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OPTIMIZATION OF THE FORCE GENERATION PROCESS OF MARINE CORPS INFANTRY BATTALIONS

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THESIS

OPTIMIZATION OF THE FORCE GENERATION PROCESS OF MARINE CORPS INFANTRY BATTALIONS

by

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June 2019

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The Marine Corps' Force Generation Process (FGP) requires multiple inputs to generate the combat forces necessary to accomplish the goals set in the National Defense Strategy (NDS). Current manpower assignment methods do not optimize the manning of Marine Corps infantry battalions to ensure maximum training readiness, manning, and deployability under the FGP. This thesis researches manpower trends, personnel timelines, deployment manpower levels, and unit deployment timelines of historical infantry battalion data from the Marine Corps Total Force Data Warehouse (TFDW). The Optimized Assignment Model (OAM), a mixed-integer linear program, optimizes manpower assignments in order to minimize the loss of available training days and improve unit manpower readiness timelines. Over a four-year time horizon, OAM improves the number of available training days for 28 of 31 rank and military occupational specialty (MOS) combinations, a median value of 44 additional days prior to deployment. Over the same horizon, OAM reduces the time required for infantry battalions to reach their deployable unit strength by nearly 85 days.

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OPTIMIZATION OF THE FORCE GENERATION PROCESS OF MARINE CORPS INFANTRY BATTALIONS

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ABSTRACT

The Marine Corps' Force Generation Process (FGP) requires multiple inputs to generate the combat forces necessary to accomplish the goals set in the National Defense Strategy (NDS). Current manpower assignment methods do not optimize the manning of Marine Corps infantry battalions to ensure maximum training readiness, manning, and deployability under the FGP. This thesis researches manpower trends, personnel timelines, deployment manpower levels, and unit deployment timelines of historical infantry battalion data from the Marine Corps Total Force Data Warehouse (TFDW). The Optimized Assignment Model (OAM), a mixed-integer linear program, optimizes manpower assignments in order to minimize the loss of available training days and improve unit manpower readiness timelines. Over a four-year time horizon, OAM improves the number of available training days for 28 of 31 rank and military occupational specialty (MOS) combinations, a median value of 44 additional days prior to deployment. Over the same horizon, OAM reduces the time required for infantry battalions to reach their deployable unit strength by nearly 85 days.

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List of Acronyms and Abbreviations

AITB Advanced Infantry Training Battalion

ASR authorized strength report

BIC billet identification code

CD&I Combat Development and Integration

DJPU date joined present unit

DoD Department of Defense

DRRS-MC Department of Defense Readiness Reporting System - Marine Corps

EAM Enlisted Assignment Model

EAM-Global Enlisted Assignment Model – Global

EAS end active service

FGP Force Generation Process

GAR grade adjusted recapitulation

GCE Ground Combat Element

HQMC Headquarters Marine Corps

HRDP Human Resource and Development Process

IHMP Infinite Horizon Manpower Problem

ITX Integrated Training Exercise

MAGTF Marine Air Ground Task Force

MARDIV Marine Division

MCCDC	Marine Corps Combat Development Command
MCO	Marine Corps Order
MET	mission essential task
MEU	Marine Expeditionary Unit
MIP	mixed-integer linear program
MIR	Manpower Information Request
MOS	military occupation specialty
M&RA	Manpower and Reserve Affairs
MRX	mission rehearsal exercise
NCO	non-commissioned officer
NDS	National Defense Strategy
NLT	no later than
OAM	Optimized Assignment Model
OEF	Operation Enduring Freedom
OpFor	Operating Forces
PCS	permanent change of station
PTP	pre-deployment training program
RUC	reporting unit code
SLE	service level exercise
SPMAGTF	Special Purpose Marine Air Ground Task Force
SPMAGTF-CR-AF	Special Purpose Marine Air Ground Task Force-Crisis Response-Africa

SPMAGTF-CR-CC Special Purpose Marine Air Ground Task Force-Crisis Response-Central Command

T/O Table of Organization

TCF tour control factor

TEEP training, exercise, and employment plans

TFDW Total Force Data Warehouse

UDP Unit Deployment Program

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Executive Summary

The Marine Corps' five-step F orce G eneration P rocess (FGP) is a complex system of inputs, restrictions, decision-points, and strategic directives from senior leaders. In order to provide capable and relevant combat forces, the Marine Corps needs to improve 'Generating the Force' and 'Ready the Force' as part of the FGP. This thesis develops the Optimized Assignment Model (OAM), a mixed-integer linear program, which improves personnel assignments to infantry battalions by increasing the number of training days of newly assigned Marines and decreasing the number of days required for units to reach their deployable unit strength.

From January 1, 2013, to January 30, 2017, Marine Corps infantry battalions deployed more than 59 times, executing Marine Expeditionary Unit (MEU), Unit Deployment Pro-gram (UDP), Special Purpose Marine Air Ground Task Force (SPMAGTF), and Operation Enduring Freedom (OEF) missions across the globe. On average, infantry battalions failed to reach their deployable unit strength until nearly 139 days prior to their scheduled deploy-ment departure, well short of the desired manning readiness date of 180 days prior. During this time, historical data shows that the median arrival date for an E-4 machine gunner (0331) was 154 days and E-4 mortarman (0341) arrived only 174 days prior to deployment.

Utilizing OAM, this research demonstrates that it is possible to increase the number of training days available to small-unit leaders and decrease the time required to fully staff a unit to their deployable unit strength. By analyzing the historical manpower data from January 1, 2013, to January 30, 2017, and deployment data during this same period, this research identifies past trends and applies OAM to improve manpower assignments. This thesis analyzes nearly 42, 000 individual Marines assigned to infantry battalions and 59 battalion size deployments that occurred during this period. OAM uses Marine Corps Manpower policies to the greatest extent possible, however key manpower factors such as unit preference, by-name requests, or individual placement restrictions are not part of the historical data available for this thesis. As such, OAM provides a benchmark on improvements without these additional restrictions.

OAM demonstrates that it is possible to improve the time required to reach the deployable unit strength of infantry battalions prior to deployment. Figure 1 shows the historical time to staff an infantry battalion prior to deployment, compared to the optimized results. A median increase of 85 training days is achieved by utilizing OAM. This provides Marines, small-unit leaders, and commanders nearly three more months of time to train and prepare their full unit for world-wide deployment.

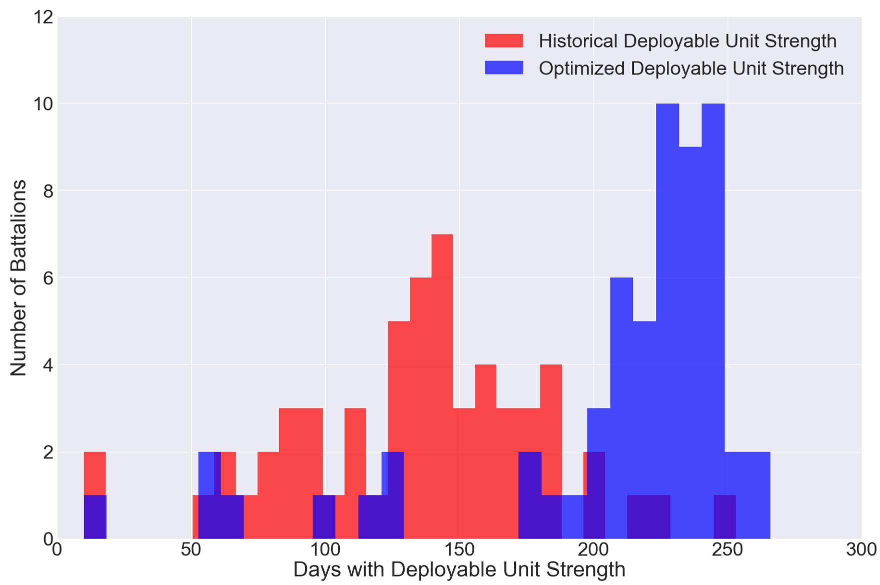

Figure 1. Days Prior to Deployment with Deployable Unit Strength.

OAM improves the assignment of personnel and ensures the median number of training days for all rank and military occupational specialty (MOS) combinations remains above a 180 day threshold before deployment. For 28 of 31 unique combinations during a four-year time horizon, OAM improves the number of available training days. A significant improvement is observed for career level non-commissioned officers (NCOs) within each infantry MOS. Utilizing OAM, the median number of days for an E-4 machine gunner increases by 129 days, to 283 days prior to deployment, and all NCOs arrive at their deploying unit a median of 261 days prior to deployment as seen in Figure 2.

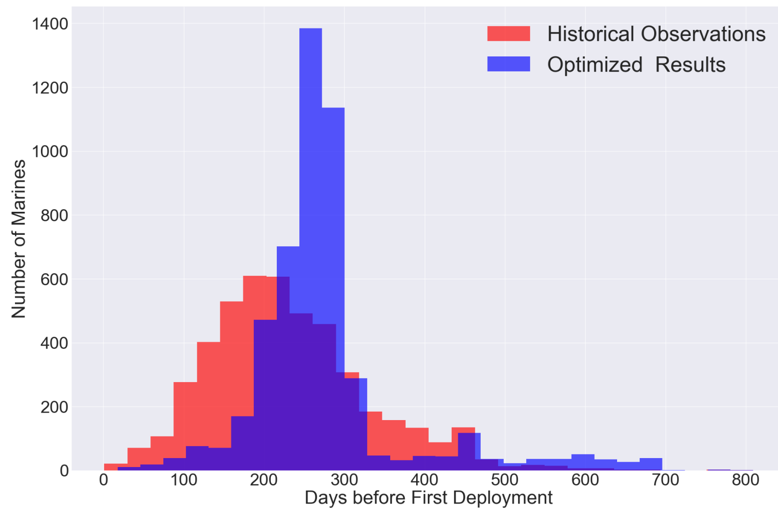

Figure 2. Histogram Comparison of E-4 & E-5 training days before first deployment.

This thesis demonstrates the viability of OAM as an effective way to improve manpower readiness at the individual and unit level. Utilizing OAM, planners and leaders can efficiently assign Marines to units that result in greater individual and unit readiness in order to support each unit's future world-wide deployment.

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I would like to thank my wife, Morgan, for all of her support and understanding as I endeavoured through this academic process. Our first time away from a deployable unit was filled with long days of me studying and nights working on homework. Without her constant encouragement and assistance, none of this would have been possible. Having a child during the thesis process added complexity, but there is nothing better than seeing the smile on Skylar's face when she sees her daddy at the end of every school day.

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A final thanks is to all of the Marines I have served with during my c areer. I cannot be more grateful to the young Marines, SNCOs, and officers who have mentored and led me to become the officer I am today. We owe our Marines more, and I hope this thesis can assist in providing an improvement to relevant deficiencies in our systems.

Semper Fidelis.

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CHAPTER 1:
Introduction

> The Marine Corps exists to defeat our Nation's enemies. Even in a world of ever-increasing technology, we must continue to provide combat formations capable of closing with and destroying the enemy.
>
> –Marine Corps Operating Concept (Commandant of the Marine Corps 2016b)

1.1 Manpower Shortfalls

The Marine Corps' Force Generation Process (FGP) requires multiple inputs to generate the combat forces necessary to accomplish the goals set in the National Defense Strategy (NDS). Current manpower assignment methods do not optimize the manning of Marine Corps infantry battalions to ensure maximum training readiness, manning, and deployability under the FGP.

Deploying units are faced with shorter pre-deployment training program (PTP) time, coupled with manning deficits that impact unit readiness prior to deployment. High turnover rates reduce the number of qualified and deployable personnel within a unit during the PTP period. This results in unqualified personnel fulfilling roles outside of their military occupation specialty (MOS) and rank on a consistent basis. Under these conditions, commanders train their units to be "good enough" for deployment and executing their assigned missions. As the continuous conflicts of the past 20 years begin to fade, the Marine Corps faces recurring deployment cycles that do not effectively utilize personnel during their periods of enlistments or commission, and do not provide Marines with the greatest amount of pre-deployment time in a unit prior to deployment. With manpower shortfalls, Marine Corps policies fail to fully staffed units to their deployable unit strength in time for leaders to conduct adequate PTP training as a unit.

1.2 Meeting Future Requirements

According to the 2016 Marine Operating Concept (Commandant of the Marine Corps 2016b), "The Marine Corps is currently not organized, trained, and equipped to meet the demands of a future operating environment." Senior Marine Corps leaders conclude that the Marine Corps' current manning policies do not meet the requirements expected in future conflicts. As an organization, the Marine Corps takes tremendous pride in its most valuable asset, its people. As part of the Ground Combat Element (GCE) in the Marine Air Ground Task Force (MAGTF), infantry battalions maintain a key aspect to future mission success. It is essential to properly, and timely, fulfill the personnel requirements for deploying infantry battalions. By optimizing personnel assignments to reduce loss of training time, it is possible to maximize individual time in a unit prior to deployment and increase overall unit readiness. This research develops a mixed-integer linear program (MIP) called the Optimized Assignment Model (OAM). Using OAM, the Marine Corps can improve the time required to achieve manpower readiness and increase an individual Marine's time in a deploying unit.

1.3 Thesis Organization

This thesis researches the historical trends of Marine Corps infantry battalion staffing and manning, deployment schedules, personnel utilization, and available training time. The remainder of this chapter discusses background information on the organization of a Marine Corps infantry battalion, an introduction to the FGP, typical infantry battalion deployments, and the basics of staffing and manning a unit to support global requirements. Chapter 2 focuses on past research in the manpower optimization field and its impact on this research. Chapter 3 explores the historical data obtained from the Total Force Data Warehouse (TFDW), the assumptions made from the historical data, and application of this historical data in the model. Chapter 4 explains OAM development and its use to maximize training days available prior to deployment and reduce the time required to achieve deployable unit levels. Chapter 5 presents conclusions and future applications of the information presented.

1.4 Marine Corps Infantry Battalion

The mission of a Marine Corps infantry battalion is to "locate, close with, and destroy the enemy by fire and maneuver or to repel his assault by fire and close combat," (Commandant of the Marine Corps 1998). Marine Corps active duty infantry battalions are currently organized under the 1st, 2nd, and 3nd Marine Divisions located in California, North Carolina, and Hawaii, respectively. The 4th Marine Corps Division is comprised of reserve infantry battalions and is not included in the scope of this research. The 1st, 5th, and 7th Marine Regiments are part of the 1st Marine Division (MARDIV); the 2nd, 6th, and 8th Marine Regiments part of the 2nd MARDIV; and the 3rd Marine Regiment under 3rd MARDIV. Each regiment typically contains three infantry battalions under its command, with the exception to 1st MARDIV regiments which contains four infantry battalions (Figure 1.1).

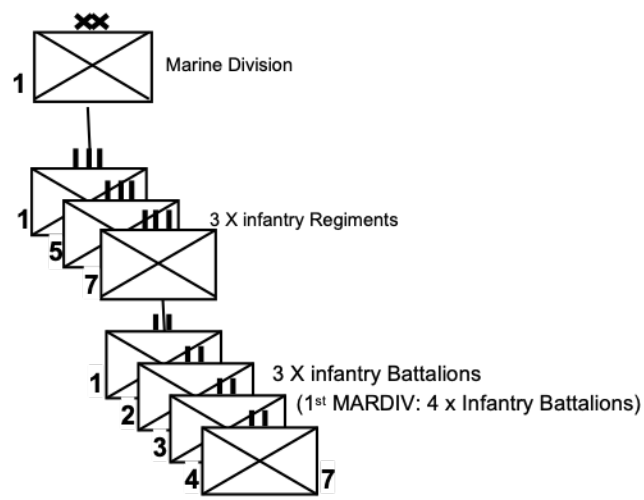

Figure 1.1. Wire Diagram of the First Marine Division's Infantry Battalions. Adapted from Commandant of the Marine Corps (1998).

Each infantry battalion consists of three rifle companies, one weapons company, and one headquarters and service company. As of 2019, the total number of personnel in a standard infantry battalion is 966 (Commandant of the Marine Corps 2018b). This total number includes all non-infantry personnel that enable the unit to conduct its mission. This research targets the specific infantry MOS that exist is a task-organized battalion (Table 1.1). This is not to negate the importance of non-infantry MOSs, but only to reduce the scope and complexity for the application of research. The fiscal year 2019 infantry battalion

Table of Organization (T/O) has 709 personnel with MOS codes of 03XX (Table A.1).

Table 1.1. Table of Infantry MOS and Ranks. Adapted from (Commandant of the Marine Corps 2018a).

MOS	Description	Ranks
0302	Infantry Officer	O1-O5
0306	Infantry Weapons Officer	CWO2-CWO5
0311	Rifleman	E1-E5
0331	Machine Gunner	E1-E5
0341	Mortarman	E1-E5
0351	Infantry Assault Marine	E1-E5
0352	Antitank Missile Gunner	E1-E5
0365	Infantry Squad Leader	E5
0369	Infantry Unit Leader	E6-E7
0399	Operations Chief	E8-E9

1.5 Force Generation Process

Marine Corps Order (MCO) 3502.6A establishes the requirements to fill Marine Corps units as part of the FGP. The intent of this order is to:

> Establish a process that focuses and synchronizes the efforts of Headquarters Marine Corps (HQMC), the supporting establishment, and the operating forces towards efficiently and effectively preparing Marine Corps personnel and units in a timely manner for operational deployments.

MCO 3502.6A defines five phases of the FGP as: synchronize the force, generate the force, ready the force, deploy the force, and redeploy the force (Commandant of the Marine Corps 2013). Each phase has a specific timeline, tasks, and end state requirements that are necessary for proper tasking of units. This research examines the requirements in Phase Two and Phase Three of the FGP. Phase Two, "Generate the Force," occurs between 360 to 180 days prior to deployment (D-360 to D-180). During this time, units continue their PTP in support of their assigned mission essential tasks (METs). At the end of this phase, units stabilize to their required levels and receive resources for the remainder of their PTP. Phase Three, "Ready the Force," occurs between 180 days prior to deployment and deployment day (D-180 to D+0). During this phase units conduct core and assigned MET training, and no later than (NLT) thirty days prior to deployment, units conduct a mission rehearsal exercise (MRX) or service level exercise (SLE) for final unit deployment certification. During this phase, units are staffed and equipped to their required deployable unit strength (Commandant of the Marine Corps 2013).

This research focus' specifically on infantry battalions, and the application of the FGP to infantry units. This research demonstrates how OAM is a viable method to improve personnel assignments as part of the keys tasks identified in phase two and three of the FGP.

1.6 Deployments

Marine Corps units support missions across the globe in a variety of purposes and scale. From 2012 to January 2018, units deployed 86 times in support of missions with Special Purpose Marine Air Ground Task Force-Crisis Response-Central Command (SPMAGTF-CR-CC), Special Purpose Marine Air Ground Task Force-Crisis Response-Africa (SPMAGTF-CR-AF), continued support to Operation Enduring Freedom (OEF), the 11th, 13th, 15th, 22nd, 24th, 26th, 31st Marine Expeditionary Units (MEUs), and the Okinawa Unit Deployment Program (UDP). Additional to the standard deployments, there are a number of deployments of battalion and smaller size elements that are tasked during the FGP. In the breadth of this research, only deployments lasting longer than 90 days, and associated with the above "standard" deployment types will be examined.

1.7 Staffing vs. Manning

The Marine Corps allocates manpower and fills units as part of the FGP in accordance with MCO 5320.12H "Precedence Levels for Manning and Staffing" (Commandant of the Marine Corps 2017). In this order, units receive a prioritization category for the assignment of personnel, in accordance with the units published T/O. The colloquial term utilized for the 100% fulfillment of manpower requirements is "manning." The Marine Corps utilizes the authorized strength report (ASR) to "purchase" a certain number of billets from unit T/Os that are actually filled with a specific Marine. This action is known as "staffing." Through "staffing" the Marine Corps fills billets with personnel in accordance with current manpower inventory, projections, fiscal constraints, and operational requirements.

MCO 5320.12H (Commandant of the Marine Corps 2017) dictates which units are assigned into four categories: "Excepted Commands" have a vital or mandated need with a minimum staffing “red-line” of 100%. "Operating Forces (OpFor) Commands" are deemed integral to current operational needs and require a minimum staffing “red-line” of 95% for officers and 97% for enlisted Marines. A "Priority Command" is a command that serves a significant function and maintains a staffing "red-line" at 95% for officers and enlisted Marines. Proportionate share commands, "Pro-Share," is any unit that is not included in the previous types, and maintain a staffing “red-line” at 94% for officers and enlisted Marines (Commandant of the Marine Corps 2017).

Actual staffing requirements are subject to available inventory of Marines to fill roles, despite “red-line” values. As described in the order, units are to be staffed with the correct rank and MOS to the maximum extent possible. When this is not feasible, alternate rank and MOS solutions will be provided to units in their staffing.

In accordance with MCO 5320.12H, this research staffs infantry companies under the OpFor Command category and utilize a 95% staffing goal for officers and 97% staffing for enlisted personnel. Deviations from rank and MOS requirements of the unit T/O are not desired in the Marine Corps staffing model and are subsequently incorporated into this research. As manning levels fluctuate, the Marine Corps adjusts staffing goals to levels that are deemed appropriate for current operational requirements and updated periodically in administrative messages (Commandant of the Marine Corps 2018b).

CHAPTER 2:
Manpower Research Literature Review

2.1 Manpower Analysis Research

Past research analyzes manpower implementation systems across a wide array of disciplines, each looking at similar but different problems and solutions. The purpose of this historical research is to understand the past problems, historical solutions, and identify possible future applications.

2.2 Study By McCarroll (2013)

McCarroll's thesis research on Manpower Management while attending the Marine Corps Command and Staff College, provides an all-inclusive background to the Marine Corps Human Resource and Development Process (HRDP). McCarroll discusses in detail the inputs and desired outputs that are involved in the HRDP. Although qualitative in nature, his thesis argues for improvements of the HRDP in order to maintain and manage the Marines Corps most important resource, its people.

In his thesis, McCarroll explains the FGP and its relationship with HRDP. He identifies a key question of manpower readiness: how to get more with less. McCarroll recommends adjusting the staffing model and ASR to provide units their actual deployment need, not to their standard T/O. This reduces the manpower requirements across the force by staffing units to levels that coincide with their assigned mission from the FGP (McCarroll 2013).

An interesting recommendation made by McCarroll is the implementation of linking enlisted promotion to contract length. He argues that by linking promotions to non-commissioned officer (NCO) ranks and assignment to a deploying unit would alleviate NCO manning shortfalls. By linking promotion and deployment, this forces Marines to be committed to the Marine Corps and meet operational requirements. McCarroll does not quantitatively address this solution, but recommends further research be conducted to identify its impact to manpower and unit readiness.

2.3 Study By Annunziata (2018)

Annunziata's analysis on manpower supply and operational demand provide insight to the procedural actions required to "man" units. Annunziata looks at the Marine Corps' manpower generation process and provides clear recommendations for improvements to the system. Her research describes the process that Combat Development and Integration (CD&I) and Marine Corps Combat Development Command (MCCDC) execute in order to generate the required T/O for Marine Corps Forces. In conjunction with this action, Manpower and Reserve Affairs (M&RA) develops the ASR, which leads to the grade adjusted recapitulation (GAR): an actual inventory of personnel available for future assignment. Figure 2.1 demonstrates that for any population, the authorized population will be less than the initial T/O.

Like McCarroll (2013), Annunziata recognizes that shortfalls in the Marine Corps HRDP result in operational units absorbing the manpower deficiencies. A failure to monitor, or project, these manpower shortfalls decreases unit readiness prior to assigned operational deployments. Annunziata argues that the inability of units to report "non-deployable" in Department of Defense Readiness Reporting System - Marine Corps (DRRS-MC) reporting, results in inaccurate reporting, and misalignment of resources. Annunziata's exploration of the "Lifecyle of an Infantry Battalion" provides a realistic look at the current manpower problems across the Marine Corps. In her research, she identifies that the current "Unit Cohesion Staffing Model" does not provide enough time for units to properly deploy within the current policy constraints Annunziata (2018). Short PTP cycle timelines, 6-month minimum staffing goals, and significant personnel turnover, cause manpower shortfalls for deploying units across the total force.

Although Annunziata looks specifically at the First Marine Division, her research can be expanded across all of the Marine Corps Infantry Divisions. Annuniziata's exploration of the manpower shortfalls provides ample background information to this topic. Her assessment on the impact of short deployment-to-dwell cycles, high personnel turn-over, and failure to meet staffing policy goals, is utilized in the subsequent chapters of this thesis in a more quantitative approach.

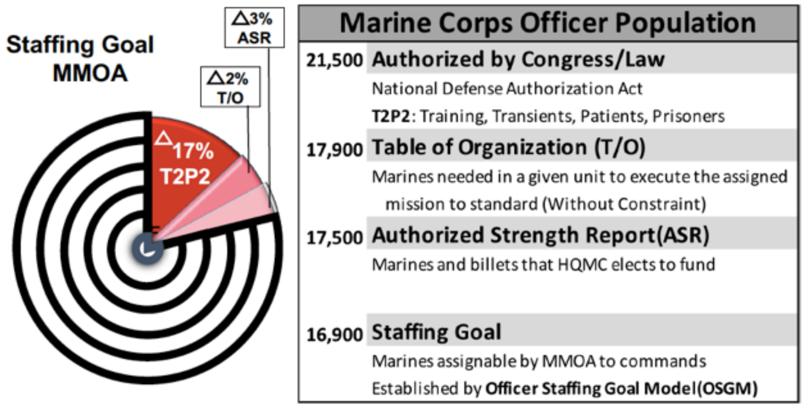

Figure 2.1. Staffing Goal Example of USMC Officer Population. Source: Annunziata (2018).

2.4 Study By Tivnan (1998)

In Tivnan's study on the Optimization of U.S. Marine Corps Enlisted Assignments, he researches the historical use of the Marine Corps Enlisted Assignment Model (EAM) (Tivnan 1998). Tivnan addresses EAMs shortcomings in appropriately filling the desired staffing goals for units across the Marine Corps. In his study, he notes that the Marine Corps fails to appropriately monitor and improve its staffing of units. EAM provides the Marine Corps a by-name assignment for Marines as they approach their anticipated rotation date. Although EAM generates a by-name recommendation, Tivnan notes that these suggested assignments are typically rejected by the enlisted assignment monitors, resulting in greater staffing deficits.

Tivnan's EAM-Global utilizes a network model to accurately optimize the by-name assignment of Marines in accordance with the required policies. His optimization allows for greater assessment and monitoring of the percentages filled at location, percentage of grade and MOS matches, number of transcontinental permanent change of station (PCS), and number of Marines available but not assigned billets. Tivnan demonstrates that his Enlisted Assignment Model – Global (EAM-Global) was capable of producing a 99% fulfillment of staffing goals.

2.5 Study By Hooper and Ostrin (2012)

Hooper and Ostrin 2012 utilize an integer program in order to minimize costs associated with PCS moves and assignments. Hooper and Ostrin formulate their model with a sample population of 15 Marine Corps officers who are due to PCS from the same location at the same time. By adjusting the factors of rank, time in grade, duty station preference, dependents, and available billets, Ostrin and Hooper calculate average "Duty Station Cost" associated with the PCS moves from that location.

Although cost savings is a key portion of their research, (Hooper and Ostrin 2012), the inclusion of duty station preferences added weight to portions of their model, and incurred additional costs to the Marine Corps when preferences were included. Although preferences increased costs in their research, this finding is not trivial. As noted in other studies by Morgan (2005) and Park and Ramirez (2003), duty station preference and assignment have a significant impact on active duty retention.

2.6 Study By Yamada (2000)

Yamada formulates an optimization model called an "Infinite Horizon Manpower Problem (IHMP)" to assist in forecasting and managing the inventory of Army officers (Yamada 2000). Yamada looks at the future officer inventory according to the policy constraints and historical data. Since future manpower availability is directly related to current inventory, his model observes and tracks the values of inventory as his time horizon moves. Utilizing service and Department of Defense (DoD) guidelines, Yamada applies maximum and minimum values to future promotions for each year in his horizon. Due to the high resolution required for daily observations, Yamada only looks at year-end inventory to assess current and future projections, reducing the complexity of his model significantly.

Yamada's IHMP model utilizes the previously calculated values and then re-applies these values in future projections. The control of personnel inventory and the ability to properly model the uncertainty associated with personnel decisions is an imprecise science. Utilizing the IHMP, Yamada forecasts and identifies shortfalls of future changes to Army brigade structures. His model accurately projects a future 17% shortfall of available field grade officers (Majors) in Army "operations" units. His model further demonstrates that forcing future manpower assignments to satisfy the field grade "operations" units to a 95%

target rate drastically impacts the staffing of other career fields (Yamada 2000).

2.7 Study By Freeman (2018)

Freeman's 2018 study on Improving the Force Generation Process for Marine Corps Infantry Battalions provides a significant background history and research on this topic. Freeman looks to optimize unit training, exercise, and employment planss (TEEPs) in order to maximize achievable readiness of deploying units. In his research he utilizes future manpower projections, and simulations, to achieve the optimal solutions for deploying units over a two-year time horizon. His use of historical manpower data, historical deployment data, and the inferred historical factors allow him to apply different models to achieve an optimal solution.

In his thesis, Freeman utilizes five component models for his optimization of unit readiness as seen in Figure 2.2. Using historical data, Freeman generates manpower data distributions by rank and MOS. Utilizing a bi-variate normal distribution, he infers the future projections of manpower arrivals, promotions, and departures for individual Marines. This generated data feeds into his Component Model 2 and Model 3 for optimization. Results are subsequently fed into Component Model 5. Freeman uses the Infantry Training and Readiness Manual (Commandant of the Marine Corps 2018a) to reference the assigned training requirements for infantry battalions, down to individual training requirements. Billet requirements are obtained from published T/O for infantry battalions, and formal school training dates and schedules are obtained through published sources.

Freeman optimizes infantry TEEPs and manpower staffing for a specific duration time horizon. Optimizing deployment dates, Freeman recommends adjusting deployment start and finish dates in order to maximize training readiness. His optimization further adjusts Integrated Training Exercise (ITX) and Advanced Infantry Training Battalion (AITB) class start and finish dates.

The large scope of Freeman's research results in an extremely large and dynamic model. The interaction between models, although possible, are very difficult to adjust in today's current operational environment. Freeman's Manpower Projections (Component Model 1) and Manpower Assignment (Component Model 2) apply to a small portion of his model, however are an important aspect of personnel assignment. His research and

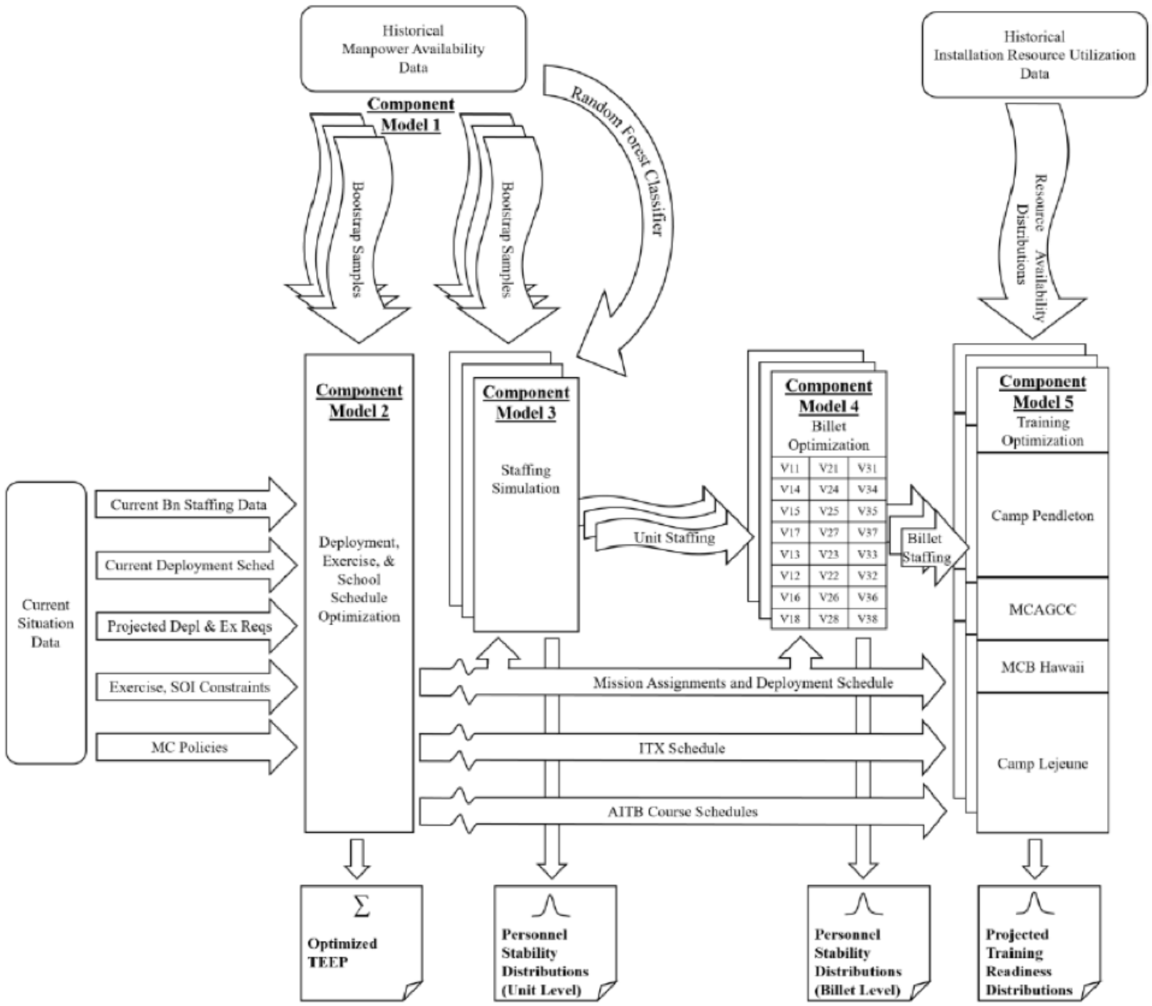

Figure 2.2. Multi-Component Model Diagram. Source: Freeman (2018).

investigation into the subject was crucial to the research conducted in this field.

CHAPTER 3: Data Processing

3.1 Historical Data

The manpower information utilized in this research is obtained through a request to the Marine Corps' TFDW, Manpower Information Request (MIR) (Lindeen 2018). The combined data results in nearly 2.1 gigabytes of raw comma separated values in three primary TFDW data files:

- TFDW snapshots of individual Marine information.
- TFDW snapshots of individual promotion timelines.
- TFDW snapshots of individual former reporting unit code (RUC).

The bulk of the manpower information is available inside the individual Marine information file as seen in Figure 3.1.

ENCRYPTED_ID	TFDW_DATE	GRADE	PMOS	PMCC	DOR	PEBD	EAS	DJPU	END_TOUR	FORMER_RUC
A98C9D7457A8B1D	1/31/06 0:00	E3	311	V16	12/1/04 0:00	12/7/02 0:00	12/7/06 0:00	9/13/03 0:00	2/5/06 0:00	54980
19166DAC604452C8	1/31/06 0:00	E2	341	V38	6/1/05 0:00	6/1/05 0:00	5/31/09 0:00	11/5/05 0:00	1/17/06 0:00	31407
61D88DA54B6F91D	1/31/06 0:00	E4	341	V22	1/1/06 0:00	6/16/03 0:00	6/15/07 0:00	11/27/03 0:00	2/7/06 0:00	31407
91D2669F1383673F	1/31/06 0:00	E3	311	V36	1/1/06 0:00	11/30/04 0:00	11/29/08 0:00	6/11/05 0:00	1/16/06 0:00	31407
EAAD5B13E682683	1/31/06 0:00	E6	369	V13	4/2/03 0:00	6/23/97 0:00	9/23/08 0:00	7/29/05 0:00	1/27/06 12:00	13101
A84A478A0011CE9	1/31/06 0:00	E3	351	V36	9/1/03 0:00	7/8/02 0:00	7/7/06 0:00	12/21/02 0:00	1/25/06 12:00	31407
A67E89DD18A6509	1/31/06 0:00	E3	311	V38	4/1/05 0:00	7/19/04 0:00	7/18/08 0:00	12/18/04 0:00	1/23/06 12:00	31407
887A729FBB5B18E	1/31/06 0:00	E3	311	V37	8/1/05 0:00	11/1/04 0:00	10/31/08 0:00	4/20/05 0:00	2/6/06 0:00	33353

Figure 3.1. Example of Data entry Obtained from TFDW. Source: Lindeen (2018).

3.1.1 Manpower Data Cleaning

The primary data file contains nearly 2.86 million data entries with date ranges from January 2006 to November 2018. The data populates from Marine Corps enterprise data systems, and possess data-entry errors that require cleaning and standardization. To simplify the research, the author reduces the number of entries in the data by removing erroneous MOS and pay-grade entries. Data cleaning and manipulation removed erroneous entries for MOSs of 0300 and 0301 as well as incompatible rank and MOS combinations for MOSs of 0307, 0313, 0317, 0321 and 0372. For example, it is impossible for a Marine of pay grade E-3 to possess the MOS of 0302 or for an officer of pay grade O-1 to possess the MOS of 0352. These incompatible entries are adjusted to the correct MOS if feasible, or simply dropped from the data set due to their inconsistency with Marine Corps MOS policies (Commandant of the Marine Corps 2018a). Additional cleaning of the data includes the adjustment of MOS codes for Marines with reductions of rank and removal from their previous MOS. This includes Marines with the MOS 0369 who were subsequently reduced to pay grade E-5 or below. The data reduces to 1.86 million data entries after initial cleaning, manipulation, and censoring to the January 2013 to January 2017 date range.

The Marine Corps' incorporation of the 0365 MOS provides challenges in both data cleaning and model implementation. Only Marines who complete the required courses and fill the billet of “Infantry Squad Leader" within an infantry battalion receive the MOS 0365. These Marines have an original MOS of 0311, 0331, 0341, 0351, or 0352 and upon completion of the required formal schools, their MOS is changed to 0365 (Commandant of the Marine Corps 2018a). Of the nearly 86,000 unique Marine observations in the sample, only 128 Marines possess the 0365 MOS. Well short of the desired requirement of (15) 0365 trained Marines in each battalion.

3.1.2 Infantry Battalion Manpower

The FGP assesses and adjusts unit T/Os as required in order to address emerging needs and changes to the total force structure (Commandant of the Marine Corps 2016c). This research addresses the published T/O as released in MARADMIN 498/19 (Commandant of the Marine Corps 2018b). This administrative message is periodically released to the total force in order to advise of changes to the Marine Corps T/O.

The Marine Corps infantry battalion currently consists of 709 infantry Marines from rank E-1 to O-5 placed in four infantry companies and one headquarters and service company (Figure 3.2). The unit T/O assigns each Marine a specific billet identification code (BIC) that consists of a MOS and rank requirement as seen in Figure 3.3. High promotion rates for junior enlisted ranks, and for simplicity of assignment, the pay grades of E-1 to E-3 are combined into one aggregate grouping. This enables OAM to assign Marines of any rank from E-1 to E-3 to an appropriate billet within their MOS. In the infantry T/O, junior officers are already "grouped" into a single pay grade of O-2. Although historical data demonstrates that O-1 officers arrive at infantry battalions at a consistent rate, they are combined with O-2 officers for execution of their duties.

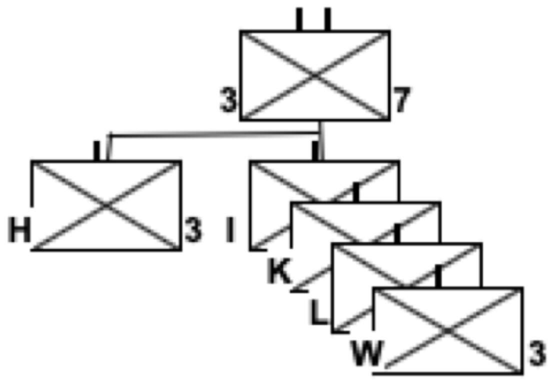

Figure 3.2. Infantry Battalion Organization Diagram. Adapted from (Commandant of the Marine Corps 1998).

co	plt	sqd	team	BIC	BilDes	GRADE	MOS
ACo	1ST PLT	1ST PLT	1ST PLT	M1111300077	PLATOON COMMANDER	O2	302
ACo	1ST PLT	1ST PLT	1ST PLT	M1111300078	PLATOON SERGEANT	E6	369
ACo	1ST PLT	1ST SQD	1ST SQD	M1111300082	SQUAD LEADER	E5	365
ACo	1ST PLT	1ST SQD	FT1	M1111300084	FIRE TEAM LEADER	E4	311
ACo	1ST PLT	1ST SQD	FT1	M1111300085	SQD AUTO RIFLEMAN	E3	311
ACo	1ST PLT	1ST SQD	FT1	M1111300086	GRENADIER	E3	311
ACo	1ST PLT	1ST SQD	FT1	M1111300087	RIFLEMAN	E1	311
ACo	1ST PLT	1ST SQD	FT1	M1111300089	FIRE TEAM LEADER	E4	311

Figure 3.3. Example of Table of Organization data. Adapted from (Commandant of the Marine Corps 2018b).

3.1.3 Entry Level vs. Career Level Marines

This research researches the difference of entry level and career level Marines, and their assignments to infantry battalions. MCO 1040.31 (Commandant of the Marine Corps 2011) defines a first-term Marine as "a Marine on their initial active duty Marine Corps enlistment contract, to include any extensions to that contract." A career Marine is "a Marine serving on their second or subsequent contract in the Marine Corps including any extensions to that contract." For commissioned officers, MCO 1001.65 (Commandant of the Marine Corps 2014b) defines career designation as the "process used to determine which company grade officers will be offered the opportunity for continued active service beyond their initial active service obligation." In the scope of this research, the term "entry level" consists only of the ranks between E-1 to E-3 and O-1 to O-2, and are assigned to their first unit since departing their initial MOS training. Subsequent assignment of these Marines alters their status to "career level".

Part of the data cleaning and preparation, a RUC is associated to each individual to identify each Marine's prior unit. Enlisted Marines who possess the former RUC of "31407", "31350", or "33353" are designated as entry-level Marines from the Marine Corps School of Infantry in Camp Lejeune, North Carolina, or Camp Pendleton, California. Officers ascending to the operating forces with the former RUCs "30315", "30317", "30306", "30305" or "30303" are considered entry level after departing from the Infantry Officers Course in Quantico, Virginia. Historical data differed greatly between rank and MOS combinations of entry and career level Marines and identification of entry-level and career-level status allows for additional analysis and comparison to be made between these factors.

3.2 Historical Deployment Data

An important source of data for this research is the deployment unit database obtained from the Center for Naval Analysis (2019). The file contains data of company level and larger sized units, their respective deployment dates, mission, and regions as seen in Figure 3.4. Information on 24 infantry battalions is extracted and interpreted to construct a table of infantry battalion deployment missions, start date, end date, and assigned unit (Figure 3.5). The deployment data requires limited cleaning, and slight adjustments to mission data was inferred from incomplete data. This research considers only battalion level deployments falling into the following categories:

- MEU Deployments (11th, 13th, 15th, 22d, 24th, 26th, 31st).
- UDP Deployments.
- SPMAGTF-CR-CC Deployments.

- SPMAGTF-CR-AF Deployments.
- OEF Deployments.

To minimize the scope of research, smaller deployments are removed, and any reserve battalion deployments, and company level detachments not incorporated with standard deployments types.

Classification: UNCLASSIFIED

BN-LEVEL NAME	UNIT SIZE	DEPL NAME	BEG DATE	END DATE	DURATION	START YEAR	START MONTH
3RD BN 1ST MARINES	BN	11TH MEU	1/2/12	5/7/12	127	2012	1
VMM-268	BN	11TH MEU	1/2/12	5/7/12	127	2012	1
VMM-365	BN	ISAF MAGTF 12.1	1/8/12	8/4/12	210	2012	1
2ND BN 2ND MARINES	BN	22ND MEU	1/10/12	1/29/12	20	2012	1
VMM-263	BN	22ND MEU	1/10/12	1/29/12	20	2012	1
1ST BN 8TH MARINES	BN	ISAF MAGTF 12.1	1/15/12	8/11/12	210	2012	1
2ND BN 2ND MARINES	BN		1/30/12	2/6/12	8	2012	1
VMM-263	BN		1/30/12	2/6/12	8	2012	1
2ND BN 5TH MARINES	BN	ISAF MAGTF 12.1	3/23/12	9/25/12	187	2012	3
1ST BN 7TH MARINES	BN	ISAF MAGTF 12.1	3/25/12	10/20/12	210	2012	3

Figure 3.4. Marine Corps Deployed Unit Database Example. Adapted from Center for Naval Analysis (2019).

	unit	mission	start_date	end_date	duration	startmonth	endmonth	startyear	endyear
1	V31	MEU_11	2012-01-02	2012-06-21	171 days	1	6	2012	2012
51	V18	OEF	2012-01-15	2012-08-11	209 days	1	8	2012	2012
39	V25	OEF	2012-03-23	2012-09-25	186 days	3	9	2012	2012
58	V17	OEF	2012-03-25	2012-10-20	209 days	3	10	2012	2012
24	V12	MEU_24	2012-03-28	2012-12-23	270 days	3	12	2012	2012

Figure 3.5. Infantry Battalion Deployment History. Adapted from Center for Naval Analysis (2019).

3.3 Historical Analysis

Prior to building a manpower assignment model, it is essential to understand the historical trends of the personnel assigned to the infantry battalion and the deployments they support. In order to conduct valid analysis the following assumptions are made:

- Each Marine's "date joined present unit (DJPU)" and departure date are correct.
- Marines assigned to an infantry battalion are considered medically fit and capable of deploying (i.e., not pending legal action).

- A Marine is considered deployable if they are within a unit during a historic deployment window.
- Units know their scheduled deployment dates and are able to make manpower requests prior to deployment.
- The desired deployable unit strength of each battalion is consistent with the historical deployable unit strength.

In order to standardize and to reduce the size of data to be manipulated, this research analyzes the trends of personnel who depart an infantry battalion after 1 January 2012 and join before 1 January 2018. This allows the analysis to match the deployment history data that spans the same time horizon.

3.3.1 Arrival Analysis

There 36 rank and MOS combinations within a standard infantry battalion. Grouping entry level, career level, and the pay grades of E-1 to E-3 and O-1 to O-2, reduces the number of unique rank and MOS combinations to 31. Entry level observations comprised 15,598 observations in the data sample, accounting for 64% of the total arrival population, while career level Marines had 8,565 observations in the sample. Figures 3.6 and 3.7 demonstrate the difference of entry level and career level Marines arriving throughout the year.

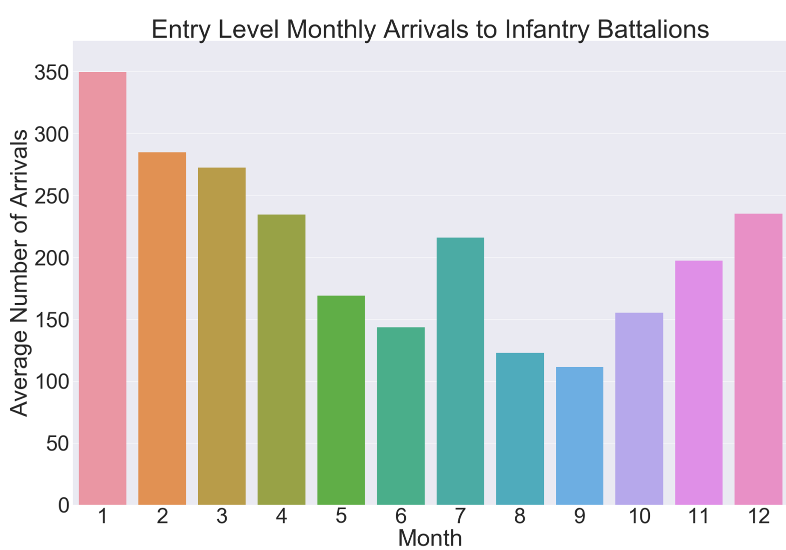

Figure 3.6. Average Entry Level Arrivals by Month.

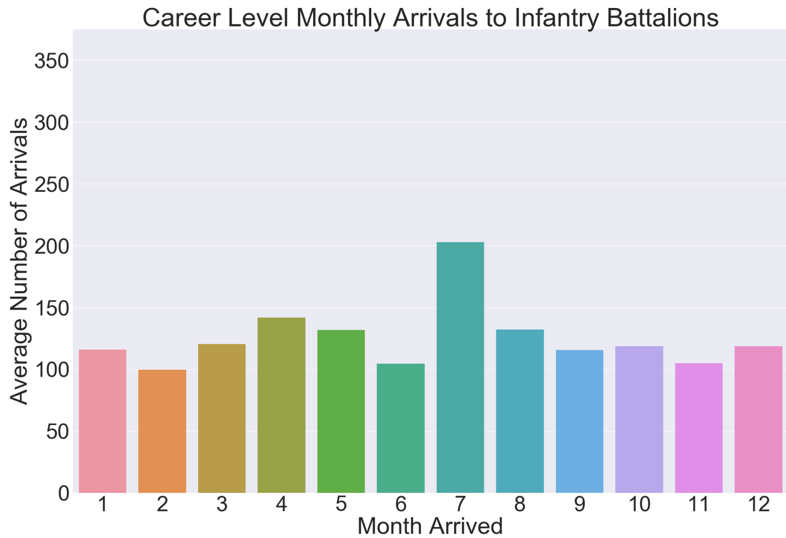

Figure 3.7. Average Career Level Arrivals by Month.

For entry level Marines, the variability between the months occurs due to the limited graduation dates of formal schools at AITB and the Infantry Officers Course. The variability of career level arrivals occurs due to previously assign tour control factors, rotation dates, and pre-existing manpower conditions. The significant increase of career level arrivals observed in July can be attributed to the summertime PCS season.

3.3.2 Manpower Departure Analysis

The amount of time personnel remain in a unit is the combination of many factors. Marine Corps policies ensure a Marine remains at their duty station for a set tour control factor (TCF) of three years. This is a general policy and can be adjusted due to the needs of the Marine Corps and specific individual needs (Commandant of the Marine Corps 2014a). The tour control factor allows planners, and leaders, to assume an individual will be present and capable of full duty during that period. Despite the set policy, the departure timeline for individual Marines can vary drastically. Each individual's end active service (EAS) date, personal desires, unit requirements, performance, and health have an impact on the amount of time someone remains with a unit. If a Marine has performance issues or conduct issues, the unit commander may initiate a transfer to an adjacent unit if needed for the success of the Marine or the unit.

In the historical data explored, only the date a Marine left the unit was identified, and not the underlying cause of departure. Table 3.1 shows the median days a career level Marine spend in an infantry battalion before being re-assigned. Figure 3.2 shows the median days for entry level Marines assigned to an infantry battalion. For standard first enlistment contract lengths, the median tour length for an entry level Marine is higher than a career level Marine. In the historical data, 2,333 Marines were assigned to units and departed before executing a deployment with the unit. Nearly 72.5% of these Marines were between the ranks of E-1 to E-3, and 51.9% were entry level Marines. The ability to move these entry level Marines between units and to execute additional permanent change of station orders is restricted by (Commandant of the Marine Corps 2014a). Although administrative separation from the Marine Corps is a factor that impacts a Marine's assignment to a unit, this research does not focus on the reasons for departures.

Table 3.1. Career Level Median Days Spent in Unit before Departure. Adapted from (Lindeen 2018)

Career Level						
PMOS	0302	0302	0302	0306	0311	0311
Rank Group	o3	o4	o5	wo	e1_e3	e4
Median Days in Unit	730	529	620	912	620	657
PMOS	0311	0331	0331	0331	0341	0341
Rank Group	e5	e1_e3	e4	e5	e1_e3	e4
Median Days in Unit	803	620	657	803	547	620
PMOS	0341	0351	0351	0351	0352	0352
Rank Group	e5	e1_e3	e4	e5	e1_e3	e4
Median Days in Unit	730	584	584	803	620	657
PMOS	0352	0365	0369	0369	0369	0369
Rank Group	e5	e5	e6	e7	e8	e9
Median Days in Unit	766	292	912	693	620	584

Table 3.2. Entry Level Median Days Spent in Unit before Departure. Adapted from (Lindeen 2018)

Entry Level						
PMOS	0302	0311	0331	0341	0351	0352
Rank Group	o1_o2	e1_e3	e1_e3	e1_e3	e1_e3	e1_e3
Median Days in Unit	985	1168	1168	1204	1204	1168

3.3.3 Training Days Before First Deployment

During the "Readying the Force" step of FGP, leaders continue their PTP in order to ensure their unit is prepared for deployment by executing of training events described in the Infantry Training and Readiness Manual (Commandant of the Marine Corps 2016a, 2013). This research, examines the number of training days until the first deployment for newly assigned Marines as the metric for training readiness. With more days available to Marines prior to deployment, leaders are able to increase individual, and collective unit readiness. Focusing on newly assigned arrivals is a key portion of unit readiness, as personnel previously assigned to the unit for prior deployment already have a level of preparedness, camaraderie, and understanding within the unit.

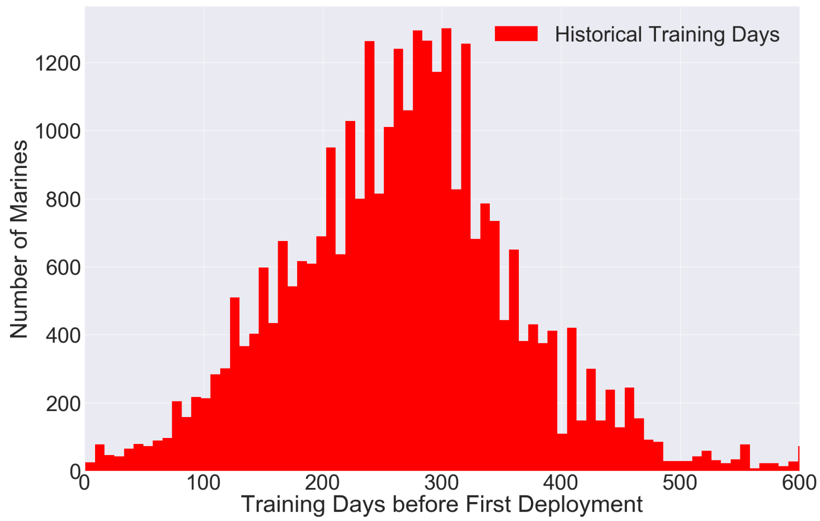

Figure 3.8. Training Days of Newly Assigned Marines Prior to First Deployment.

3.3.4 Deployable Unit Strength

The current published T/O for infantry battalions is set at 709 infantry personnel (Commandant of the Marine Corps 2018b) and is seen as the target goal for manning set in the FGP (Commandant of the Marine Corps 2017). Observing deployment timelines and manpower data, only one battalion, Second Battalion Eighth Marines (V28), deployed at or above the T/O with 713 personnel when it deployed in support of OEF in April 2013. Of 86 observed deployments, an average deployable unit strength of 641.08 personnel with a standard deviation of 44.8 personnel is observed within the sample, nearly 65 personnel short of the published infantry battalion T/O (Figure 3.9).

Although the T/O is the goal, units are rarely capable of deploying to this number. As McCarroll identified in his thesis, staffing units to their required deployment strength is a better use of manpower assets (McCarroll 2013). This significant finding is implemented in OAM by adjusting the desired strength of each unit to meet the historical deployable unit strength observed during that time step. This research is unable to identify a systematic reason why units deployed below the published T/O.

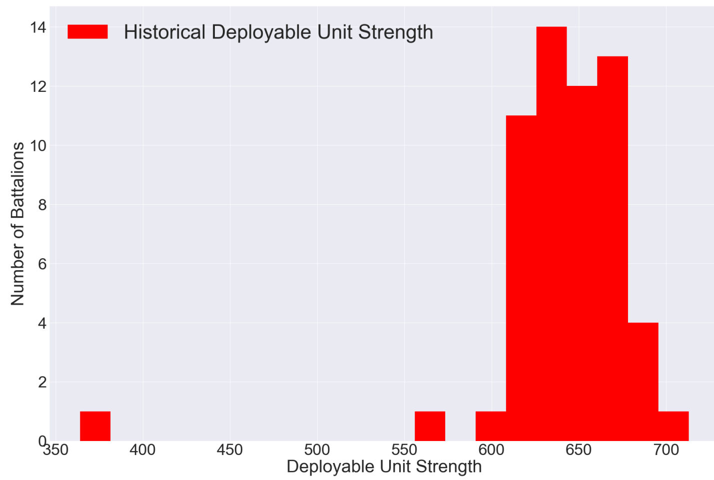

Figure 3.9. Historical Deployable Unit Strength (2012-2018)

3.3.5 Historic Deployment Data

Exploring the deployment data from the Marine Corps Deployed Unit Database (Center for Naval Analysis 2019) demonstrates interesting trends in infantry battalion deployments. Figure 3.10 demonstrates the total count and distribution of mission types from 2012 to 2018 of infantry battalion deployments while Figure 3.11 utilizes the same deployment data and assess the mission duration and variability between observations. As expected, the UDP and 31st MEU exhibit a small variance in their deployment length, due to their cyclic and set schedules. Missions sets with SPMAGTF-CR-CC and other MEU deployments exhibited much more variability in their deployment duration. The uncertain nature of global deployment cause each deployment to change its duration in order to support the needs of the Marine Corps. The fast paced requirements of the FGP are evident in the total number of units deploying every year. Observing historical trends, an infantry battalion deploys approximately every 2 months throughout the time horizon.

This research utilizes the historical deployment data as a key input into OAM. It assumes that the start and end deployment dates do not shift drastically for the planning process and for deriving data utilized within the model.

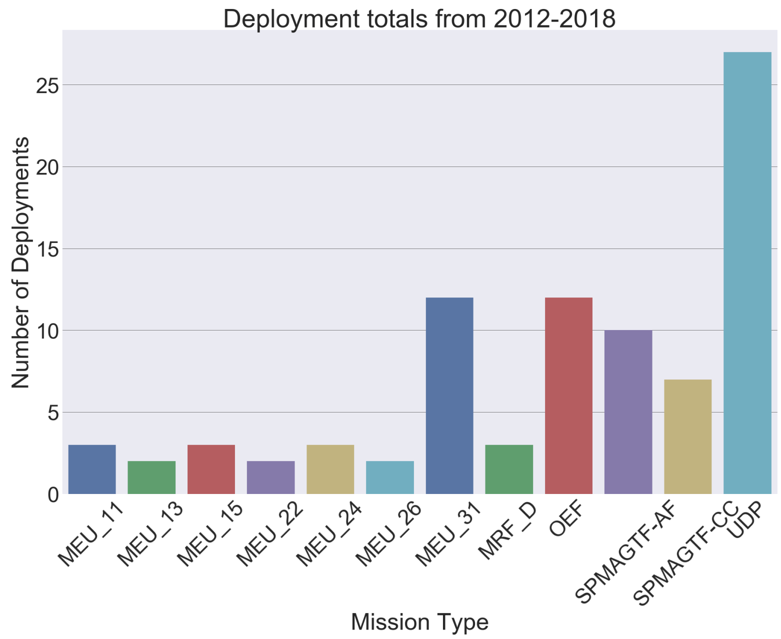

Figure 3.10. Number of Battalion Deployments from 2012-2018. Adapted from Center for Naval Analysis (2019).

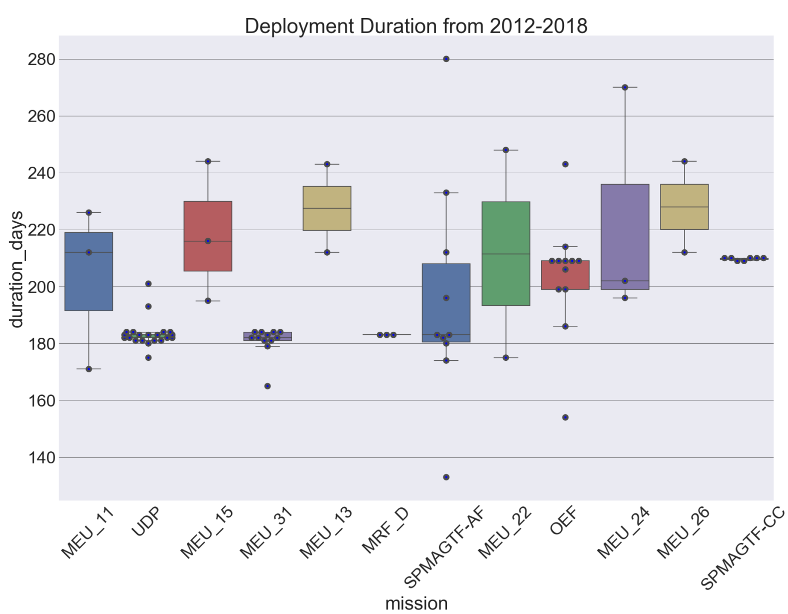

Figure 3.11. Deployment Duration from 2012-2018. Adapted from Center for Naval Analysis (2019).

CHAPTER 4:
Optimization Model Formulation

The MIP formulation of OAM in this research assists senior leaders in "Generating the Force" as part of the FGP (Commandant of the Marine Corps 2013). OAM utilizes historical information of personnel arriving at units and optimizes their assignment to improve the number of training days available for a Marine once assigned to a unit. OAM attempts to utilize current Marine Corps policies, however does not currently include personal unit preferences, by-name requests, or specific individual assignment requirements. These factors, although important, are not included in the breadth of this research or included in the data collected.

4.1 Optimized Assignment Model (OAM) Formulation

OAM utilizes historical data to optimize the assignment of each individual available for assignment. Individuals arrive in the form of i individuals with rank r, and MOS m. These data are derived from the true observations on a specific day from the historic sample. The aggregate total of Marines for a given month-period are combined for optimization within OAM for the 4-year time horizon from January 1, 2013 to January 30, 2017.

For each month-long time step, OAM calculates a "need", $need_{urm}$, for each unit u, by MOS and rank. The $need_{urm}$ is a composition of required number of personnel according to the T/O and the manning "red-line" percentage in accordance with the published current deployable inventory (Commandant of the Marine Corps 2017). OAM recalculates $need_{urm}$ as each time step proceeds and personnel depart the unit or promote.

OAM calculates the number of days until a unit deploys and stores this as a parameter, $tday_u$. This parameter designates the number of days until unit, u, is scheduled to deploy. The parameter $rday_u$ assigns the number of days remaining until unit, u returns (re-deploys) to their home-station. A negative value for $rday_u$ designates that the unit is still deployed, while a positive $rday_u$ identifies the number of days since the unit returned from its last deployment. The parameters $mintday$ and $maxrday$ set thresholds that prohibit joining a unit before deployment and prevent joining a unit prior to their re-deployment window.

OAM utilizes these controls to ensure that personnel cannot join a unit only days before a scheduled deployment, and prevents joining units while they are deployed. The model only allows personnel to join a unit as the unit approaches its scheduled re-deploy date, within the set threshold $maxrday$.

4.2 OAM In NPS Format

Below is the NPS formulation of the mixed-integer linear program, OAM, utilized in this research.

Indices and Sets:

$i \in I$	individuals.
$u \in U = (V11, V21, V31 \ldots V38)$	infantry units.
$m \in M$	infantry military occupational specialties.
$r \in R$	military ranks.
$F_r \subset R$	set of ranks that can fill rank r.

Data and Parameters:

$rank_i$	rank for Marine i.
mos_i	MOS for Marine i.
$djpu_i$	DJPU for Marine i.
$need_{urm}$	number of Marines of rank r and MOS m needed in unit u.
$tday_u$	number of days until unit u deploys.
$rday_u$	number of days since unit u last deployment.
$mintday$	minimum days before deployment to join any unit.
$maxrday$	maximum days before re-deployment to join any unit.
pri_u	priority of unit u.
rev_u	reverse priority unit u.
$depinv_u$	current deployment strength of unit u.

$histinv_u$	historic deployment strength of unit u.
pen	scalar penalty value.

Variables:

$X_{iu} \in \{0, 1\}$	Marine i assigned to unit u.
$DEV_{urm} \in [0, \infty)$	deviation of assignments below unit requirement.
$ODEV_{urm} \in [0, \infty)$	deviation of assignments above unit requirement.
$MAXI_u \in [0, \infty)$	Marines added above rank and MOS limit.
$OTO_u \in [0, \infty)$	number of personnel assigned above unit T/O.
$UTO_u \in [0, \infty)$	number of personnel assigned below unit T/O.
$PRD_{iu} \in [0, \infty)$	days assigned prior to unit re-deployment threshold.
$PD_{iu} \in [0, \infty)$	days assigned after unit deployment threshold.

Objective Function:

$$\text{minimize} \sum_{\substack{u \in U \\ r \in R \\ m \in M}} (pri_u \cdot DEV_{urm} + rev_u \cdot ODEV_{urm})$$

$$+ \sum_{u \in U} (rev_u \cdot MAXI_u + pen \cdot (OTO_u + UTO_u))$$

$$- \sum_{\substack{i \in I \\ u \in U}} (X_{iu} \cdot tday_u - pen \cdot (PRD_{iu} + PD_{iu})) \tag{4.1}$$

Subject to:

$$\sum_{u \in U} X_{iu} = 1 \qquad \forall i \in I \tag{4.2}$$

$$\sum_{\substack{i \in I | rank_i = r \\ mos_i = m}} X_{iu} \geq need_{urm} - DEV_{urm} \qquad \forall u \in U, r \in R, m \in M \tag{4.3}$$

$$\sum_{\substack{r' \in F_r \\ i \in I | rank_i = r' \\ mos_i = m}} X_{iu} \leq \sum_{r' \in F_r} need_{ur'm} + ODEV_{urm} \qquad \forall u \in U, r \in R, m \in M \tag{4.4}$$

$$\sum_{r \in R, m \in M} ODEV_{urm} \leq 15 + MAXI_u \qquad \forall u \in U \tag{4.5}$$

$$\sum_{i \in I} X_{iu} + depinv_u = histinv_u + OTO_u - UTO_u \qquad \forall u \in U \tag{4.6}$$

$$X_{iu} \leq PD_{iu} \qquad \forall i \in I, u \in U | djpu_i \geq tday_u - mintday \quad (4.7)$$

$$X_{iu} \leq PRD_{iu} \qquad \forall i \in I, u \in U | djpu_i \leq rday_u - maxrday \quad (4.8)$$

4.3 Objective Function

The objective function (Equation 4.1) expresses the total penalty for deviation from desired goals.

4.4 Model Constraints

Constraint set 4.2 ensures that each individual is assigned to exactly one unit. Constraint set 4.3 tracks the deviation below each unit, rank, and MOS combination requirement. Constraint set 4.4 tracks any assignment above those requirements, including filling positions one rank up. Constraint set 4.5 restricts over-assignment of personnel within each unit. Constraint set 4.6 matches optimized deployment unit strength, $depinv_u$, to the historical deployment unit strength, $histinv_u$. Constraint set 4.7 and Constraint set 4.8 prevent unpenalized assignment of a Marine to a unit once it has passed a minimum training day limit or re-deployment date limit.

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CHAPTER 5:
OAM Results

OAM is implemented in the Python language with Pyomo (Hart et al. 2017, 2011) and the CBC solver (Forrest et al. 2018). The results are obtained on a 1.6Ghz Intel i5 dual-core processor with 8 gigabytes of memory. OAM solves 48 instances to cover the 48 month time horizon, with the number of historical arrival observations impacting the number of variables and constraints for each run. The minimum number of decision variables is 6,417 with 1,726 constraints, and the maximum number of decision variables is 23,460 with 8,485 constraints. The total run-time using CBC is approximately 22 minutes.

A date range from January 1, 2013 to January 30, 2017 is chosen as the applicable time horizon for OAM due to the availability of deployment data (Center for Naval Analysis 2019) and the lack of drastic changes to the operational tempo of infantry battalions observed during this time. This time horizon provides information of approximately 42,000 Marines and their assignment to 23 infantry battalions. 3rd Battalion 4th Marines (V34) is removed from the data set and assignment due to its changing status as an active to inactive battalion between 2013 and 2016.

Prior to initiating the optimization, 16,606 personnel populate units within the model according to their historical assignment. During the model's execution, an additional 26,194 personnel become available for assignment and are optimally assigned to units, while maintaining historical deployment schedules, manning requirements, and Marine Corps policies in place.

5.1 Optimization Results

The optimization model uses 16,606 initial assignments as the baseline inventory at the time horizon start date. Adjusting the start date results in a different initial inventory, however the method utilized in OAM remains the same. OAM optimizes the monthly arrival according to the current inventory, and assigns individuals to optimal billets according to their rank, MOS, and unit need. Each time step concludes with an updated inventory with key information on each Marine's DJPU, initial rank, current rank, and historic date they departed the unit. Upon initiation of a new time step, updated ranks are identified for Marines assigned in the current inventory. This ensures that a correct rank and MOS requirement is identified for each unit. The final output is the total inventory of personnel assigned to any unit from the start date to the end date of the time horizon.

5.2 Days Before First Deployment

OAM optimizes manpower assignments in order to provide personnel with more time in a unit prior to their first deployment. This allows individuals more time to train, develop, and prepare effectively as individuals and as a cohesive unit prior to deploying overseas.

OAM successfully increases the median number of training days available for 28 of 31 rank and MOS combinations. The full breakdown of each rank and MOS combination can be seen in Table A.2 and Table A.3. Using OAM, career level rank and MOS combinations increase a median value of 44 training days with a median absolute deviation of 45.16 training days. Improvements vary from 22 days for career level E1 to E3 riflemen (0311), to a significant median increase of 269 days for E-5 antitank missile gunners (0352). OAM improves the arrival timelines of all career level NCOs. The NCO ranks, E-4 and E-5, increase for all MOSs a median value of 58 training days with a median absolute deviation of 64.22 training days (Figure 5.2). By enabling NCOs to to arrive sooner, commanders can ensure that these junior leaders are placed in their leadership positions sooner, send them to formal schools at the AITBs, and improve the readiness of the unit by having key leaders in place. Senior enlisted Marines experience a median improvement of 82 training days for E-6 and 69 training days for E-7 infantry unit leaders (0369), enabling these leaders to be present in their units sooner into their PTP.

Three entry-level MOS and rank combinations show decreases of training days as a result of the OAM. These decreases occur only for entry-level Marines, and do not impact the career level Marines of the same rank and MOS. The optimized results produce a median reduction of 52 training days for entry level E-1 to E-3 rifleman (0311), a 36 day reduction for E-1 to E-3 machine gunners (0331), and a 31 day reduction for O-1 to O-2 infantry officers (0302). Figure 5.3 shows the reduction of training days for E-1 to E-3 rifleman (0311) as produced by OAM. Although a reduction from historical observations,

	PMOS	first_rank	make_dep_hist_tday	entry_lvl	make_dep_sim_tday	observations	diff
1	302	o1_o2	297.0	True	266.0	684	-31.0
7	306	wo	207.0	True	299.0	26	92.0
9	311	e1_e3	302.0	True	250.0	8347	-52.0
15	331	e1_e3	302.0	True	266.0	2322	-36.0
19	341	e1_e3	266.0	True	276.0	2350	10.0
23	351	e1_e3	274.0	True	283.0	1022	9.0
27	352	e1_e3	246.0	True	266.0	847	20.0

Figure 5.1. Median Days before First Deployment of Entry Level Marines.

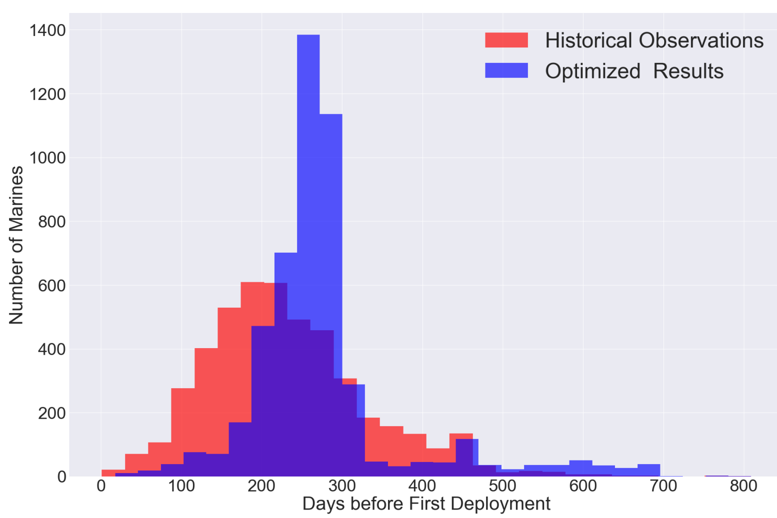

Figure 5.2. Histogram Comparison of E-4 & E-5 Training Days before First Deployment.

OAM still assigns the entry level Marines to a deploying unit well before the 180 day staffing threshold.

The entry level E-1 to E-3 rifleman (0311) population accounts for nearly 34% of the total number of assigned personnel in the OAM. In comparison, career level E-1 to E-3 rifleman increase their number of training days prior to deployment by an average 22 days, accounting for 11% of the assigned population. A limitation in the OAM is present in the assignment of entry level personnel. 923 Marines, 11% of the E-1 to E-3 entry level population, are initially assigned to a unit and fail to deploy with that unit due to their set departure date from historical observation. If that Marine has remaining time on their contract, they are re-assigned in the model at the current time step. Further information, and future research, is required to properly identify the reason for departure for entry level Marines.

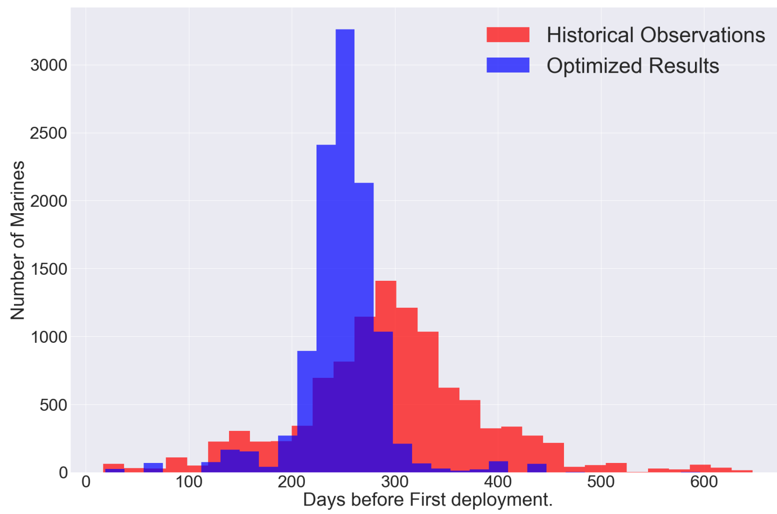

Figure 5.3. Histogram Comparison of Entry Level E-1 to E-3 (0311) Training Days before First Deployment.

5.3 Deployable Unit Strength

OAM assigns Marines to units to decrease the deviation from the need for each rank and MOS combination. The model minimizes the personnel deviation in each unit, and maximizes the number of training days achieved with each assignment. This results in manpower assignments that meet the need of the unit and give the unit more time with its at a deployable unit strength. OAM fills units to an average of 97.725% of their historical deployed strength with a standard deviation of 1.13% during the time horizon. Seen in Figure 5.4, the distribution of optimized deployment strengths from 2012 to 2018 are within 1.5% of historical observations.

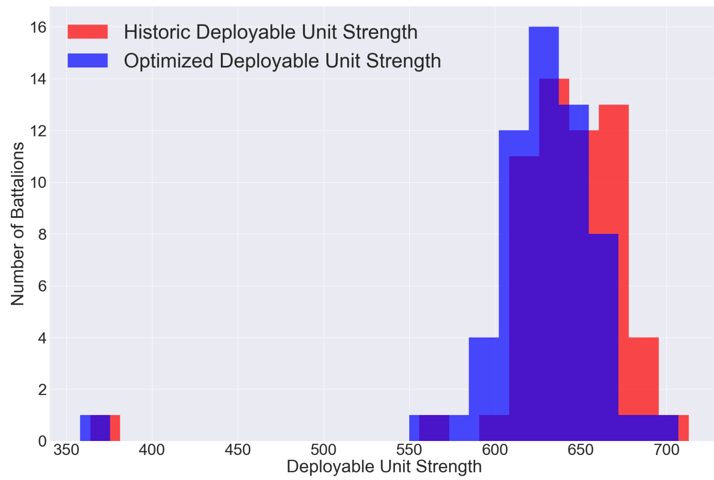

Figure 5.4. Deployable Unit Strength

5.4 Time To Achieve Deployable Unit Strength

As discussed in Chapter 3, using historic deployable unit strength provides a realistic comparisons for optimized results. OAM uses the historic deployment observations and successfully increases the amount of time units have at their deployable unit strength prior to executing assigned deployments. Historically, units achieve their deployable unit strength between 105 to 169 days prior to deployment, with a median time of 139 days prior to deployment. OAM increases the number of training days with full deployable unit strength to between 206 and 237 days (Figure 5.6), with a median time of 224 days prior to deployment (Figure 5.5). The increase of 85 training days gives commanders, and unit leaders at all levels, nearly three more months to train their entire deployable force.

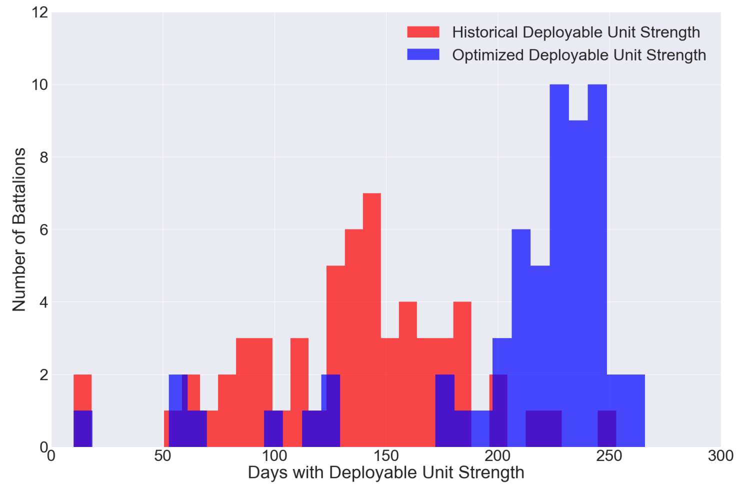

Figure 5.5. Histogram Comparison of Training Days at Deployable Unit Strength.

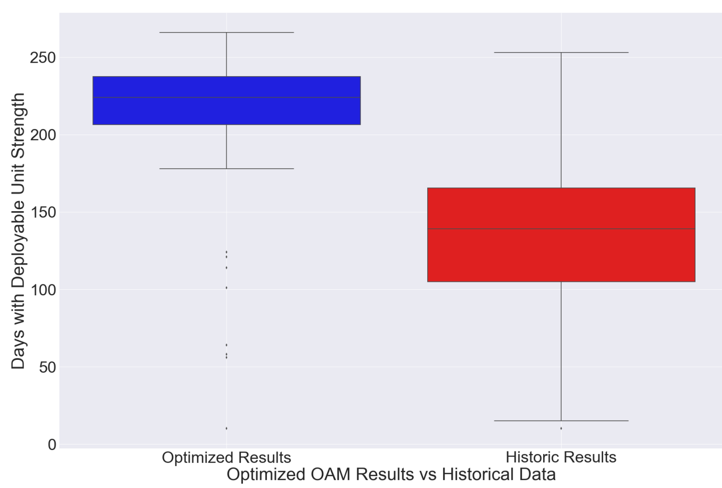

Figure 5.6. Boxplot Comparison of Training Days at Deployable Unit Strength.

Each infantry battalion demonstrates unique timelines for reaching their desired deployable unit strength using OAM. Figure 5.7 demonstrates the improvement of the optimization in comparison to historical manning for 3rd Battalion 7th Marines (V37). V37's first scheduled deployment is September 26, 2013, and historically reaches its deployable unit strength 180 days prior to deployment. Using OAM, V37 is fully staffed to deployable unit strength at 222 days prior to deployment. Subsequent deployments for V37 show further improvement. For deployment on April 1, 2015, OAM fills the manpower requirements

249 days prior to deployment, while the historical observation occurred 109 days prior. For the third deployment in the time horizon, V37 is fully staffed 224 days prior to deployment using OAM, an increase of 49 days from historical observations.

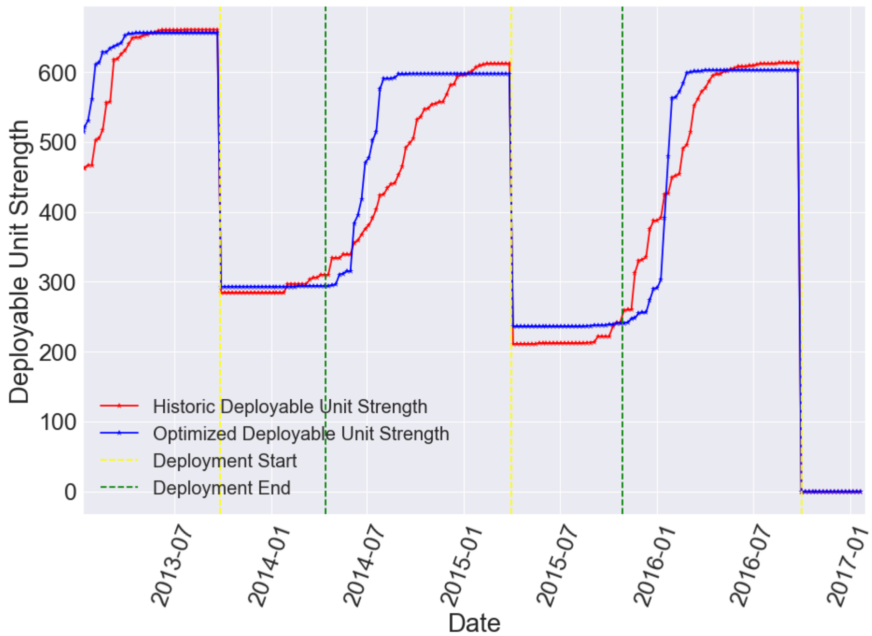

Figure 5.7. Deployable Unit Strength of V37 over Time.

OAM maintains or improves 57 of 59 unit manning timelines within the sample set. Only two unit deployment result in small decreases to the number of training days needed to reach a deployable unit strength. OAM fulfills manning requirements as soon as possible in order to reduce penalties and to ensure the greatest number of training days for new arrivals. OAM adjusts to sequential deployments with limited time between re-deployment and deployment by constantly assigning available personnel (Figure 5.8).

A shortfall in the model is identified in the extremely early manning of units. Assigning Marines too far ahead of their scheduled deployment causes the reduction of follow on employment further in the time horizon. Due to the fixed contractual length of each individual Marine, the earlier they are assigned to a unit, does not necessarily allow them to deploy on a second deployment within their initial contract length. As seen in Figure 5.8, OAM reaches the deployment strength 42 days after the historical observation. Although behind the historic observation, the late staffing of the unit creates a larger number of Marines who will be deployable in the unit for a subsequent deployment. This is an inherent problem with manpower assignments and requires further research.

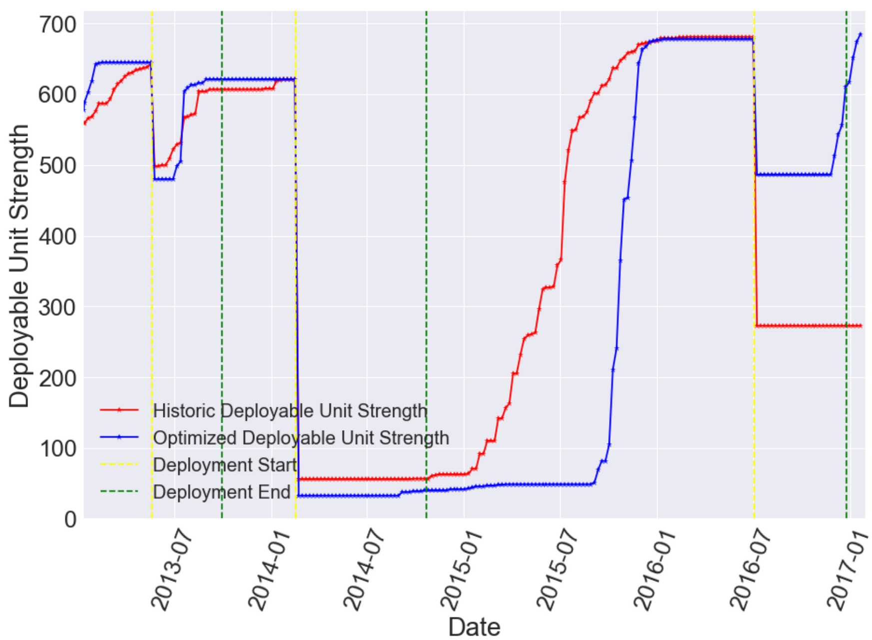

Figure 5.8. Deployable Unit Strength of V16 over Time.

5.5 Recommended Future Research

Manpower analysis requires a comprehensive look at historical trends and future predictions of personnel availability, requirements, and future deployment demand. This research focused on the historical trends and the optimization of historical data. While this provides a good metric for comparison, it fails to look at future requirements and future manpower assignments.

5.5.1 Future Manpower Projections

Future manpower projections, generated from the historical data, can be implemented into OAM with a given initial inventory. Future deployment data can be sourced from the force synchronization phase of the FGP. If real data is not available, utilizing the historical trends of deployment dates, mission sets, and deployment lengths, a future projection of deployments can be generated and supplied to OAM for optimization. Application of this research will allow leaders to identify possible manning shortfalls in both aggregate unit strength, MOS and rank combinations, and timelines needed to achieve training requirements.

5.5.2 Optimization Of First Term Marines

Enlisted contract lengths restrict the deployability of Marines as they progress through their time in a unit (Figure 5.8). Future research is recommended in the optimization of personnel assignments to maximize the number of deployments Marines can make within their first-term c ontact. Historical data from 2012-2018 demonstrates that 2,333 Marines were assigned to a unit and failed to deploy with that unit. 72.5% (1,692 Marines) of these Marines were E-1 to E-3. OAM reduces this number of non-deployable assignments to 1,254; however, further research is recommended. Detailed information on a Marine's reason for departure is not included in the original data and not incorporated into the development of OAM. Identifying personnel who possess the required time on contract to support an adjacent unit's deployment will significantly reduce the burden placed on units prior to, and after deployment. Identification of these Marines will allow units to receive deployable Marines sooner and reduce the number of non-deployable Marines that remain in a battalion's personnel inventory.

5.6 Conclusions

Utilizing the Optimized Assignment Model (OAM), this research improves the the individual number of training days available to new Marines prior to their first unit deployment for all career level rank and MOS combinations and maintains entry level Marines above the 180 day threshold. OAM significantly improves the number of training days available to units with a after reaching their deployable unit strength, greatly increasing each units ability to train as a complete unit prior to deployment.

This research demonstrates the ability to increase the timeline to achieve deployable unit strength prior to deployment, and the ability to increase the time individuals have in a unit prior to their first deployment. The best attempt was made to model assignment of personnel in order to increase individual time in a unit before deployment, while maintaining the ability to meet the manpower requirements in each unit.

It is the author's hope that this research may influence senior decision makers by identifying shortfalls in the assignment system and demonstrate that personnel can be assigned differently to achieve a greater opportunity for individuals and leaders to prepare for deployment.

APPENDIX

A.1 Fiscal Year 2019 Infantry Battalion Table of Organiation

Table A.1. Number of Personnel Assigned to each Rank and MOS by T/O for Fiscal Year 2019. Adapted from (Commandant of the Marine Corps 2018b).

MOS	0302	0302	0302	0302	0306
Rank	1STLT	CAPT	MAJ	LTCOL	CWO2
Number T/O	**22**	**5**	**3**	**1**	**1**
MOS	0311	0331	0341	0352	0331
Rank	PVT	PVT	PVT	PVT	PFC
Number T/O	**84**	**24**	**32**	**2**	**3**
MOS	0341	0352	0311	0331	0341
Rank	PFC	PFC	LCPL	LCPL	LCPL
Number T/O	**1**	**2**	**211**	**36**	**19**
MOS	0352	0311	0331	0341	0352
Rank	LCPL	CPL	CPL	CPL	CPL
Number T/O	**18**	**135**	**23**	**19**	**17**
MOS	0311	0331	0341	0352	0365
Rank	SGT	SGT	SGT	SGT	SGT
Number T/O	**28**	**10**	**11**	**4**	**15**
MOS	0369	0369	0399	0399	
Rank	SSGT	GYSGT	MSGT	MGYSGT	
Number T/O	**25**	**9**	**5**	**1**	

A.2 Historical and Optimized Median Training Days by Rank and MOS

Table A.2. Median Number of Training Days before First Deployment of Career Level Marines

PMOS	Rank	Historical TDays	Optimized TDays	Difference	Observations
0302	o1_o2	220.0	264.0	44.0	113
0302	o3	243.0	282.0	39.0	279
0302	o4	282.0	298.0	16.0	69
0302	o5	313.0	444.5	131.5	38
0306	wo	192.0	533.0	341.0	9
0311	e1_e3	225.0	247.0	22.0	2671
0311	e4	217.0	250.0	33.0	2275
0311	e5	205.0	278.0	73.0	336
0331	e1_e3	238.0	266.0	28.0	361
0331	e4	154.0	283.0	129.0	187
0331	e5	194.0	289.5	95.5	90
0341	e1_e3	196.0	274.5	78.5	324
0341	e4	174.0	277.0	103.0	185
0341	e5	185.0	283.5	98.5	102
0351	e1_e3	209.0	290.0	81.0	183
0351	e4	195.0	290.0	95.0	72
0351	e5	176.0	330.0	154.0	29
0352	e1_e3	209.0	270.0	61.0	91
0352	e4	185.0	283.0	98.0	121
0352	e5	199.0	468.5	269.5	32
0365	e5	175.0	367.5	192.5	18
0369	e6	191.0	273.0	82.0	697
0369	e7	214.0	283.0	69.0	231
0369	e8	263.0	329.0	66.0	52

Table A.3. Median Number of Training Days before First Deployment of Entry Level Marines

MOS	Rank	Historical TDays	Optimized TDays	Difference	Observations
0302	o1_o2	297.0	266.0	-31.0	684
0306	wo	207.0	299.0	92.0	26
0311	e1_e3	302.0	250.0	-52.0	8347
0331	e1_e3	302.0	266.0	-36.0	2322
0341	e1_e3	266.0	276.0	10.0	2350
0351	e1_e3	274.0	283.0	9.0	1022
0352	e1_e3	246.0	266.0	20.0	847

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