161.1
2029	n(8)	86.3	167.9	109.8	42.2	5.5	46.4	73.9	45.0	406.3	170.8
2030	n(9)	86.7	172.8	114.5	44.1	5.6	48.7	78.7	47.2	418.0	180.1
2031	n(10)	86.8	176.7	118.5	45.9	5.6	50.6	83.3	49.6	427.9	189.0
Steady-State	n*	87.1	189.9	140.2	59.7	5.7	58.4	117.9	94.5	476.9	276.5

Leaving all other parameters unchanged, by adjusting fixed recruiting (accessions) from 32 to 81 for the next ten years (2022-2031), our model forecasts that OP can reach its desired end strength of 50 3111 O6QR-qualified SC officers by 2031.

However, increasing accessions from 32 to 81 is not a feasible solution. The need to adjust *R* so substantially to achieve our desired 2031 end strength for O6QR-qualified officers is a potential indicator that transition rates are too low. This indicates that the Supply Corps is likely not offering enough follow-on tours for its FM officers following their initial FM tours. Additionally, based on the steady state inventory, further downward adjustments would need to be made in 2031 to prevent massively overshooting OP's goal of 50 O6 3111QR-qualified SC officers. fixed inventory

The fixed inventory model is useful for manpower planners in determining the number of accessions necessary to reach a pre-determined end strength goal, given the current transition matrix. To achieve NAVSUP OP's inventory goal of 50 3111 O6QR-qualified SC officers by year 2031, holding all other parameters constant, the SC's FM community requires an end strength of 676 SC officers. At present (n=0), the FM community's end strength is 296, meaning end strength must grow substantially (by 380) by year 2031 to attain OP's O6QR inventory goal. Rapidly increasing end strength by 380 is an expensive plan and is not feasible. Rather than stressing the system, our model incrementally raises accessions by 38 annually, beginning at year n=1, until we achieve an end strength goal of 676 officers. Table 9 shows the number of accessions (*R*) required annually from 2022 to 2031 to achieve OP's goal of 50 3111 O6QR-qualified officers.

Table 9. Fixed Inventory for 3111 SC Officers (Incremental End Strength).

		O3	O4	O5	O6	O3QR	O4QR	O5QR	O6QR	E/S	
2021	n(0)	34	75	53	26	2	26	46	34	296	R
2022	n(1)	51	85	60	27	2	26	48	35	334	70
2023	n(2)	63	98	67	29	3	27	50	36	372	74
2024	n(3)	71	112	75	31	4	29	52	37	410	77
2025	n(4)	77	126	82	33	4	32	55	38	448	81
2026	n(5)	83	140	90	35	5	36	59	39	486	85
2027	n(6)	88	152	98	38	5	39	63	41	524	88
2028	n(7)	93	164	106	40	6	43	68	43	562	93
2029	n(8)	97	176	114	43	6	47	73	45	600	96
2030	n(9)	101	187	121	46	6	50	79	47	638	100
2031	n(10)	106	197	129	49	7	54	85	50	676	104

In this specific example, increasing end strength by 380 over a ten-year period is still not a feasible solution to achieve OP's desired end state of 50 3111 O6QR-qualified officers by 2031. Similar to the observations in the fixed recruiting model, our model suggests that end strength must increase substantially to achieve OP's O6QR goal for the community. Again, this is a potential indicator that the Supply Corps is not offering enough follow-on tours for its FM officers following their initial FM tours.

C. STEADY STATE INVENTORY

Bartholomew et al. (1991) stress the importance of understanding a system's steady state structure, stating that "it has the property that once achieved, will be maintained as long as the parameters are unchanged" (p. 107). In other words, a system that reaches its steady state is one that achieves equilibrium when accessions (R) and transition rates (P) remain unchanged. Our model's output is unique, as the value of R calculated in the fixed recruiting model (32) closely matches the value of R in the community's steady state. Table 10 shows the steady state inventory for 3111QR-qualified SC officers when average annual accessions is 32. In its steady state, the FM community maintains a total inventory of 37 3111 O6QR-qualified SC officers. This matches the forecast from our fixed recruiting model, where fixed accessions are 32 and the 3111 O6QR-qualified SC officer end strength is 37 by year 2031. Based on this data, it appears the 3111 community has reached a steady state.

Table 10. Steady state Inventory for 3111QR Officer ($R=32$).

		O3	O4	O5	O6	O3QR	O4QR	O5QR	O6QR	E/S	E/S QR
Steady State	n*	34.42	75.02	55.39	23.56	2.24	23.06	46.59	37.33	188.40	109.24

However, even in a steady state, the FM community's end strength of approximately 37 O6 3111QR SC officers falls short of OP's desired end state goal of 50. Table 11 shows the steady state inventory for 3111QR officers when R increases to 43.

Table 11. Steady state Inventory for 3111QR Officers ($R=43$).

		O3	O4	O5	O6	O3QR	O4QR	O5QR	O6QR	E/S	E/S QR
Steady State	n*	46.25	100.81	74.43	31.67	3.01	30.99	62.61	50.16	253.17	146.79

Our forecast shows that by increasing accessions from 32 to 43 annually (i.e., by adding 11 new entry-level 3111 billets), our model reaches a steady state of 50.16 3111 O6QR-qualified SC officers, which achieves OP's inventory goal for the community. However, our model shows that by increasing accessions to attain 50 O6QR-qualified SC officers over time, the FM community must increase its end strength by approximately 102 officers. Attempting to achieve OP's O6QR goal for the FM community through increased accessions alone would cause excess inventory levels of 3111S and 3110P officers through the O3 to O6 ranks. Tables 12 and 13 show the steady state probability vectors at each rank and qualification level when accessions are 32 and 43, respectively. Table 13 highlights the increase in inventory of 3111S- and 3110P-qualified officers as a result of this change.

Table 12. Steady State Probability Vector ($R=32$)

R=32		O3	O4	O5	O6	O3QR	O4QR	O5QR	O6QR	Total E/S
Steady State	n*	34.42	75.02	55.39	23.56	2.24	23.06	46.59	37.33	297.64
	% E/S	11.6%	25.2%	18.6%	7.9%	0.8%	7.7%	15.7%	12.5%	

Table 13. Steady State Probability Vector (R=43)

R=43		O3	O4	O5	O6	O3QR	O4QR	O5QR	O6QR	Total E/S
Steady State	n*	46.25	100.81	74.43	31.67	3.01	30.99	62.61	50.16	399.96
	% of ES	11.6%	25.2%	18.6%	7.9%	0.8%	7.7%	15.7%	12.5%	

Table 14 shows the FM community's forecasted excess inventories at the O3 to O6 ranks if OP elects to achieve its O6QR inventory goals through accessions alone. These deltas, specifically at the O4 to O6 level, suggest that achieving OP's inventory goal through accessions is achievable, but will lead to significant excess inventory of 3111S- and 3110P-qualified officers.

Table 14. Excess Inventory of 3111S and 3110P SC Officers

Rank	# of Billets	OP Planning Factor	OP Inventory Goal	Actual Officer Inventory (R=43)	Delta
O3	38	N/A	38	49	+11
O4	35	N/A	35	132	+97
O5	34	2.5	85	137	+52
O6	0	0	0	32	+32
O6QR	20	2.5	50	50	0

Analyzing this data further, by summing the end strength percentages in our steady state probability vector, we find that 63.3% of SC officers (O3-O6) with FM experience do not receive follow-on tours following their initial FM tour. Additionally, only 28.2% of officers transition to O5QR (15.7%) and O6QR (12.5%) in the current pipeline.

By further tailoring the transition matrix (and recruitment vector), OP can reduce the mismatch between steady state inventory and inventory targets. As demonstrated in the adjusting transition rates section, these deltas and transition probabilities can improve by increasing the number of follow-on tours for officers who have already completed their initial FM assignments.

D. ADJUSTING TRANSITION RATES

In previous sections, we employ Markov models by adjusting only one parameter (accessions or inventory target) and holding all others constant. Both models showed that by increasing accessions, OP can achieve its O6QR inventory goal for the FM community. Unfortunately, as seen in the previous section, achieving this goal through accessions alone likely results in a significant excess inventory for the FM community. This section offers a potential solution to excess inventory by demonstrating how manpower planners can adjust transition rates between states. In theory, by increasing transition rates (from 3111 to 3111QR), we demonstrate the impact that increasing the number of FM follow-on tour billets has on improving the community's O6QR inventory.

Initially, manpower planners may consider adjusting transition rates while leaving accession rates fixed. If the forecasted inventory goal is still not reached, a manpower planner can also adjust the level of annual accessions until a specific inventory goal is reached. In practice, this would be accomplished by increasing the number of follow-on tours at the O3 to O6 level (to achieve Q and R codes) and by increasing the number of entry-level tours at the O1 to O3 level (S and P codes).

Table 15 shows the unaltered transition matrix (P) that we compiled from data obtained from OP between 2016 to 2020. Table 16 shows the inventory forecast for the FM community through 2031 with a fixed recruitment (R) of 32. If transition rates and fixed recruitment remain unchanged, by year 2031 the SC is forecasted to have an inventory of 37 O6QR qualified officers with a steady state inventory of 37, both of which fail to achieve OP's goal of 50 3111 O6QR-qualified SC officers. The next section demonstrates how to adjust transition rates while leaving accessions fixed. Then, we demonstrate how to adjust transition rates and accessions rate simultaneously until a desired end state is achieved.



Table 15. Unaltered Transition (P) Matrix for 3111 Qualified SC Officers

	O3	O4	O5	O6	O3QR	O4QR	O5QR	O6QR	Attrite
O3	0.59	0.26	0.00	0.00	0.02	0.02	0.00	0.00	0.11
O4	0.00	0.77	0.08	0.00	0.00	0.07	0.01	0.00	0.07
O5	0.00	0.00	0.79	0.07	0.00	0.00	0.05	0.00	0.10
O6	0.00	0.00	0.00	0.78	0.00	0.00	0.00	0.02	0.20
O3QR	0.00	0.00	0.00	0.00	0.50	0.31	0.00	0.00	0.19
O4QR	0.00	0.00	0.00	0.00	0.00	0.67	0.25	0.00	0.08
O5QR	0.00	0.00	0.00	0.00	0.00	0.00	0.78	0.09	0.13
O6QR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.87	0.13

Table 16. Inventory Forecast for the 3111 Community

		O3	O4	O5	O6	O3QR	O4QR	O5QR	O6QR	E/S
2021	n(0)	34	75	53	26	2	26	46	34	296.0
2022	n(1)	34.2	74.9	53.5	25.3	2.1	25.0	46.8	34.4	296.1
2023	n(2)	34.3	74.9	53.9	24.8	2.2	24.3	47.1	34.8	296.2
2024	n(3)	34.3	74.9	54.2	24.4	2.2	23.8	47.2	35.2	296.3
2025	n(4)	34.4	74.9	54.4	24.2	2.2	23.6	47.2	35.6	296.4
2026	n(5)	34.4	74.9	54.6	24.0	2.2	23.4	47.2	35.9	296.5
2027	n(6)	34.4	74.9	54.8	23.8	2.2	23.3	47.1	36.1	296.6
2028	n(7)	34.4	74.9	54.9	23.7	2.2	23.2	47.0	36.3	296.7
2029	n(8)	34.4	75.0	55.0	23.7	2.2	23.1	46.9	36.5	296.8
2030	n(9)	34.4	75.0	55.1	23.6	2.2	23.1	46.8	36.6	296.9
2031	n(10)	34.4	75.0	55.1	23.6	2.2	23.1	46.8	36.7	297.0
Steady-State	n*	34.4	75.0	55.4	23.6	2.2	23.1	46.6	37.3	297.7

First, we explore the feasibility of doubling transition rates from O3 to O3QR/O4QR, from O4 to O4QR/O5QR, and from O5 to O5QR to improve our inventory forecast for 3111 O6QR-qualified officers, leaving accession rate fixed at 32. Table 17 highlights the adjusted transition rates for each of these states. Table 18 shows the updated inventory forecast resulting from increased transition rates, highlighting forecasted inventory for O6QR in 2031 and at a steady state.

Table 17. Transition (P) Matrix with Increased Transition Rates

	O3	O4	O5	O6	O3QR	O4QR	O5QR	O6QR	Attrite
O3	0.57	0.26	0.00	0.00	0.04	0.04	0.00	0.00	0.11
O4	0.00	0.70	0.07	0.00	0.00	0.14	0.02	0.00	0.07
O5	0.00	0.00	0.74	0.07	0.00	0.00	0.10	0.00	0.10
O6	0.00	0.00	0.00	0.78	0.00	0.00	0.00	0.02	0.20
O3QR	0.00	0.00	0.00	0.00	0.50	0.31	0.00	0.00	0.19
O4QR	0.00	0.00	0.00	0.00	0.00	0.67	0.25	0.00	0.08
O5QR	0.00	0.00	0.00	0.00	0.00	0.00	0.78	0.09	0.13
O6QR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.87	0.13

Table 18. Inventory Forecast with Increased Transition Rates

		O3	O4	O5	O6	O3QR	O4QR	O5QR	O6QR	E/S
2021	n(0)	34	75	53	26	2	26	46	34	296.0
2022	n(1)	33.4	69.9	50.1	25.3	2.7	30.8	50.3	34.4	296.7
2023	n(2)	33.0	66.1	47.5	24.6	3.0	33.4	54.4	35.2	297.2
2024	n(3)	32.8	63.4	45.4	23.8	3.1	34.7	58.0	36.1	297.5
2025	n(4)	32.7	61.5	43.6	23.1	3.2	35.3	60.9	37.3	297.6
2026	n(5)	32.6	60.1	42.2	22.4	3.2	35.4	63.1	38.5	297.6
2027	n(6)	32.6	59.1	41.0	21.8	3.2	35.3	64.6	39.8	297.5
2028	n(7)	32.6	58.4	40.1	21.3	3.2	35.1	65.7	41.0	297.4
2029	n(8)	32.6	57.9	39.4	20.8	3.2	34.9	66.4	42.2	297.3
2030	n(9)	32.6	57.5	38.8	20.3	3.2	34.6	66.8	43.2	297.1
2031	n(10)	32.6	57.3	38.3	20.0	3.2	34.4	67.0	44.2	296.9
Steady-State	n*	32.6	56.7	36.8	18.1	3.2	33.6	65.5	49.3	295.8

In practice, doubling transition rates in this manner requires OP to add 7 additional follow-on billets at the O3 level, 31 additional follow-on billets at the O4 level, and 14 additional follow-on billets at the O5 level. Adding 52 follow-on billets is likely not a quick process. However, those 52 billets may not all need to be brand new. Further analysis should be conducted to determine if existing billets should be classified as a follow-on tour, or if the scope of existing billets could be modified to include FM duties.

By doubling transition rates from 3111 to 3111QR through the O3 to O5 ranks while leaving the accession rate constant, our forecasted inventory of 3111 O6QR-qualified SC officers in 2031 increases from 36.7 to 44.2. Additionally, steady state inventory increases from 37.3 to 49.3. A major advantage of adjusting transition rates in this manner is that the community's steady state end strength remains at 296 SC officers, meaning that OP can achieve its O6QR goal without increasing accessions by 100, as seen in the previous



example. The forecasted steady state inventory of 49.3 suggests that increasing the number of follow-on tours at the O3 to O5 level will enable the SC to close the gap between the steady state inventory and target inventory at all ranks.

Next, we explore how increasing accession rates (R) while also increasing transition rates effects inventory forecasts within the 3111 community. Table 19 shows the FM inventory forecast when fixed accessions increase slightly, from 32 to 33, with increased transition rates from Table 17 still in effect.

Table 19. Inventory Forecast with Increased Accessions Rate and Increased Transition Rates

		O3	O4	O5	O6	O3QR	O4QR	O5QR	O6QR	E/S
2021	n(0)	34	75	53	26	2	26	46	34	296.0
2022	n(1)	33.8	70.2	50.2	25.4	2.7	30.8	50.3	34.4	297.7
2023	n(2)	33.7	66.7	47.9	24.7	3.0	33.5	54.5	35.2	299.1
2024	n(3)	33.7	64.3	45.9	24.0	3.2	35.0	58.1	36.2	300.2
2025	n(4)	33.6	62.6	44.2	23.3	3.2	35.6	61.1	37.4	301.1
2026	n(5)	33.6	61.3	42.9	22.7	3.3	35.9	63.5	38.6	301.7
2027	n(6)	33.6	60.5	41.8	22.1	3.3	35.9	65.2	39.9	302.3
2028	n(7)	33.6	59.9	40.9	21.6	3.3	35.8	66.4	41.2	302.7
2029	n(8)	33.6	59.5	40.3	21.1	3.3	35.6	67.3	42.4	303.0
2030	n(9)	33.6	59.2	39.7	20.7	3.3	35.4	67.8	43.5	303.3
2031	n(10)	33.6	59.0	39.3	20.4	3.3	35.3	68.1	44.5	303.5
Steady-State	n*	33.6	58.5	38.0	18.6	3.3	34.7	67.5	50.9	305.0

By increasing accessions from 32 to 33 in conjunction with increased transition rates, our forecasted inventory of 3111 O6QR-qualified SC officers in 2031 increases slightly, from 44.2 to 44.5. Meanwhile, steady state inventory increases from 49.3 to 50.9, which, in theory, achieves NAVSUP OP's inventory goal of 50 3111 O6QR-qualified SC officers.

However, as mentioned earlier, the need to increase the number of follow-on tour opportunities by 52 billets is likely not a practical solution to attain OP's goal of 50 3111 O6QR-qualified SC officers. Not only is this scenario costly, but it also draws personnel from a shallow inventory pool needed by other SC communities (contracting, supply chain management) that have a higher number of O5/O6 critical billets that need to be filled. By realizing the most cost-effective balance of increasing both follow-on tours and initial FM

tours, OP can find the most feasible way to achieve its O6QR inventory goal without significantly increasing the community's end strength.

E. CHAPTER SUMMARY

This chapter demonstrates how manpower planners can employ Markov models (fixed recruitment, fixed inventory, and steady state) to analyze the relationships between accession rates, transition rates, and end strength goals to achieve specific manpower goals for the FM community. If the SC's 3111 community remains in a steady state and continues to average 32 accessions per year, OP will likely never achieve its minimum inventory goal of 50 3111 O6QR-qualified SC officers. To achieve this goal without significantly increasing the community's end strength, OP must find the most cost-effective blend of increasing the number of follow-on tours and initial FM tours throughout the community.



VI. CONCLUSION AND RECOMMENDATIONS FOR FUTURE RESEARCH

A. CONCLUSION

NAVSUP OP requested our assistance to analyze and critically evaluate the overall health of the Navy Supply Corps' Business Financial Management (3111) community in terms of manpower and experience across all ranks. To do so, we obtain historical data from OP to build and employ various Markov models to demonstrate the flow of 3111QR officers through the system. In doing so, we examine the forecasted end strength of Navy Supply Corps officers with FM experience, and we assess whether the current training pipeline facilitates the creation of enough FM experts at the O5/O6 levels to achieve OP's planning factor goal of 2.5 qualified 3111QR officers for every O5 and O6 3111 billet, respectively.

We determine that if the SC's FM community continues along its current trajectory, taking into consideration historical 3111 accessions, promotions, and attrition rates, OP achieves its inventory goal at the O5 rank, but falls short of achieving its inventory goal at the O6 rank. The SC has averaged 32 accessions into the 3111 community annually over the past ten years. Our fixed recruiting Markov model demonstrates that if the FM community continues to average 32 accessions into the community annually, by year 2031 (and beyond) OP is likely to achieve a steady state inventory of 37 3111 O6QR-qualified SC officers, which falls short of its inventory goal of 50.

Our models find multiple ways that OP can achieve its O6QR minimum inventory goals. One option is to increase annual fixed recruitment from 32 to 43. However, this will require growing the FM force by approximately 102 officers. If OP determines that adding 11 new entry-level FM billets is not a feasible solution because of timing or budget constraints, our second recommendation is the hybrid approach of adding a limited number of new entry-level billets while more substantially increasing the number of follow-on tour billets for officers with 3111S and 3110P codes. As we demonstrate in Chapter V, by increasing the number of FM follow-on tours, OP increases opportunities for SC officers to transition from 3110P to 3111Q, or from 3111S to 3111R, thereby increasing transition



rates between states and minimizing excess inventory levels of 3111S and 3110P officers across the O3-O6 ranks. As policies continue to change, we recommend that OP manpower planners utilize Markov models as a “best practice” to forecast inventory levels and to reach desired end states across all of its SC communities. We also recommend that OP perform a cost-benefit analysis to determine the right blend of increasing both accessions and follow-on tour opportunities to achieve OP’s O6QR inventory goal for the FM community.

Lastly, we recommend that OP review its existing policy to explore the practicality of a 2.5 planning factor as a blanket determination for the “health” of its SC communities at the O5/O6QR level. Ostensibly, the SC’s forecasted steady state inventory of 37 3111 O6QR-qualified SC officers appears more than adequate to fill the community’s 20 3111 O6QR billets (a 1.85 planning factor). However, OP’s current 2.5 planning factor suggests that the community is undermanned by approximately 13 O6QR SC officers. Given the SC’s current manning shortfalls to fill operational tour billets and critical billets in other major SC competency areas, fixing the O6QR inventory “shortage” is likely not a major concern. We believe that OP should conduct additional research to determine a more reasonable planning factor value that serves as an efficient, cost-effective barometer for determining the health of all SC communities’ end strengths.

B. RECOMMENDATIONS FOR FUTURE RESEARCH

We recommend the following future research objectives for the FM community:

- Conduct a cost-benefit analysis to determine the right blend of increasing both accessions and follow-on tour opportunities to achieve OP’s O6QR inventory goal for the FM community.
- Review the validity of a 2.5 manpower planning factor as a blanket determination for manpower “health” at the O5 and O6 levels across all SC communities.



- Examine the long-term impact of the shift from DAWIA's three-level experience certification to the Back-to-Basics Framework on the readiness of the military and/or civilian workforce.
- Create manpower models for the SC's remaining core competency areas (i.e., supply chain management, fuels, planners, operations research, logistics information and technology).



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