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FORECASTING INVENTORY LEVELS WITH MARKOV MODELS FOR THE ACQUISITION AND CONTRACTING SUBSPECIALTY (1306) IN THE SUPPLY CORPS

June 2021

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13. ABSTRACT (maximum 200 words)

The U.S. Navy Supply Corps consists of officers with subspecialties (SSP) that are required to fill certain billets. Manpower planners are tasked with ensuring that the community trains and qualifies officers in each SSP to keep the Supply Corps healthy and able to fill all critical billets. Navy Supply Systems Command Office of Personnel has stated that the Acquisition and Contracting SSP (1306) is the most "at risk" for not having enough qualified personnel to fill the O-6 billets.

This MBA project develops and employs Markov models to create a 10-year 1306 inventory forecast for FY22 through FY31. We use a fixed inventory model to determine the number of accessions needed to achieve 1306 end-strength goals, a fixed recruitment model that determines a projected end-strength by an accession policy, and a steady-state model that shows inventory levels of each state when the system reaches equilibrium. Finally, we demonstrate how changing transition rates and accessions can help manpower planners develop courses of action to meet manpower requirements.

Through the employment of the Markov models, we find that if the average number of accessions continue with the current transitions rates, then the SC will never be able to meet their planning goals. The models prove to be a useful tool for manpower planners; therefore, we recommend using the models to forecast the 1306 inventory.

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ABSTRACT

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LIST OF ACRONYMS AND ABBREVIATIONS

AFQ	all fully qualified
AQD	additional qualification designators
BUPERS	Bureau of Naval Personnel
BUPERS-3	Bureau of Naval Personnel 3
DAU	Defense Acquisition University
DAWIA	Defense Acquisition Workforce Improvement Act
DLA	Defense Logistics Agency
DOPMA	Defense Officer Personnel Management Act
FY	Fiscal Year
FYDP	future years defense program
JO	junior officer
JQO	joint qualified officer
FLC	Fleet Logistic Center
LDO	Limited Duty Officer
NAVADMIN	naval administrative message
NAVSUP	Navy Supply Systems Command
NPC	Navy Personnel Command
NROTC	Navy Reserve Officer Training Corps
OCM	Officer Community Manager
OCS	Officer Candidate School
OPNAV	Office of the Chief of Naval Operations
ODIS	on-line distribution information system
OMPF	officer's official military personnel file
OP	Office of Personnel
OPA	officer programmed authorizations
OSR	officer summary record
POCR	Probationary Officer Continuation and Redesignation
PSR	performance summary record
SC	Supply Corps
SECNAV	Secretary of the Navy
SME	subject matter expert
SSP	subspecialty
SYSCOM	Systems Command

TYCOM	Type Command
USNA	United States Naval Academy
WSS	Weapons System Support
YG	year group

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I. INTRODUCTION

A. OBJECTIVES / PURPOSE

The U.S. Navy Supply Corps (SC), like any community, is involved with personnel planning. The SC has the responsibility to design an appropriate force structure that supports the fleet in addition to planning for the ever-changing end-strength numbers. One of the biggest challenges for the SC is the development of officers in a wide array of subspecialities (SSP) and additional qualification designators (AQD) that will ensure that the community has enough qualified officers at the senior ranks. This development must start early, due to the limited opportunities to gain SSPs/AQDs. It is imperative for the SC community to have billets available early in a SC officer's career to allow them to gain experience and be prepared for the challenging and demanding billets at the senior ranks of O-5 to O-6.

This MBA project develops and employs Markov models to create a ten-year forecast of SC inventory by rank and SSP qualification level. We focus on the Acquisition and Contract Management (1306) subspecialty within the SC. This has been determined to be the most "at risk" subspecialty of not having qualified personnel to fill the senior ranks. We demonstrate how Markov models can be used by manpower planners to achieve the inventory/billet requirements for 1306 qualified officers at each rank over the next ten fiscal years (FYs) (FY22-FY31).

B. BRIEF BACKGROUND

U.S. Navy Supply Corps Officers are in charge of all the supply and logistics functions required to sustain ongoing operations in the Navy. Supply Officers are experienced in a broad range of specialties that include contracting, supply chain management, financial management, fuels management, operations analysis, information systems, expeditionary logistics, material and operational logistics, disbursement, inventory control, and food service. (U.S. Navy, n.d.). The core subspecialties in the SC Community are designated by a four-digit SSP code along with an alphanumeric suffix code that qualifies the level of SSP experience gained by a specific SC officer. To obtain

an SSP or a graduated experience suffix for an SSP, a qualifying officer must serve in a billet that provides the requisite experience and time for that individual to record that experience in their official record. Each year, the SC community managers publish their valued achievements prior to the O-4, O-5, and O-6 promotion boards and among these valued achievements, significant experience in one SSP and progressing experience in a second SSP is consistently stressed.

In recent years, the U.S. Navy Supply Corps Office of Personnel (NAVSUP OP) has stated that the community is experiencing difficulties in filling the critical contracting (1306) billets at the rank of O-6. The FY22 O-6 Staff Convening Order for the O-6 promotion board expresses the need for subject matter experts (SME) in contracting, "the SC has a critical need for officers selected for captain who have significant contracting expertise. These selections should only be realized if there is a sufficient number of officers determined best qualified among those fully qualified officers who possess contracting expertise" (Assistant Secretary of the Navy (Manpower and Reserve Affairs), 2021). In response to this recognized need for O-6 contracting officers, NAVSUP OP requested assistance in modeling and forecasting the manpower requirements for the 1306 community.

C. SCOPE

The SC community health is important, but our particular interest is the behavior of the Acquisition and Contract Management SSP (1306). This requires an examination of accessions, transitions, and attritions to ensure the SC has experienced and qualified officers at every level to fill existing SC billets. The scope of this MBA Project consists of 1306 SC officers pay-grades O-1 through O-6 from 2018 to 2020. The data obtained from the On-line Distribution Information System (ODIS) allows us to create the probabilities for accessions, transitions, and attritions within the 1306 SC community.

D. APPROACH

We develop Markov models that show the flow of 1306 SC officers though the system. From the data, a transition matrix, a recruitment vector, and an inventory vector were created and used in the model. The model then identifies the number of 1306 SC

officers at each state (O-3/1306 through O-6/1306) and the probability of them transitioning to the next state annually. Officers either remain at their current state, promote to the next state, or leave the system (attrite). We build separate models for the aggregate of 1306s and 1306s with suffix of Q or R (1306QR). We use a fixed inventory model to determine the number of accessions needed to achieve 1306 end-strength goals, a fixed recruitment model that determines a projected end-strength by an accession policy, and a steady-state model that shows inventory levels of each state when the system reaches equilibrium. Finally, we demonstrate how changing transition rates and accessions can help manpower planners develop courses of action to meet manpower requirements. These models allow us to make recommendations for SC manpower management.

E. CONCLUSIONS / RECOMMENDATIONS

To meet the requirement for the SC contracting community, we recommend SC manpower planners at NAVSUP OP use the Markov models for manpower forecasting of 1306 officers. Based on the information derived from models, we observe that the current average of 41 accessions per year into the 1306 community will not be sufficient to attain NAVSUP OP's planning factor of 2.5 qualified O-6 1306QR officers to one O-6 1306 billet. To obtain this goal, 1306 entry level billets and experience tours must increase. Manpower planners can use the fixed inventory, fixed recruitment, and steady-state inventory to evaluate the different states in the system and use this information to make policy changes within the SC to address any manpower issues.

F. ORGANIZATION OF STUDY

This chapter examines the objectives/purpose, scope, approach, and conclusions/recommendations of this MBA project. Chapter II provides an overview of the Navy SC and gives background on the SC community. Chapter III reviews literature on Markov models and examines civilian and military use of Markov models. Chapter IV describes the data and methodology implemented in the development of Markov models for the SC community with a focus on the 1306 SSP. Chapter V employs the Markov model. The final chapter offers conclusions, recommendations, and potential areas of further research.

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II. BACKGROUND

A. UNITED STATES NAVY SUPPLY CORPS

The SC has multiple competencies that must be developed in the community which requires junior officers (JO) to begin this training early in their career so they can develop the skills necessary to become subject matter experts (SME). This developed expertise is necessary for the SC to fill critical billets at senior ranks. The SC has even stressed the importance of the SC competencies and placed it in the convening orders for officer promotion boards. All competencies are important, but the following paragraph pulled from the FY22 O-6 Staff Convening Order shows a critical need for contracting officers (1306).

> Officers who are subject matter experts in at least one principal SC competency such as supply chain management, contracting, financial management and planner, and have experience in a second principal competency have demonstrated the potential to succeed at the level of captain. *Additionally, the SC has a critical need for officers selected for captain who have significant contracting expertise. These selections should only be realized if there is a sufficient number of officers determined best qualified among those fully qualified officers who possess contracting expertise*. (Assistant Secretary of the Navy (Manpower and Reserve Affairs), 2021, p.15)

1. Roles and Responsibilities / End-Strength

The role of a SC Officer is to manage all supply related activities both at sea and on shore. Responsibilities are not comprehensive but rather incorporate accounting and dispensing of assets, appropriation of provisions, stock control techniques and frameworks, disposition of excess and out of date stock, and storage and conveyance of material (U.S. Navy, n.d.). Supply Officers retain broad information on supply, readiness, logistics, combat support, and contracting and monetary issues. SC Officers are knowledgeable about an assortment of specialties such as food administration contracting, information systems, inventory control, and fuels management.

The current SC officer strength, Figure 1, shows that the total inventory is 2,176, which is 103 less than the authorized 2,279 (Office of Supply Corps Personnel, 2021). The

inventory column does not count Supply Officers that are students, on legal or medical hold, or in the process of separating or retiring from military service. This dramatically decreases the available inventory needed to fill billets.

Supply Corps Officer Strength

3100 Active Component

Paygrade	Authorized	Inventory	Gross Over/Under	3100s in non 3100 billets	GSA/IA Fills	Delta
O-6	172	172	**0**	3	0	**-3**
O-5	346	304	**-42**	2	2	**-46**
O-4	508	484	**-24**	4	0	**-28**
O-3	691	715	**24**	1	1	**22**
O-2	285	305	**20**	0	2	**18**
O-1	277	196	**-81**	0	0	**-81**
Totals	**2279**	**2176**	**-103**	**10**	**5**	**-118**

* *Source: Officer Personnel Information System (OPINS) data as of 31 Dec 20. Online Distribution Information System (ODIS) data query. 3100 Supply Corps Fall 2020, FY-21 Officer Program Authorization.*

Figure 1. Supply Corps Officer Strength. Source: Office of Supply Corps Personnel (2021).

Unlike some Navy communities, SC officers do not begin their career with a specific SSP but earn them over time. While there are various SSPs that can be earned over a SUPPO's career, the FY22 O6 convening order places greater value on a few principal competencies. These competencies are Supply Chain Management (1302), Acquisition & Contract Management (1306), and Financial Management (3111). These principal competencies are earned through years of schoolings, specific billets, internships, and experiences.

2. Accession Planning

The Navy has two organizations that work together to manage human resources and that is Navy Personnel Command (NPC) and Bureau of Naval Personnel 3 (BUPERS-3). NAVSUP Office of Personnel (OP) is located within NPC and are responsible for detailing and placement of SC officers. Within BUPERS-3, the SC has the Supply Corps Officer Community Manager (OCM) (Carnal & Tobias, 2015).

The OCM is responsible for taking the authorized inventory levels from the Officer Programmed Authorization (OPA) and develop a manpower plan to stay within the authorized levels. The OCM has to manage the SC officer inventory by planning for annual accessions and current billet structures. Each billet is structured by officer designator and rank and OPA is funded to the billet authorizations. OPA figures are published bi-annually with current year plus Future Years Defense Program (FYDP). The OCM manages the inventory to align with OPA. This promotes a healthy community with desired manning (Carnal & Tobias, 2015).

Accessions into the SC are critical to manpower planning because the number of officers brought in each year will help maintain the authorized inventory levels. The accessions are calculated by total inventory levels and the number of officers required to meet second operational tour requirements (Carnal & Tobias, 2015). The retention rates of the officers that fill these second operational billets also factor into accession planning.

3. Officer Promotions and Career Milestones

Each year promotion boards for the SC are held for the ranks of lieutenant commander (O-4), commander (O-5), and captain (O-6). A Supply Officer's eligibility for promotion to the next rank is based on their date of rank and precedence number. An officer's precedence is a product of the Year Group (YG) they belong to, the effective date of their commission, and their percentile of class standing amid the other ensigns appointed from every commissioning source of the same date, or with the same initial date of rank (Office of Supply Corps Personnel, 2015). The Defense Officer Personnel Management Act (DOPMA) Grade Table informs the annual Officer Promotion Plan, which then feeds the "Zone" NAVADMIN that is produced each December by the Secretary of the Navy (SECNAV). The "Zone" NAVADMIN informs the Navy when promotion selection boards will convene in the following year and what officers will be in-zone or eligible for promotion based on their precedence number. The DOPMA Grade Table caps the number of lieutenant commanders, commanders, and captains in the Navy based on total officer end-strength, rank vacancies due to promotions, retirements and separations, and force requirements (Office of Supply Corps Personnel, 2015). Annual promotion boards are

divided by rank and whether the individual serves as an Unrestricted/Restricted Officer or as a Staff Corps Officer (Department of the Navy, 2021). SC officers are classified as Staff Corps Officers.

Promotion Opportunity for an officer is based on their zone size (chance for selection), promotion rate, and the average time to promotion to the next rank (flow point). The flow points and promotion opportunities for the ranks of ensign through captain can be seen in Figure 2 (Office of Supply Corps Personnel, 2015). While the flow point for a newly appointed ensign to promote to lieutenant junior grade is typically two years and the Promotion Opportunity is All Fully Qualified (AFQ), the flow point for a captain is 21 to 23 years with a Promotion Opportunity of 50 plus or minus 10% from the rank of commander.

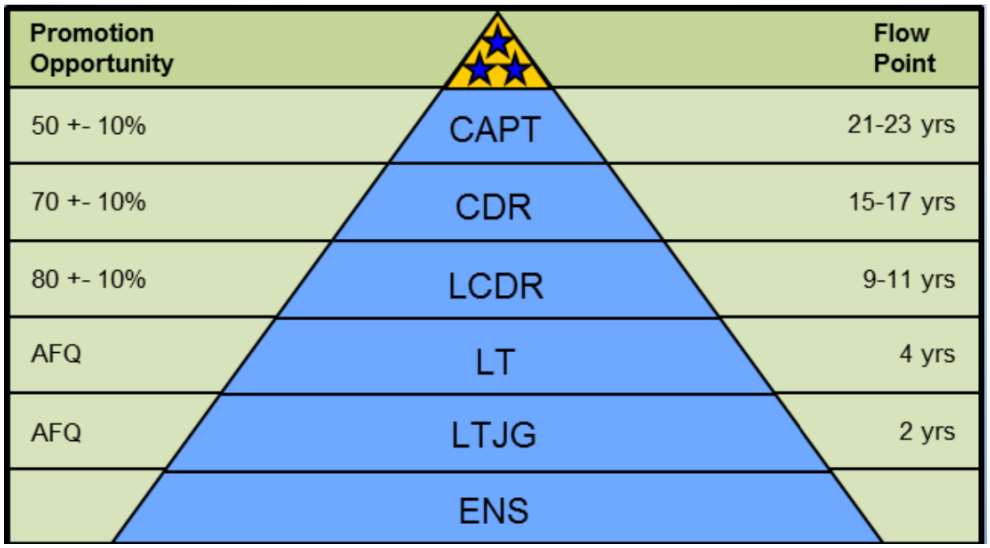

Figure 2. Promotion Opportunity and Flow Points. Source: Office of Supply Corps Personnel (2015).

The Bureau of Naval Personnel (BUPERS) annually produces promotion board schedules, convening dates, and board requirements for all SC officers who are eligible for promotion. The requirements will include the recorders necessary to support the board as well as the composition of the board members. SC promotion board members and recorders are selected based on diversity within the SC community (experience, warfare

qualifications, SSPs) and recommendations by Supply Corps Flag Officers to the Chief of the Supply Corps. Promotion boards are typically composed of five to seven board members, and each board member must be senior to all of the officers considered for promotion in that board. Guidance for board members is provided via the precept and convening order. While the precept is a generic document generated by the convening authority and provides guidance on criteria upon which selections should be made, the convening order is a more specific document for a particular board that provides the convening details as well as community guidelines, career achievements and specific qualifications for board members to look for when making their selections. These criteria for selections are derived from community management briefs and/or approved program instructions (Office of Supply Corps Personnel, 2015).

Once the board has convened, the board members review the records of the eligible officers and cast a secret ballot vote on their confidence that each officer should be selected. Confidence votes are cast with five options:100% (100 percent confident Officer should be selected), 75%, 50%, 25%, and 0% (zero confidence in selecting the Officer). The only information reviewed or shared during a board comes from each eligible Officer's Official Military Personnel File (OMPF), their Performance Summary Record (PSR)/Officer Summary Record (OSR), and any correspondence submitted to the board from that particular Officer about their record. The OMPF contains information such as fitness reports, personal awards, and any other matters of official record while the PSR/OSR acts as a career resume that contains summary information. After the board deliberates and votes to confirm the candidates that are best qualified for promotion, the board then provides the list back to SECNAV, and it is ultimately approved by the Secretary of Defense (Office of Supply Corps Personnel, 2015).

A general foundation for a successful SC officer career has been outlined in a NAVSUP OP published "playbook" called *It's Your Career*. This acts as a strategic, overarching conversation regarding SC career philosophy, mentorship, and a general approach in career success. When it comes to Supply Corps Career Milestones mentioned in this document, the community has had the same milestones at each rank for the last ten

years, despite changes in the needs of the Navy and changing professional needs within the SC. The career milestones for each rank can be seen in Figure 3.

Figure 3. Career Milestones in *It's Your Career Playbook*. Source: Office of Supply Corps Personnel (2011).

Each year the NAVSUP OP also publishes its valued achievement prior to the ranks of lieutenant commander, commander, and captain as a part of their presentation during its OP Roadshows. As of 2020, the valued achievements prior to the rank of lieutenant commander were gaining a warfare qualification and completing two operational tours at sea, in an expeditionary command or a combination of both. The valued achievements prior to the rank of commander are obtaining a master's degree associated with an SC competency, experience in an SC competency and progress toward a second one (SSP strongly encouraged), and a tough visible tour that balances operational experience and skillset development. Examples provided by NAVSUP OP for these tough visible tours that balance operational expertise and skillset development include those on large afloat vessels such as Aircraft Carriers, NAVSUP Headquarters/Office of the Chief of Naval Operations (OPNAV), Fleet Staff, Type Command (TYCOM), Systems Command

(SYSCOM), Weapon Systems Support (WSS), Fleet Logistics Center (FLC), Joint, and Defense Logistics Agency (DLA). The valued achievements prior to achieving the rank of captain include the proven ability to lead and direct military and civilian personnel and organizations in tough, highly visible, and challenging environments, expertise in one and experience in another competency (SSP), Joint Qualified Officer (JQO) or Acquisition Corps membership, and completion of an O-5 milestone tour. The O-5 milestone tours include Command as an O-5 and Department Head on a large afloat vessel (Secretary of the Navy, 2020). A breakdown of the most current career milestones according to NAVSUP OP can be seen in Figure 4. Common among both the *It's Your Career* playbook and OP Roadshow presentations is a theme of developing leadership skills and sustaining superior performance throughout a career in the Supply Corps.

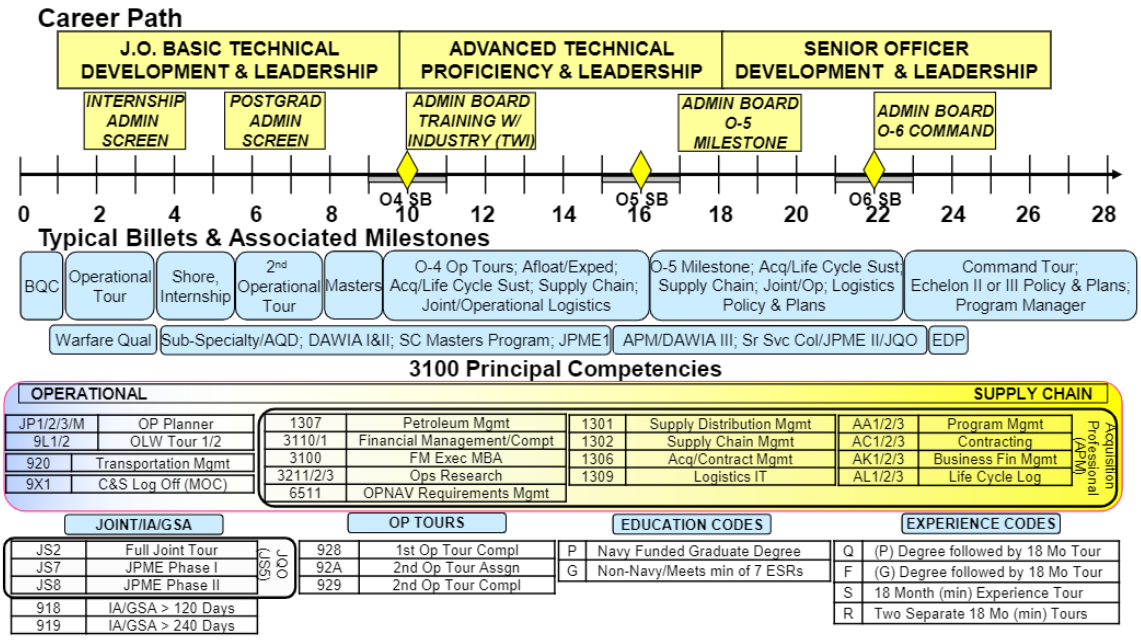

Figure 4. Career Milestones in FY22 Staff Corps Community Brief. Source: Secretary of the Navy (2020).

4. How to Obtain SSPs and AQDs

After junior SC officers complete their first operational assignment and earn their first warfare pin, they will have the opportunity to gain an SSP and AQD at follow-on

commands. They can earn an SSP and AQD in a SC line of operation and functional subspecialties through the SC internship program or be assigned to a coded billet. This allows junior officers to gain experience in these fields and gain exposure to different SC line of operations (Engler, 2016).

Not all officers have received an SSP or AQD by the time they are accepted to a graduate program. Officers, even if they already have an SSP/AQD, are screened and selected to attend the Naval Postgraduate School, the 810 program to attend a top 30 business school, the 811 program at Kansas University fuel program, or they may obtain their graduate degree on their own. Once an officer graduates from one of these programs they will have obtained an SSP that will prepare them for an experience tour to validate their education.

AQDs are obtained while an officer is attached to a coded billet and has completed the necessary courses from Defense Acquisition University (DAU) to achieve Defense Acquisition Workforce Improvement Act (DAWIA) Level I/II/III certification. DAWIA Level III is necessary for senior officers to hold critical billets in that line of operation.

SSPs gain a suffix based on education level and experience, and AQDs increase in levels based on DAWIA certification and experience. Table 1 shows the meaning of SSP suffixes and AQD levels.

Table 1. SSP Suffix and AQD Levels. Adapted from Department of the Navy (2020).

Subspecialty Code Suffixes	
S	18 or more consecutive months in a subspecialty coded billet
R	Two separate experience tours, at least 18 months each
T	Currently enrolled in Navy-funded master's program
P	Navy funded graduate degree (awarded after graduation)
Q	Navy funded graduate degree followed by an experience tour of at least 18 months
G	Non-Navy funded graduate degree that meets 70% of Core Skill Requirements (CSR)
AQD Levels (i.e., AC*)	
N	Non-Critical Acquisition Billet
1	Level 1 Career Field Certified
2	Level 2 Career Field Certified
3	Level 3 Career Field Certified
C	Critical Acquisition Billet
K	Key Leadership Position

B. SUPPLY CORPS ACCESSIONS

The SC community receives officers from five sources, and they are Officer Candidate School (OCS); Probationary Officer Continuation and Redesignation (POCR) boards; Limited Duty Officer (LDO) boards; United States Naval Academy (USNA); and Navy Reserve Officer Training Corps (NROTC) (Reel, 2019). First and second operational tour requirements determine the number of accessions required annually. The priority of NAVSUP OP is to ensure that all operational billets are filled at the JO ranks (Reel, 2019).

1. Officer Candidate School

OCS provides approximately two thirds of accessions into the SC. Senior SC officers review candidates for OCS on a quarterly basis and use factors such as grade point average, Officer Aptitude Rating, work experience, and minimum academic qualifications for Naval Postgraduate School to recommend a candidate to OCS (Reel, 2019). If selected,

the officer candidate then has to complete OCS in Newport, Rhode Island before being commissioned as a SC officer.

2. Probationary Officer Continuation and Redesignation Boards

The POCR board is the second largest source for SC accessions. This is approximately a third of accessions into the SC. This board allows officers who did not meet all the requirements in their initial community to redesignate to another community in the Navy. The officers are required to have less than six years of commissioned service (Reel, 2019).

3. Limited Duty Officer Boards / United States Naval Academy / Navy Reserve Officer Training Corps

These remaining three sources have very limited accession inputs into the SC. The USNA and NROTC conduct an internal review process to determine if a student will be commissioned into the SC and the LDO board may select 6–8 officers to join the community. LDOs are expected to become a 3100 (Supply Corps Officer Designator) by their fifth year of commissioned service (Reel, 2019).

III. LITERATURE REVIEW

A. OVERVIEW

The research that is reviewed in this chapter provides civilian and military applications that helps reinforce the methodology used in this study. Most manpower planning studies usually concentrate on manning in the civilian sector and the military studies were on other communities in the Navy other than the SC. The studies that were found on the acquisition and contract management community did not develop a model to forecast 1306 SC officers. This MBA project attempts to fill that gap.

B. STATISTICAL APPROACH TO MANPOWER PLANNING

Bartholomew, Forbes, and McClean provide multiple stochastic models used by many manpower analysts in the second edition of their book, *Statistical Techniques for Manpower Planning* (1991). Each stochastic model examines how manpower planning can use this application and provides the technical information for the execution of the model. Well-known researchers such as Bartholomew (1971), Vajda (1975), Grinold and Marshall (1974) have developed and researched stochastic models in the past. Bartholomew et al. provides the building blocks necessary to develop our Markov model.

Most manpower planning problems are suitable for statistical application because of two features: the concern for aggregates and the concern for uncertainty (Bartholomew et al., 1991). Historical data of a manpower system can be explored and aggregated to provide a portrayal of that system. The aggregated data is then represented by probabilities and this reflects the uncertainties that human behavior presents in any model (Bartholomew et al., 1991).

SC officers can exist in a particular state at one given time and this is considered a heterogeneous system (Bartholomew et al., 1991). Due to these mutually exclusive states, a transition model based on the theory of Markov chains is the best model to forecast manpower in the military and is most applicable to this study.

C. CIVILIAN STUDIES

Various studies on organizational manpower using Markov models have been conducted by the military over the last 50 years, but few civilian manpower studies have made use of Markov models in predicting future trends and using that data to meet organizational needs. The following two studies follow a very similar methodology employed in this study. Other prominent manpower studies in the civilian sector can be found in studies conducted by McClean et al. (1997), Davies (1973; 1981) and Sales (1971).

In Stelios Zanakis and Martin Maret's 1980 manpower study, they present a Markov model for engineers in a department of a chemical company that aimed to meet the company's future manpower needs (demand) and resources (supply) given multiple company objectives, such as people skills inventory, organization history, policies regarding hiring, promotions, training, retirement, and firing. Markov chains can be used to forecast personnel supply in a company or organization by modeling the flow of individuals through various "states," such as years of service, skill level, or position level. To model the flow of engineering personnel through the company as a Markov chain, Zahakis and Maret define the stage interval and states, collect historical data on personnel movement through the system, estimate the matrix of transition probability (**P**) and validate the model. They use years as the stage interval (time) because hiring quotas, budgets, and long-term organizational plans were prepared by the company on a yearly basis. The states for this model are position level of the employee, types of gains, and types of losses. Using historical data, the annual transition rates are manually calculated by state. From this data the team creates a **P**, which reflects the probability that a "typical" employee in the organization would transition from one state to another within the period of a year. The **P** can then be used to multiply by different input vectors to make future manpower distributions by state and examine different long and short-term accession policies. The results of the study lead to a conclusion that historical data of a company's transitions to and from levels of position, as well as accessions and additions can be used to develop an advantageous Markov chain model for manpower and longer periods of observation.

Another conclusion is that extensive time periods of data collection are not necessarily better in model application as organizational policy changes may lead to poor predictions.

Zahakis and Maret's study is applicable to this study as we are using a transition probability Markov model to address accessions that will meet the future needs (O-6 1306) of the SC. We use a stage interval based on years due to annual maximum quotas imposed on the SC community. We also use historical data to calculate the annual transition rates by state, which helps us to produce a **P** from which we make predictions for the necessary annual accessions within the SC 1306 community to meet the required number of critical 1306 O-6 billets.

A 1999 study by Raymond Hackett, Alexander Magg, and Sarah Carrigan uses a time-dependent Markov chain to model strategies for faculty replacement at the College of Veterinary Medicine at Auburn University. The team collects eleven years of data from the faculty and develops a planning model incorporating projections of tenure, academic rank, and appointment rates by age and time. The **P** utilizes various states within the areas of staff employment status, age, and type of attrition from employment. Using the actual distribution of faculty for the most recent year, and the transition probabilities from the data accrued over a ten-year period, the team develops staffing predictions based on current year figures or adjusted for potential personnel policy changes. Results of the model are validated based on the trends exhibited by historical data. Through testing of various strategies to minimize the cost of maintaining faculty, the team finds that a combination of a hiring freeze and an early retirement option would produce an appropriate mix between age, rank and size of faculty that would ultimately yield the best results in minimizing employment cost. This study relates to the study we are conducting as we are using historical SC officer data to create a transition matrix that shows accessions, attritions, and promotions through the 1306 community. Furthermore, we are able to make predictions and recommendations for future SC community manning. Whereas the Hackett et al. study is based on budgetary restraints, our study is constrained by limitations on annual accessions and opportunities to attain various states of qualifications (SSP suffixes) within the 1306 community.

As was previously mentioned, there are limited organizational manpower studies using Markov models to predict or meet the future needs of civilian organizations, but the military has conducted various studies that use the methodology we employ in this study. The following section covers some of the military manpower studies that employ manpower models and how they lend themselves to the research being conducted in this project.

D. MILITARY STUDIES

Military personnel, specifically SC officers, have several characteristics like rank and subspeciality codes. During the course of a career, SC officers transition to numerous ranks and gain multiple subspeciality codes. Other characteristics of military manpower systems include a strict hierarchy, no lateral entry, and up or out promotion process.

Inside the Department of Defense, the utilization of Markov models, unlike traditional approaches such as regression models, allows for an explanation of military manpower planning over time and answers a number of important questions. At the service level, the military application of Markov chains includes the management of Marine Corps first term enlisted (Nguyen, 1997), the survival pattern of United States Naval Officers (Korkmaz, 2005), and forecasting continuation rates of enlisted prior service and non-prior service in the selective Marine Corps Reserves (Erhardt, 2012). On a more restricted scale, at the community level, Markov models have been utilized in planning military subpopulations such as the Navy Nurse Corps (Deen & Buni, 2004), Marine Corps Acquisition Community (Nicholson, 2012), Naval Helicopter Community (Crawford, 2014), and Navy Medical Service Corps (Josiah, 2014). Military applications span across topics from comprehensive groups to smaller categories, but there are limited studies on Navy SC contracting officers.

There are a few SC specific related studies that focus on the SC and contracting community. Aurelio (2017) touches on all the SC SSP, Schonenberg (1988) and Newell (1994) focused on acquisition and contract management within the SC. While these studies focus on the contracting community, they do not create a manpower planning tool to address future manpower in the SC.

E. CHAPTER SUMMARY

This chapter shows how Markov chains can be used as a manpower planning tool for both civilian organizations and military communities. The research discussed strengthens the relevance of the Markov model and how it will address the primary question of this study. It also provides to tools needed to apply the models to the 1306 SC community.

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IV. DATA AND METHODOLOGY

A. INTRODUCTION

This chapter introduces the Markov model that we apply in this study to create a ten-year forecast (FY22 to FY31) of SC personnel inventory levels by rank and 1306 SSP. Chapter IV describes the data used for this study. Personnel, with 1306 SSP, in this Markov model transition through the system by staying at current rank, staying at current rank and qualifying (earning an Q or R suffix), promoting to the next rank, promoting to the next rank and qualifying, or attrite from the system. We neglect demotions since they are so rare.

1. Data

a. Variables Used in Model

The data for this project was obtained from NAVSUP OP as an Excel file from the ODIS database. The following descriptive variables are pulled from all active-duty SC officers (3100s) over three years (FY18 to FY20). Three variables from this data were pulled and exported to Microsoft Excel to incorporate into Markov models. It is important to note that officers with an apparent gap in service are removed from the data set.

b. Unique Identifier

The data file from OP assigned a unique identifier (P3SCID) that could identify and track an individual through the system.

c. Rank

For this project, the ranks of ensign (O-1) through captain (O-6) were used from the data. The variable rank was represented by six possible values (ENS, LTJG, LT, LCDR, CDR, CAPT).

d. SSP

The SSP code variable captured the primary SSP of each SC officer and focused on any level of 1306 SSP obtained. This could be 1306S, 1306R, 1306T, 1306P, 1306G, or 1306Q.

2. Observations

The sample size includes 1356 observations and consists of SC officers in pay-grades O-1 to O-6 with a 1306 SSP from FY18 through FY20. Figure 5 is 1306 observations by rank and Figure 6 is 1306 observations by rank and Q or R suffix.

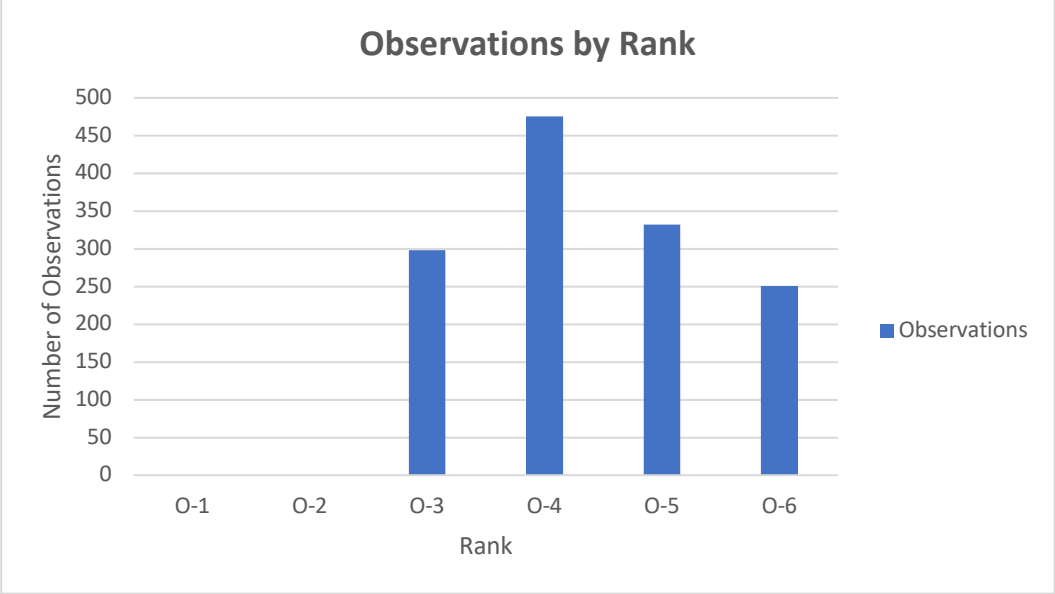

Figure 5. 1306 Observations by Rank.

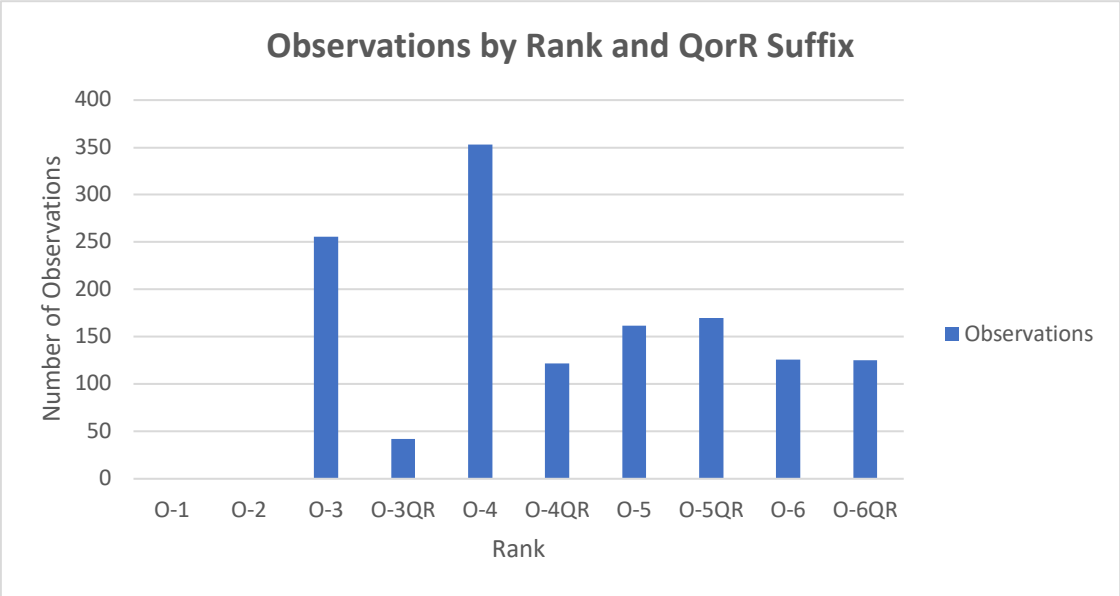

Figure 6. 1306 Observations by Rank and Q or R Suffix.

B. MARKOV MODEL ASSUMPTIONS

Markov models can prove to be exceptionally useful to any manpower planner because it allows the planner to forecast total end-strength and various states in the system. The development of this model is based on three fundamental assumptions: Finite State Space, Markovian Property, and Stationary Transition Probabilities (Seagren, 2021).

Our model adheres to the first assumption of finite state space because the model has multiple "states" that a 1306 officer may reside in for some time. These states are finite, mutually exclusive, and exhaustive. The states employed in the model consist of rank-subspecialty combinations (i.e., O-4 and O-4QR) and attrite. The "attrite" state is for officers that are no longer active-duty and for those who have promoted to admiral (O-7). Figures 7 and 8 show the basic functionality of the system used in this MBA project.

The Markovian Property states that the probability the system will transition to another state depends on its current state (Seagren, 2021). Our model consists of all officers with any level of 1306 in their record and we determine what state the officer is in on an annual basis. There are a few possible outcomes for these officers. The possible outcomes include an O-4 continues as an O-4, an O-4 may qualify to O-4QR (gain Q or R suffix), an

O-4 may promote to O-5, an O-4 may promote and qualify to O-5QR, an O-4QR may promote to O-5QR, and finally, an O-4 or O-4QR may attrite or leave the system. This applies to the other ranks also except a promotion from O-6 to O-7 is considered as an "attrite" because they are leaving our system.

The final assumption is that transition probabilities remain stationary over the life of the model. Mathematically, this requirement is shown as $\Pr(X_{n+1} = j \mid X_n = i) = \Pr(X_1 = j \mid X_0 = i)$. This represents that the probability that an element transitions from state i to state j at time $t = 0$ is the same for i to j at $t = 1$. The probabilities remain constant through time (Seagren, 2021).

1. Applied Method

a. Basic Functionality of the System

To understand the basic functionality of the system, a visual representation of the model is created to show how an officer can flow through the system and how transition probabilities are associated with each arc. Figure 7 represents the aggregated model of 1306 Supply Officers. The probability of an O-3 remaining an O-3 is represented by p_{33} (p_{ij}) and the probability of an O-3 promoting to an O-4 is p_{34}. We consider any officer who leaves the system, or is promoted to O-7, an attrite. Figure 8 represents the model when the 1306QR is added. This model has the same attrite state as the aggregate; however, this has been suppressed to show the additional states added.

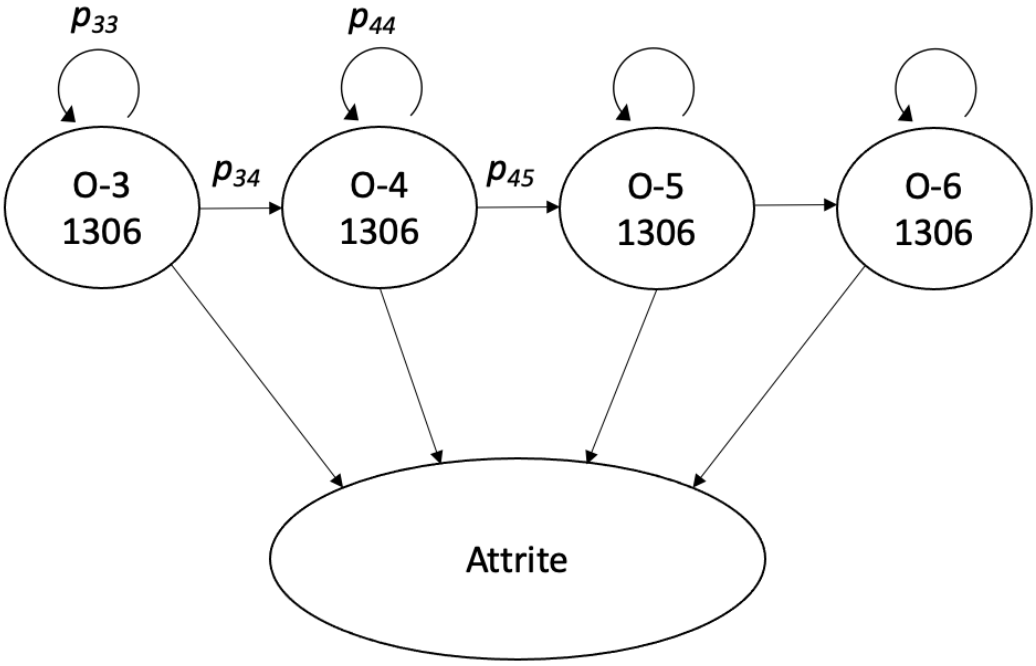

Figure 7. Visual Representation of the Markov Model for 1306 Officers.

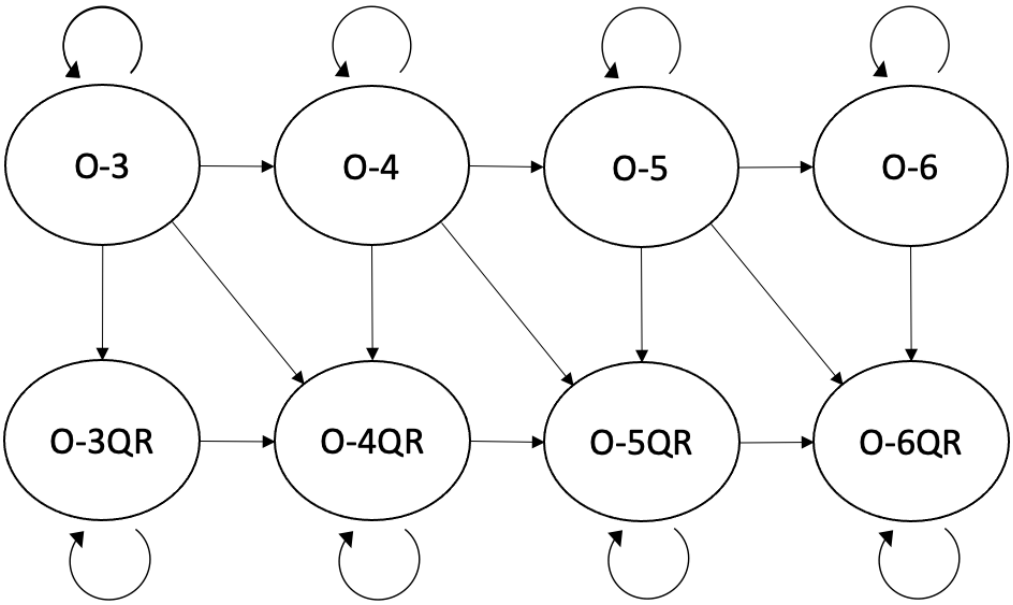

Figure 8. Visual Representation of the Markov Model with 1306QR State Added (Attrite State is Suppressed).

b. Flows and Transition Matrix

Prior to creating a **P** matrix, the flows from FY18 to FY20 must be combined. A flow chart is created for each fiscal year then aggregated into one flow chart. Table 2 shows this aggregated flow for 1306 officers and Table 3 shows the aggregated flows of 1306 to 1306QR officers.

Table 2. Aggregated Flows of 1306 Qualified SC Officers from FY18-FY20.

Flows	O3	O4	O5	O6	Attrite	Total
O3	192	67			39	298
O4		397	54		24	475
O5			271	29	32	332
O6				216	35	251

Table 3. Aggregated Flows of 1306QR Qualified SC Officers from FY18-FY20.

Flows	O3	O4	O5	O6	O3QR	O4QR	O5QR	O6QR	Attrite	Total
O3	147	49			20	4			36	256
O4		279	22			29	5		18	353
O5			121	17			7	0	17	162
O6				107				6	13	126
O3QR					25	14			3	42
O4QR						89	27		6	122
O5QR							143	12	15	170
O6QR								103	22	125

The **P** matrix is created by taking the sum of particular state from FY18-FY20 and dividing it by the total inventory. To illustrate this, take the probability of an O-3 continuing as an O-3 in the transition matrix for 1306 SC officers. This is calculated by Pr (O-3 | O-3) = 192/298 = 0.64. The p_{ij} is calculated for each state to complete the matrix. Table 4 shows the completed **P** matrix for the aggregated 1306 officers and Table 5 shows the completed **P** matrix for 1306QR officers.

Table 4. **P** Matrix for 1306 SC Officers.

	O3	O4	O5	O6	Attrite
O3	0.64	0.22			0.13
O4		0.84	0.11		0.05
O5			0.82	0.09	0.10
O6				0.86	0.14

Table 5. **P** Matrix for 1306QR SC Officers.

	O3	O4	O5	O6	O3QR	O4QR	O5QR	O6QR	Attrite
O3	0.57	0.19			0.08	0.02			0.14
O4		0.79	0.06			0.08	0.01		0.05
O5			0.75	0.10			0.04	0.00	0.10
O6				0.85				0.05	0.10
O3QR					0.60	0.33			0.07
O4QR						0.73	0.22		0.05
O5QR							0.84	0.07	0.09
O6QR								0.82	0.18

2. Manpower Inventory Models

a. Bartholomew's Inventory Equation

Before the manpower inventory models are explained, it is important to understand Bartholomew's inventory equation. This equation is used for both the fixed inventory and fixed recruitment models.

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

Bartholomew et al. (1991, p. 98) provides the definitions for the terms in this equation. The $\mathbf{n}(t)$ is the inventory vector for timestep t. The timestep in our model is on an annual basis so t =0,1,2,3…T. The next term, $\mathbf{n}(t\text{-}1)$, is the inventory vector for the previous timestep and the vector begins at $\mathbf{n}(0)$. The **P** is the transition probability matrix. The probability of an individual transitioning from state i to state j is indicated by p_{ij}. $R(t)$ is a number that describes the total number of accessions for a given year or timestep. The last term, **r**, is the recruitment vector, which describes the proportion of new accessions

that flow into the various states. This is the proportion of new accessions that arrive in each state. Simply, the equation states that current inventory at time *t* equals the previous inventory multiplied by the transition matrix plus the product of accession numbers and the accession vector (Seagren, 2021).

b. Fixed Inventory and Fixed Recruitment Models

The fixed inventory model allows for end-strength numbers to be set ahead of time for future years and utilizing solver in Excel to determine the number of accessions, *R*, required to meet the end-strength goals. With end-strengths determined by OPA, this is a powerful model that can be used to ensure manpower goals are met. This model helps answer the question of how many new 1306 officers are necessary to meet target end-strengths over the next X years.

The fixed recruitment model takes predetermined accession numbers, *R*, and allows planners to observe the behavior of the system through the years that are in question. This model allows manpower planners to set fixed recruitment numbers and then observe the expected end-strength. This model helps answer the question of what the expected end-strength over the next X years is, if the number of accessions is fixed.

c. Steady-State Inventory Model

The steady-state of a system is the equilibrium state to which the system converges if the system is undisturbed indefinitely. This requires the transition probabilities, *R,* and **r** not to change. The steady-state inventory vector, n*, is calculated using the fundamental matrix of the system. This is shown as n* = *R***rS** (Seagren, 2021). The fundamental matrix, **S**, provides the average time spent in each state. The steady-state inventory can be calculated with the determined accessions (*R*), recruitment vector (**r**), and the fundamental matrix (**S**). We use the model to solve for the *R* that obtains the desired steady-state inventory for O6QRs. The drawback to this approach is the fact that manpower systems rarely reach steady-state; however, this model is relevant because it could give an idea of what inventory levels would look like if accessions never changed.

C. CHAPTER SUMMARY

This chapter discusses the data and methodology used to construct the fixed inventory, fixed recruitment, and steady-state models. The Markov models used in this MBA project can be used by manpower planners to maintain the health of the 1306 SC community.

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V. EMPLOYMENT OF MODELS

A. OVERVIEW

This chapter employs fixed recruitment, fixed inventory, and steady-state inventory Markov models and demonstrates how manpower planners could use these techniques to answer managerially relevant questions of importance within the SC. We explore the relationships between accessions, end-strength goals, and transition rates and how they affect the outputs (inventory forecasts) of the models. Each of the Markov models are implemented for the aggregate 1306 community, and the 1306QR qualified officers.

B. FIXED RECRUITMENT

In the fixed recruitment model, the determined accessions (R) is calculated from the average number of accessions (41) into the 1306 community over the last ten years (FY11 to FY20). This figure closely matches the annual number of 1306 billet opportunities, which is calculated by adding the number of internships (17), 1306 coded billets (10), and seats at NPS (18). This yields an annual opportunity figure of 45. Figure 9 shows the values of R used in the fixed recruitment models. Figures 10 and 11 show the values of **r**. These values, and **P**, are placed in the inventory formula $\mathbf{n}(t) = \mathbf{n}(t\text{-}1)\mathbf{P} + R(t)\mathbf{r}$.

	R
2022	41
2023	41
2024	41
2025	41
2026	41
2027	41
2028	41
2029	41
2030	41
2031	41

Figure 9. Fixed R Values for the Fixed Recruitment Models.

r			
O3	O4	O5	O6
0.684	0.298	0.018	0

Figure 10. Accession Vector for 1306 Model.

r							
O3	O4	O5	O6	O3QR	O4QR	O5QR	O6QR
0.684	0.298	0.018	0.000	0.000	0.000	0.000	0.000

Figure 11. Accession Vector for 1306QR Model.

Utilizing the fixed recruitment model for the aggregate of 1306 officers, the inventory forecast for the SC comes out to 452.2 with 73.4 officers at the rank of O-6 by 2031 if 41 1306 officers enter the system each year for the next ten years. The outputs of the model are given in Figure 12. The next model, Figure 13, gives the inventory forecast when the states of 1306QR are added. This model allows a manpower planner to see inventory levels for qualified officers with experience tours. If 41 accessions are used again, then the model shows that at year 2031, there will be 42.8 O-6 1306QR qualified officers. A manpower planner could use the forecast outputs of this model and the number of O-6 billets to determine if the forecasts will meet the manpower requirements to fill those billets. Manpower planners can also change fixed accessions (R) within the model to reach desired qualifications at various states.

		O3	O4	O5	O6	E/S
2021	n(0)	88	179	108	81	456
2022	n(1)	84.8	181.6	109.2	79.1	454.7
2023	n(2)	82.7	183.1	110.5	77.6	453.9
2024	n(3)	81.3	183.8	111.7	76.5	453.4
2025	n(4)	80.4	184.1	112.8	75.6	453.0
2026	n(5)	79.9	184.2	113.8	74.9	452.7
2027	n(6)	79.5	184.2	114.5	74.4	452.6
2028	n(7)	79.3	184.0	115.1	74.0	452.5
2029	n(8)	79.1	183.9	115.6	73.7	452.4
2030	n(9)	79.0	183.7	116.0	73.6	452.3
2031	n(10)	79.0	183.5	116.3	73.4	452.2
Steady-State	n*	78.9	182.4	116.8	73.2	451.3

Figure 12. Inventory Forecast for the Aggregate of 1306 Officers (Fixed Recruitment).

		O3	O4	O5	O6	O3QR	O4QR	O5QR	O6QR	E/S
2021	n(0)	76	125	43	40	12	54	65	41	456
2022	n(1)	71.7	125.6	40.6	38.5	13.1	54.9	70.3	40.3	454.8
2023	n(2)	69.2	125.2	38.9	36.9	13.4	55.8	74.8	40.0	454.2
2024	n(3)	67.8	124.4	37.6	35.5	13.4	56.5	78.7	40.0	453.9
2025	n(4)	67.0	123.6	36.5	34.0	13.3	57.0	82.1	40.2	453.7
2026	n(5)	66.5	122.7	35.7	32.7	13.1	57.2	85.0	40.5	453.5
2027	n(6)	66.2	121.9	35.0	31.6	13.0	57.2	87.4	41.0	453.4
2028	n(7)	66.1	121.3	34.5	30.5	12.9	57.1	89.5	41.4	453.3
2029	n(8)	66.0	120.7	34.0	29.5	12.9	57.0	91.1	41.9	453.1
2030	n(9)	66.0	120.3	33.7	28.6	12.8	56.8	92.4	42.4	452.9
2031	n(10)	65.9	119.9	33.4	27.8	12.8	56.6	93.5	42.8	452.7
Steady-State	n*	65.9	118.5	32.0	22.3	12.7	55.5	96.6	44.8	448.2

Figure 13. Inventory Forecast for 1306QR Qualified Officers (Fixed Recruitment).

C. FIXED INVENTORY

For each of the fixed inventory models we establish a notional end-strength goal of 635 1306 SC officers. To reach an end-strength of 635, we could immediately set end-strength to 635 or incrementally increase end-strength from **n**(0), by any amount, to achieve 635. We chose to incrementally increase the end-strength goal each year by 25, starting with an initial end-strength goal of 475 in the first year. By incrementally increasing the end-strength goals, the required accessions per year are more evenly distributed across the

ten-year period, eliminating an immediate requirement for 221 accessions in the first year when end-strength goals remain constant at 635. Figures 14 and 15 demonstrate how *R* values are affected when end-strength inputs are varied in the aggregate 1306 model. Figure 16 gives the required accessions to meet the end-strength goals for 1306QR. These *R* values are the number of accessions required each year to reach the desired end-strength. Manpower planners can use this model to determine the required number of accessions to meet determined end-strength goals. The model also allows manpower planners to monitor the inventory levels for each state, such as O6QR.

		O3	O4	O5	O6	E/S			
2021	N(0)	88	179	108	81	456	E/S Goal	*R*	
2022	N(1)	98.6	187.7	109.6	79.1	475.0	475	2022	**61.3**
2023	N(2)	110.7	199.6	112.0	77.7	500.0	500	2023	**69.0**
2024	N(3)	120.1	212.9	115.4	76.6	525.0	525	2024	**71.2**
2025	N(4)	127.5	226.8	119.7	76.0	550.0	550	2025	**73.3**
2026	N(5)	133.6	240.7	124.8	75.9	575.0	575	2026	**75.3**
2027	N(6)	139.0	254.3	130.6	76.2	600.0	600	2027	**77.3**
2028	N(7)	143.8	267.4	136.9	77.0	625.0	625	2028	**79.2**
2029	N(8)	138.0	275.6	143.3	78.2	635.0	635	2029	**66.3**
2030	N(9)	127.7	278.2	149.3	79.8	635.0	635	2030	**56.7**
2031	N(10)	120.8	278.0	154.5	81.7	635.0	635	2031	**56.3**

Figure 14. Fixed Inventory for Aggregate 1306 Officers with Incremental End-Strength Goals.

		O3	O4	O5	O6	E/S			
2021	N(0)	88	179	108	81	456	E/S Goal	*R*	
2022	N(1)	208.1	235.4	112.4	79.1	635.0	635	2022	**221.3**
2023	N(2)	175.8	261.7	119.6	77.9	635.0	635	2023	**61.0**
2024	N(3)	153.4	275.7	128.4	77.5	635.0	635	2024	**58.6**
2025	N(4)	137.9	282.0	137.1	77.9	635.0	635	2025	**57.2**
2026	N(5)	127.5	283.5	145.0	79.0	635.0	635	2026	**56.4**
2027	N(6)	120.4	282.3	151.6	80.7	635.0	635	2027	**56.0**
2028	N(7)	115.8	279.7	156.8	82.7	635.0	635	2028	**55.9**
2029	N(8)	112.9	276.5	160.8	84.8	635.0	635	2029	**55.9**
2030	N(9)	111.1	273.2	163.6	87.0	635.0	635	2030	**56.1**
2031	N(10)	110.1	270.1	165.6	89.2	635.0	635	2031	**56.3**

Figure 15. Fixed Inventory for Aggregate 1306 Officers with Fixed End-Strength Goals.

		O3	O4	O5	O6	O3QR	O4QR	O5QR	O6QR	E/S		
2021	N(0)	76	125	43	40	12	54	65	41	456	E/S Goal	*R*
2022	N(1)	85.5	131.6	41.0	38.5	13.1	54.9	70.3	40.3	475.0	475	**61.2**
2023	N(2)	96.2	140.9	40.0	37.0	14.5	56.5	74.9	40.0	500.0	500	**68.9**
2024	N(3)	104.0	151.0	39.9	35.6	16.1	59.1	79.2	40.0	525.0	525	**71.2**
2025	N(4)	109.8	161.1	40.5	34.4	17.7	62.5	83.6	40.2	550.0	550	**73.3**
2026	N(5)	114.6	170.8	41.6	33.5	19.1	66.5	88.2	40.7	575.0	575	**75.3**
2027	N(6)	118.6	180.0	43.1	32.8	20.3	70.7	93.1	41.4	600.0	600	**77.2**
2028	N(7)	122.3	188.6	44.8	32.4	21.4	75.0	98.4	42.2	625.0	625	**79.2**
2029	N(8)	115.5	192.2	46.4	32.2	22.3	79.2	104.0	43.3	635.0	635	**66.2**
2030	N(9)	105.0	190.9	47.6	32.2	22.3	82.8	109.7	44.5	635.0	635	**56.5**
2031	N(10)	98.6	187.6	48.4	32.3	21.5	85.2	115.4	46.0	635.0	635	**56.0**

Figure 16. Fixed Inventory for 1306QR with Incremental End-Strength Goals.

D. STEADY-STATE INVENTORY

The steady-state inventory model allows manpower planners to observe the equilibrium state of the model if *R* and **P** remain the same. To determine the steady-state of each model we continue to use an *R* of 41 as this value represents the average annual accessions into the 1306 community. We also demonstrate what happens to the steady-state of the system when the value of *R* is changed thus allowing manpower planners to see what fixed accessions will do to the system. It is important to understand that the steady-state of the system may not reach equilibrium for many years. Figure 17 demonstrates the steady-state inventory for the aggregate of 1306 officers. Figure 18 demonstrates the steady-state for the 1306QR model when *R* equals 41. This shows that at steady-state there will be 44.8 1306Q or R O-6 officers which does not meet NAVSUP OP's goal of 63. The goal of 63 qualified 1306 O-6 QR officers is based on a planning factor of 2.5 qualified officers to fill each of the current 25 1306 O-6 billets. To achieve 63, we change *R* until the O6QR state showed at least 63. The model, Figure 19, found that 58 annual accessions are required to achieve a steady-state of 63 O-6 1306QR officers.

R= 41	O3	O4	O5	O6	E/S
n*	78.9	182.4	116.8	73.2	451.3

Figure 17. Steady-State Inventory for Aggregate 1306 Officers.

R=41	O3	O4	O5	O6	O3QR	O4QR	O5QR	O6QR	E/S
n*	65.9	118.5	32.0	22.3	12.7	55.5	96.6	44.8	448.2

Figure 18. Steady-State Inventory for 1306QR Officer (*R*=41).

R=58	O3	O4	O5	O6	O3QR	O4QR	O5QR	O6QR	E/S
n*	93.2	167.6	45.3	31.5	18.0	78.5	136.6	63.3	634.0

Figure 19. Steady-State Inventory for 1306QR Officers (*R*= 58).

E. OTHER USES OF THE MODEL

The previous models allow for manpower planners to run the models with either a fixed accession plan or a desired end-strength goal. These models use calculated transition rates from historical data and are untouched in the model; however, another use of the model could be to adjust the annual accession numbers and transition rates to see how this would affect the inventory forecasts. Changing the transition rates can essentially parallel changes in the number of opportunities to get qualified. Manpower planners could adjust the transition rates in the model while maintaining the number of accessions to see if the inventory levels meet their needs. If the new transition rates achieve their goal, then the planner has to determine how many 1306QR qualifying billets need to be generated to make this happen. If changing the transition rate is not enough, the planner can also change the rate and accession numbers. This would require the creation of more billets to earn the SSP and more billets to gain experience (earn Q or R).

To demonstrate the flexibility of the models, we first adjusted *R* to the highest *R* achieved in the last ten years, which was 57. With current transition rates, the model shows that after ten years the SC would only achieve 44.6 1306QR officers (Figure 20). After more than doubling the transition rate for each qualifying state, Figure 21, the model

achieves the goal of 63 O-6 1306QR officers in ten years when *R* is 57 (Figure 22). Finally, we used the modified transition rates and changed *R* back to the average of 41 and found that in ten years the system failed to reach 63; however, at steady-state, the goal is achieved (Figure 23).

		O3	O4	O5	O6	O3QR	O4QR	O5QR	O6QR	E/S	
2021	n(0)	76	125	43	40	12	54	65	41	456	R
2022	n(1)	82.6	130.3	40.9	38.5	13.1	54.9	70.3	40.3	470.8	57
2023	n(2)	86.5	135.8	39.7	37.0	14.2	56.4	74.9	40.0	484.4	57
2024	n(3)	88.6	140.9	39.1	35.6	15.2	58.4	79.1	40.0	496.9	57
2025	n(4)	89.9	145.3	39.0	34.3	16.0	60.6	83.1	40.2	508.5	57
2026	n(5)	90.6	149.1	39.2	33.2	16.5	62.9	87.1	40.6	519.3	57
2027	n(6)	91.0	152.2	39.6	32.3	16.9	65.1	91.0	41.2	529.3	57
2028	n(7)	91.3	154.7	40.0	31.6	17.2	67.0	94.8	41.9	538.5	57
2029	n(8)	91.4	156.7	40.5	31.0	17.4	68.8	98.5	42.7	547.1	57
2030	n(9)	91.5	158.4	41.0	30.6	17.5	70.3	102.0	43.7	554.9	57
2031	n(10)	91.5	159.7	41.5	30.3	17.5	71.5	105.4	44.6	562.2	57
Steady-State	n*	91.6	164.7	44.5	31.0	17.7	77.1	134.2	62.2	623.1	

Figure 20. Inventory Forecast when Number of Accessions are Increased, and Transition Rates are Unaltered.

Pij	1306QR								
2018-20	O3	O4	O5	O6	O3QR	O4QR	O5QR	O6QR	Attrite
O3	0.49	0.17	0.00	0.00	0.16	0.04	0.00	0.00	0.14
O4	0.00	0.71	0.05	0.00	0.00	0.18	0.02	0.00	0.05
O5	0.00	0.00	0.81	0.08	0.00	0.00	0.08	0.02	0.10
O6	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.10	0.10
O3QR	0.00	0.00	0.00	0.00	0.60	0.33	0.00	0.00	0.07
O4QR	0.00	0.00	0.00	0.00	0.00	0.73	0.22	0.00	0.05
O5QR	0.00	0.00	0.00	0.00	0.00	0.00	0.84	0.07	0.09
O6QR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.82	0.18

Figure 21. P Matrix with Increased Transition Rates.

		O3	O4	O5	O6	O3QR	O4QR	O5QR	O6QR	E/S	
2021	n(0)	76	125	43	40	12	54	65	41	456	R
2022	n(1)	76.2	118.7	42.1	35.4	19.3	68.9	72.6	43.2	476.5	57
2023	n(2)	76.4	114.2	41.0	31.7	23.7	81.1	82.0	45.1	495.3	57
2024	n(3)	76.4	111.1	39.9	28.7	26.3	90.7	92.5	47.0	512.6	57
2025	n(4)	76.4	108.9	38.9	26.1	27.9	98.0	103.3	48.9	528.4	57
2026	n(5)	76.5	107.3	38.0	24.0	28.8	103.4	113.9	51.0	542.8	57
2027	n(6)	76.5	106.2	37.1	22.2	29.4	107.4	123.9	53.2	555.9	57
2028	n(7)	76.5	105.4	36.4	20.8	29.7	110.3	133.1	55.6	567.7	57
2029	n(8)	76.5	104.8	35.7	19.5	29.9	112.4	141.4	58.0	578.2	57
2030	n(9)	76.5	104.4	35.2	18.5	30.1	113.9	148.8	60.4	587.7	57
2031	n(10)	76.5	104.1	34.7	17.6	30.1	115.0	155.2	62.8	596.1	57
Steady-State	n*	76.5	103.4	32.5	13.0	30.2	117.4	193.0	88.5	654.5	

Figure 22. Inventory Forecast when Transition Rates and Number of Accessions Increased.

		O3	O4	O5	O6	O3QR	O4QR	O5QR	O6QR	E/S	
2021	n(0)	76	125	43	40	12	54	65	41	456	R
2022	n(1)	65.3	113.9	41.8	35.4	19.3	68.9	72.6	43.2	460.5	41
2023	n(2)	60.0	104.2	40.3	31.7	21.9	79.8	81.9	45.1	465.0	41
2024	n(3)	57.5	96.4	38.5	28.6	22.7	86.7	91.9	46.9	469.2	41
2025	n(4)	56.2	90.5	36.8	25.9	22.7	90.5	101.5	48.8	472.8	41
2026	n(5)	55.6	86.0	35.0	23.7	22.5	92.1	110.1	50.7	475.8	41
2027	n(6)	55.3	82.7	33.4	21.8	22.3	92.4	117.6	52.6	478.0	41
2028	n(7)	55.1	80.4	31.9	20.1	22.1	91.9	123.7	54.5	479.7	41
2029	n(8)	55.1	78.7	30.6	18.6	22.0	91.1	128.5	56.3	480.8	41
2030	n(9)	55.0	77.4	29.4	17.3	21.9	90.2	132.3	57.9	481.5	41
2031	n(10)	55.0	76.6	28.4	16.2	21.8	89.2	135.1	59.4	481.8	41
Steady-State	n*	55.0	74.4	23.4	9.3	21.7	84.4	138.8	63.6	470.8	

Figure 23. Inventory Forecast with Increased Transition Rates and Average Annual Accessions.

F. CHAPTER SUMMARY

This chapter demonstrates how the fixed recruitment, fixed inventory, and steady-state inventory models can be used by manpower planners. If accessions continue to average 41 per year, then the goal of 63 O-6 1306QR will not be met. To increase the number of O-6 1306QR officers, manpower planners must increase accessions and/or increase the chances of obtaining a Q or R by increasing experience tour billets. We demonstrated this by altering transition rates and accession numbers in the model.

VI. CONCLUSION / RECOMMENDATIONS/FURTHER RESEARCH

A. SUMMARY/CONCLUSION

In recent years, NAVSUP OP has stated that the community is experiencing difficulties in filling the critical contracting (1306 SSP) billets at the rank of O-6. The FY22 O-6 Staff Convening Order for the O-6 promotion board expresses the need for SMEs in contracting. In response to this recognized need for O-6 contracting officers, NAVSUP OP requested assistance in modeling and forecasting the manpower requirements for the 1306 community.

This MBA Project develops Markov models that show the flow of 1306 SC officers though the system. The model identifies the number of 1306 SC officers at each state and the probability of them transitioning to the next state annually. We employ a fixed inventory model to determine the number of accessions needed to meet 1306 end-strength goals and a fixed recruitment model to determine a projected end-strength by a predetermined accession policy. The inventory forecast models have proved to be a useful tool in studying the behavior of the 1306 community and this tool could help manpower planners maintain the health of the SC community.

B. RECOMMENDATIONS

Based on the models demonstrated, we recommend that manpower planners at NAVSUP OP use the Markov models for manpower forecasting of 1306 officers. The models created in this project have demonstrated that increasing annual accessions into the 1306 system and/or increasing opportunities to gain a 1306QR will ultimately increase the number of qualified O-6 1306QR officers. In the fixed recruitment model, we demonstrate that if accessions remain at 41, the number of qualified O-6 1306QR officers will only reach 42 by FY31, which falls well short of NAVSUP OP's goal of 2.5 qualified O-6 officers per billet (63). We recommend increasing the number of 1306 opportunities for entry level qualifications into the 1306 community so that the number of qualified O-6 officers will increase. In the fixed inventory model, we demonstrate the effects on annual

accessions given a predetermined end-strength for the 1306 community. Using this model, we also demonstrate that incrementally increasing end-strength goals annually to reach the ultimate desired end-strength may be more feasible than trying to achieve a desired end-strength the following year. We do not recommend using the fixed inventory model for manpower planning unless the SC has a predetermined end-strength goal for the 1306 community. The final Markov model we demonstrate is the steady-state model. We found that if the current annual accessions into the system remain at 41, then the number of qualified O-6 1306QR officers in the SC will eventually become constant at 44. In order to achieve NAVSUP OP's goal of 63 qualified O-6 officers, we observed that the number of determined accessions, *R*, would need to increase from 41 per year to 58. Our final recommendation is that NAVSUP OP manpower planners explore possibilities in increasing accessions while increasing transition rates into 1306QR states to achieve end-strength goals. Increasing these variables will require 1306 entry level billets and experience tours to increase.

C. FURTHER RESEARCH

The following focus areas are recommended for future research topics:

- Cost benefit analysis on cost of additional 1306 coded billets to include internships, seats at NPS, and experience billets.
- The role of gate keepers and their overall influence on the health of the SC and the careers of officers.
- Decreasing tour lengths to allow for more officers to get qualified especially at the O2-O4 ranks.
- Evaluate how AQDs influence the requirement to fill billets that require an SSP.
- Create manpower models for the remaining SSPs in the SC.
- Evaluate all billets in the SC and determine if any of these billets would qualify to be coded.

- Research the utilization of officers with an SSP to evaluate the amount of experience tours completed before O-6.
- Explore the validity of a 2.5 planning factor for SC O-6 officers.

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