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A MODERNIZED RECRUIT DISTRIBUTION MODEL

by

Ryan J. Martinez

June 2021

Thesis Advisor:	Emily M. Craparo
Second Reader:	Ross J. Schuchard

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The Marine Corps is undertaking an organizational shift to better fulfill its role in the future national defense strategy. A crucial aspect of creating a more specialized and capable fighting force is ensuring optimal talent management. This requires assigning the best fit military occupational specialty (MOS) to over 30,000 new recruits each year. This is currently done using the Recruit Distribution Model (RDM) run at Marine Corps Manpower and Reserve Affairs (M&RA). While the RDM assigns each recruit to an MOS within the parameters of their respective contract, it is almost 40 years old, written in an outdated programming language, and does not successfully consider all aspects of talent management. The current RDM assigns each recruit an MOS that the recruit is qualified for predominantly based on school seat availability. While this model is effective, it does not optimize talent management in accordance with the Commandant's vision for a more adept and lethal organization. This thesis creates a modernized RDM written in Python that considers many more factors in optimal MOS assignment. Examples of improvements include minimizing idle time spent between training schools, maximizing goodness of fit pairings, and ensuring the assignments over the course of a year are approximately achieving M&RA staffing goals. The modernized model provides the required flexibility to adapt over time and achieve optimal talent management among the enlisted force.

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A MODERNIZED RECRUIT DISTRIBUTION MODEL

Ryan J. Martinez
Captain, United States Marine Corps
BS, United States Naval Academy, 2015

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June 2021

Approved by: Emily M. Craparo
Advisor

Ross J. Schuchard
Second Reader

W. Matthew Carlyle
Chair, Department of Operations Research

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ABSTRACT

The Marine Corps is undertaking an organizational shift to better fulfill its role in the future national defense strategy. A crucial aspect of creating a more specialized and capable fighting force is ensuring optimal talent management. This requires assigning the best fit military occupational specialty (MOS) to over 30,000 new recruits each year. This is currently done using the Recruit Distribution Model (RDM) run at Marine Corps Manpower and Reserve Affairs (M&RA). While the RDM assigns each recruit to an MOS within the parameters of their respective contract, it is almost 40 years old, written in an outdated programming language, and does not successfully consider all aspects of talent management. The current RDM assigns each recruit an MOS that the recruit is qualified for predominantly based on school seat availability. While this model is effective, it does not optimize talent management in accordance with the Commandant's vision for a more adept and lethal organization. This thesis creates a modernized RDM written in Python that considers many more factors in optimal MOS assignment. Examples of improvements include minimizing idle time spent between training schools, maximizing goodness of fit pairings, and ensuring the assignments over the course of a year are approximately achieving M&RA staffing goals. The modernized model provides the required flexibility to adapt over time and achieve optimal talent management among the enlisted force.

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LIST OF ACRONYMS AND ABBREVIATIONS

ACT	American College Testing
ASVAB	Armed Services Vocational Aptitude Battery
CID	Course Identification Code
CL	Clerical Score
EL	Electronics Score
ESM	Enhanced Shipping Model
FLC	Fleet Learning Center
GT	General Technical Score
ICP	Initial Classification Plan
M&RA	Manpower and Reserve Affairs
M-RDM	Modernized Recruit Distribution Model
MAT	Marine Awaiting Training
MCRD	Marine Corps Recruit Depot
MCT	Marine Combat Training
MCOSM	Marine Corps Occupational Specialty Matching
MM	Mechanical Maintenance Score
MMIB	Manpower Management Integration Branch
MOS	Military Occupational Specialty
MSG	Marine Security Guard
MSGAT	Marine Security Guard Assignment Tool
NAVMC	Navy Marine Corps Publication
NPS	Naval Postgraduate School
OCSP	Officer Career Satisfaction Program
OEMA	Office of Economic and Manpower Analysis
OR	Operations Research
PEF	Program Enlisted For
PFT	Physical Fitness Test
RDM	Recruit Distribution Model
TECOM	Marine Corps Training and Education Command
TMOS	Training Military Occupational Specialty

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EXECUTIVE SUMMARY

The Marine Corps needs to recruit approximately 30,000 individuals every year in order to maintain the organization at proper manning levels. Each of these individuals needs to be assigned a specific job called a Military Occupational Specialty (MOS). Every Marine holds an MOS that details exactly what role they fulfill within the organization and encompasses every community from logistics and supply to infantry and reconnaissance. A crucial task of Marine Corps Manpower and Reserve Affairs (M&RA) is to assign every recruit an MOS in a manner that achieves annual staffing goals.

M&RA currently uses an optimization model called the Recruit Distribution Model (RDM) to conduct MOS assignments. The current RDM has been in place for nearly 40 years. Although the RDM does fulfill its intended purpose of assigning an MOS to every recruit, it is inefficient, requires excessive manpower hours, and produces less-than-optimal results in the context of talent management.

Talent management in the Marine Corps is a difficult goal due to its conflicting nature. There are three main tenets of talent management that should be considered by the organization which are currently not being addressed by the RDM. Meeting staffing needs, leveraging the unique skillsets of every individual, and minimizing the amount of time required to create fully trained Marines all need to be considered when determining how to optimally manage enlisted talent. The current RDM not only assigns MOSs in a short-sighted and inflexible manner but requires extensive human labor in order to do so.

This thesis presents the Modernized Recruit Distribution Model (M-RDM). The M-RDM is a Python-based integer linear program which is specifically designed to give M&RA the flexibility to fluidly determine how to best achieve talent management within the Marine enlisted population. The M-RDM objective function includes terms and weight parameters for each tenet of talent management, giving subject matter experts at M&RA the flexibility to determine how important each aspect is in a continuous manner to meet the current demands of the organization.

To validate the M-RDM, multiple iterations of the model are run with various penalty parameters on a single recruit dataset. A portfolio of solutions is generated to fully explore the range of options available to the Marine Corps via this model. The model can heavily decrease recruit idle time, drastically improve goodness of fit scores, or conduct assignments that equally balance all tenets. The Marine Corps does not need to have a clear definition of how to specifically achieve talent management in perpetuity. The purpose of this thesis is not to detail exactly how the Marine Corps should manage the enlisted force, but rather, provide a modernized tool which allows the flexibility to assign MOSs in the optimal manner the organization deems fit.

The M-RDM is additionally compared directly to the RDM on a dataset of 667 recruits. The M-RDM is able to assign recruits in a manner that decreases the number of days between recruit training and MOS school by 34% and increases calculated goodness of fit scores by 4%. In addition to these quantitative metrics, the M-RDM automates the staffing needs of the organization, which is the single aspect that requires the largest amount of manpower hours in the previous model. It takes the M-RDM approximately 15 seconds to assign 667 recruits to MOSs in a manner that optimizes tenets of talent management not currently being considered by the RDM.

We anticipate that the M-RDM will save countless hours of manpower effort that was required previously by the RDM. Furthermore, the M-RDM will have an immense impact by helping to shape the entire enlisted force of the Marine Corps. The M-RDM balances all three major aspects of talent management that were not considered fully in the previous model. The M-RDM directly meets the focus efforts of the Commandant and Director of M&RA to utilize modernized models to improve talent management and operational readiness of the entire organization.

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I. INTRODUCTION

A. PROBLEM

The Department of Defense utilizes each of its six main service branches to fulfill a specific role in the national defense strategy. The Marine Corps must be properly manned and equipped to fulfill its mission within this overall strategy, while also operating under staffing and budgetary constraints imposed by Congress. The overarching goal of Marine Corps Manpower & Reserve Affairs (M&RA) is determining the manner to properly staff the organization to succeed in its mission while also operating under these imposed restraints (United States Marine Corps [USMC] 2020a).

M&RA needs to recruit roughly 30,000 new Marines every year to properly maintain the Marine Corps at the appropriate strength to fulfill its warfighting role (USMC 2017). To accomplish this objective, each of the 30,000 recruited individuals need to go through the entire process of becoming a fully trained and operational Marine.

Each Marine fulfills a specific job within the organization called a Military Occupational Specialty (MOS). MOSs encompass every type of job from logistics and supply to infantry and reconnaissance. Currently, there are over 150 different MOSs within the Marine Corps, each of which serve a specific purpose to meet the needs of the team (USMC 2020b). One of the methods that M&RA ensures the Marine Corps can fulfill its delineated warfighting role is by both determining how many new Marines to recruit each year, in addition to what jobs those new Marines should hold.

The branch of M&RA that oversees the enlisted MOS assignment process is called Manpower Management Integration Branch (MMIB). MMIB assigns every recruit an MOS using an optimization model called the Recruit Distribution Model (RDM). The current RDM has been in place for nearly 40 years. Although the model is outdated, it does fulfill its intended purpose of assigning an MOS to every recruit. This is the primary reason the model has remained in place for such a long period of time. Despite its overall functionality, however, many improvements could be made to this outdated model. The current RDM is inefficient, requires excessive manpower hours, and produces less-than-optimal results in the context of talent management.

In June of 2020, M&RA approached the Naval Postgraduate School (NPS) Operations Research (OR) department for assistance in creating a modernized model. OR analysts at M&RA determined a new model should be created not only because the current RDM was written in an outdated programming language, but because a modernized model could do a much better job of talent management within the Marine enlisted force.

The purpose of this thesis is to create a Modernized Recruit Distribution Model (M-RDM). This research project leverages the use of optimization techniques and a modern programming language to create a model that better achieves talent management among the enlisted ranks of the Marine Corps. The M-RDM utilizes an integer linear program to fulfill its intended purpose of ensuring every recruit receives an MOS. More importantly, the M-RDM conducts MOS assignment in a manner that provides flexibility to the subject matter experts at M&RA, which subsequently allows them to ensure assignments are more in line with talent management principles across the entire organization.

B. MARINE CORPS OPERATIONAL CONTEXT

The Marine Corps is currently going through an immense tactical and administrative revamp. The Commandant of the Marine Corps has laid out wide sweeping expectations on how he wants the shape and construct of the Marine Corps to change in order to fulfill its key role in the national defense strategy (USMC 2019). While the entire depth of this strategy shift need not be explained, the overall concept can be summarized as: the Marine Corps is shifting its primary focus to great power competition and a renewed focus on the Indo-Pacific region (USMC 2020c). The strategy shift requires the Marine Corps to return to its Naval roots by operating in smaller, lighter, and more agile amphibious forces.

The Marine Corps is making this organizational shift under the context of budgetary constraints, however. While the Commandant plans to invest heavily in technological advancements, the projected budget for the Marine Corps will remain constant (USMC 2019). The vision to balance these constraints is to divest in units and equipment that will not play as large of a role in the future fight, in addition to decreasing the overall size of the Marine Corps. This not only opens monetary funding but decreases the number of personnel in the organization to better fill this more agile role. Examples of this personnel downsizing are evident in the plan to remove three engineer bridging companies, two light attack helicopter squadrons, three medium tiltrotor squadrons, and three infantry battalions (USMC 2019). Tanks have already been phased out of the organization, and all Marines who held tank-related MOSs have laterally moved into other MOSs across the Marine Corps.

This operational context clearly shows the immensely important role that M&RA will hold in shaping the organization. The Marine Corps is downsizing personnel significantly to invest in technological upgrades and attain a more mobile force. Due to this overall decrease in the number of Marines, the specific role of every individual will become increasingly amplified in the following years.

The structural layout of the Marine Corps has been designed with an explicit purpose. Every Marine that deploys in the future fight will hold a clearly defined role that they need to be fully capable of fulfilling. The organization simply will not have robustness it is accustomed to by deploying Marines to serve in overlapping capacities. Every single individual needs to be adequately prepared to carry out their trained and assigned skill set.

In the context of the M-RDM, we can clearly see the importance of ensuring the right Marine is assigned to the right job. These assignments are paramount to the Marine Corps success in future conflict. With such a high volume of the organization needing to be recruited each year, every individual needs to be assigned an MOS that will prepare them for success since their unit, and the nation, will be counting on their ability to execute their role.

C. TALENT MANAGEMENT

According to the Marine Corps, talent management is defined as the ability to maximize "potential, outcomes, and outputs for every individual in the system in order to produce the greatest organizational results" (USMC 2021, p. 1). The Commandant has identified talent management as a key to success during this organizational shift for the future fight. He has delineated two approaches to better manage talent: by optimizing the unique capabilities of each individual, in addition to minimizing the amount of time taken to deliver new, highly qualified Marines, to operational units (USMC 2019).

Upon initial glance, the problem seems like it would lend itself to a straight-forward solution: assign every individual the MOS that utilizes their unique skillset. This would presumably make both the individual and the organization reach higher levels of performance. There are multiple reasons why talent management is not this simple in an organization like the Marine Corps, however. First and foremost, there is the underlying tenet that the Marine Corps' primary mission will always be to meet the needs of the nation. As the Marine Corps states, "where institutional needs and individual desires are not in alignment, deference will be given to the needs of the Marine Corps" (USMC 2021, p. 1). This will always be the case given that the success of the organization hinges upon the team, not the individual.

However, there is undoubtedly a substantial benefit to the Marine Corps in assigning each individual the job that best utilizes their unique skillset. Best fit assignment would allow for optimal performance of each individual, increasing the overall effectiveness of the organization, which will similarly lead to forming a Marine Corps postured to succeed. Best fit assignment is another means of improving the organization to fulfill the needs of the nation.

The final factor that should weigh heavily in determining optimal job assignment is the amount of time it takes to train everyone. The Marine Corps has a lot to gain in expediting the process it takes to create fully trained Marines. As multiple instances throughout history have demonstrated, the nation never knows when the next conflict will occur. While ideal assignment should consider skillset and manning quotas, an undeniable aspect that needs to be measured is how fast gaps in the organization can be filled. Events like the bombing of Pearl Harbor have demonstrated that at certain times, the single most important aspect of optimal assignment is employing Marines as fast as possible. If the next fight occurs at a time when the Marine Corps is not at full strength, the organization will be at a severe disadvantage towards winning any future conflict.

All these factors demonstrate why talent management is such a difficult problem in the Marine Corps. The underlying principle is that the needs of the nation need to be met, but there are clearly advantages to different manners in accomplishing that end state. The manning requirements of the Marine Corps, job assignment that utilizes the unique skill sets of each individual, and the amount of time required to create fully trained Marines, all need to be considered when assigning MOSs and achieving optimal talent management. Given the number of Marines that are recruited each year, combined with the possible permutations of MOSs that can be assigned to everyone, the RDM serves a vitally important role in achieving optimal talent management within the Marine Corps.

D. LITERATURE REVIEW

This literature review focuses on two main aspects. The first is the importance and effects of talent management within the military. We examine multiple studies conducted by an Army organization called the Office of Economic and Manpower Analysis (OEMA) to explore talent management within the context of a large military institution. The second aspect of the literature review is an examination of relevant personnel assignment models that aided in development of the M-RDM.

1. OEMA Studies on Talent Management

The OEMA literature review is organized into four separate parts. The first is a study overview explaining the context in which OEMA views talent management within the Army. The subsequent sections contain summaries of key OEMA studies regarding talent management, talent accession, and talent retention.

a. Study Overview

OEMA was founded in 1983 with the purpose of providing “a sound basis for policy and planning for the Army of the future” (Office of Economic and Manpower Analysis [OEMA] 2021). OEMA is nested within the Department of Social Sciences at the United States Military Academy (referred to as West Point).

We review four studies conducted by OEMA to understand the purpose, relevance, and effect of talent management within a military organization. Given that OEMA resides at West Point, all their work regarding talent management is conducted within the context of the Army officer corps. Despite this difference, the fundamental principles of officer talent management in the Army are applicable and relevant to the enlisted population of the Marine Corps.

OEMA utilizes a four-step method to explain the Army talent management process called the Army Officer Human Capital Model (Colarusso et al. 2010a). Figure 1 shows that these steps are access, retain, develop, and employ. The key steps that we examine during this literature review are access, retain, and develop.

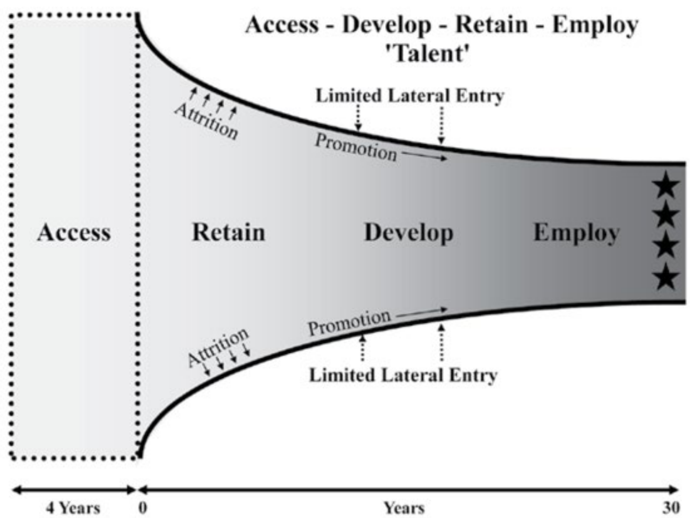

Figure 1. Army Officer Human Capital Model. Source: Colarusso et al. (2010a).

It is important to reiterate that this research is examined under the context of the Marine Corps RDM. Although the role the RDM plays in talent management is at the early stages of the Marine Corps manpower process, it certainly has cascading consequences that can affect the entire organization. Most Marines receive an MOS by the RDM and stay within that occupational field for the duration of their careers. The initial MOS assignment by the RDM holds a crucial role in this overall talent management picture discussed within the context of the Army. Although the RDM is not explicitly in charge of retaining or developing enlisted

Marines, the initial assignment of an MOS will undoubtedly influence the overall Marine Corps manpower system, which we explore throughout the literature review.

b. Views of Army Talent Management

All OEMA studies underscore the fact that talent management is crucial to overall human resource development of the Army. Giving an individual a purpose and utilizing their specific talents will reap dividends for the entire organization. Proper talent management leads to individuals finding purpose in their work. When people have a purpose, they reach higher levels of performance. Many individuals will then remain longer in the organization that affords them success and purpose, therefore increasing the overall reputation and desirability of the organization. A more desirable organization results in acquiring new talent, and the cycle starts again. Talent management clearly has an important part to play in every aspect of the Army Officer Human Capital Model.

Colarusso and Lyle (2014) note that the main issue with the Army's view on talent management is that it perceives individuals as interchangeable parts. Conversely, they define talent not as the top 10 percent of workers, but as the "unique intersection of skills, knowledge, and behaviors in each of us" (Colarusso and Lyle 2014, p. 34). Correctly utilizing everyone's talents creates "optimal levels of performance in a much larger segment of a workforce" (Colarusso and Lyle 2014, p. 34).

The authors also assert that Army "officers desire an assignment that leverages their unique talent set" (Colarusso et al. 2010d, p. 21). There are benefits for both the individual and the Army to assign a position that match individual talent against requirements. The recurrent theme throughout all OEMA studies is that talent management is achieved when an individual find purpose in their work, which in turn triggers a cycle that substantially increases the overall effectiveness of an organization.

c. Accessing Talent

OEMA additionally states that "improvements in talent acquisition provide greater flexibility to the organization" (Colarusso et al. 2010a, p. 3). Every military organization constantly operates in a cloud of uncertainty. While the Marine Corps is currently shifting to the Indo-Pacific region, there is no guarantee that location is where the future fight will occur. The Marine Corps did not foresee over two decades spent fighting in the Middle East until September 2001, for example.

Colarusso et al. (2010a) discuss how proper talent management allows for the Army to operate in this field of uncertainty. Accessing more talented individuals into the organization allows the flexibility for organizational priorities to shift given the assumption that future priorities will change. Their conclusion is that proper talent management of the current pool will "burnish the Army's reputation, creating a virtuous cycle that makes it easier to attract talented young people tomorrow" (Colarusso et al. 2010a, p. vi).

Another important distinction is that proper accession programs are not purely based around targets. While quotas certainly need to be achieved, they clarify that "accessing the right talent means more than accessing the correct number of officers to fill existing billets. It means acquiring the proper breadth and depth of talent across the Army's organizations" (Colarusso et al. 2010a, p. vi). Proper MOS assignment by the RDM at the very beginning of a Marine's career will similarly influence these aspects of talent management. The Marine Corps' ability to remain flexible to adapt to the future fight, in addition to increasing the organization's reputation to recruit future talent, hinge upon the effectiveness of the RDM.

The last topic discussed in these studies is how accessing talent in the Army is different from every other typical large-scale organization. Being a member of the Army requires warfare knowledge and experience at upper management levels and does not lend itself to accessing talent from any other organization, therefore limiting its ability for lateral movement. As the authors state, the Army cannot "poach maneuver, fires, or effects officers from Microsoft" (Colarusso and Lyle 2014, p. 74). The purpose of this example demonstrates that all military organizations are forced to groom and promote talent from within the organization. This similarly demonstrates how something seemingly simple such as MOS assignment by the RDM clearly has repercussions that can affect the talent pool at all levels of seniority.

d. Retaining Talent

The final aspect of the manpower process explored in the OEMA studies is the effect talent management has on retention. As they state, the goal is not to retain officers, but to retain talented officers (Colarusso et al. 2010d). The common theme throughout each aspect of the manpower process in the context of talent management is that the organization is better when each individual finds purpose in their work. This OEMA research discusses three examples, two unsuccessful and one successful that confirm this idea.

In the modern world, every military organization must contend with losing talented individuals to a competitive labor market. OEMA created the following figure to show the competing interests that every individual has in mind when determining whether to remain in the Army.

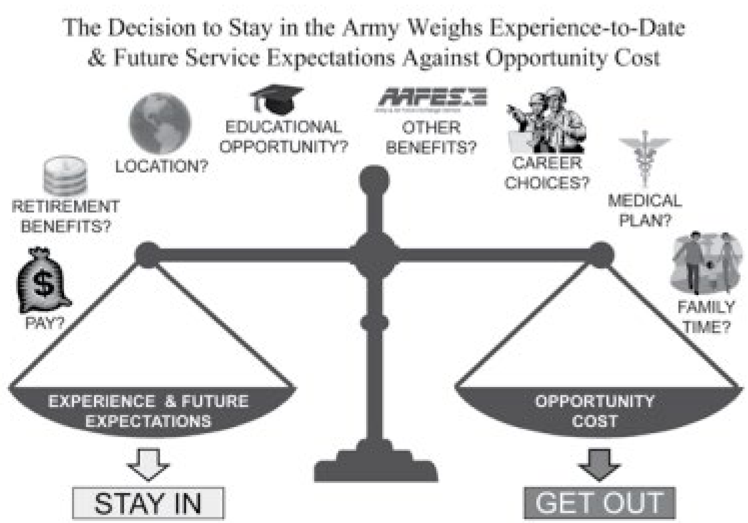

Figure 2. Individual Retention Decision. Source: Colarusso et al. (2010d).

At the time of their study, the Army was facing a retention problem among the junior officers (Colarusso et al. 2010d). To mitigate this problem, the initial solution was to decrease the time between promotions, therefore creating more captains in the Army to replace all the talented individuals who left for competing civilian endeavors. While this approach fixed the immediate issue of having fewer captains, it started a vicious cycle that put the Army in a worse position than when it began. Due to faster promotion rates, less talented officers were attaining the rank of captain and being placed in charge of a larger number of soldiers. The suboptimal abilities of this new leadership cohort caused overall discontent among those they led, resulting in more junior soldiers exiting than previously exhibited (Colarusso et al. 2010d). Individuals want to remain in an organization where they find purpose and direction.

The second failed example of an officer retention solution was a different means of enticing talented individuals to remain in the organization. This was a straightforward approach that can be broadly summarized to cash incentives. The thought was that offering more money to stay in the Army would be enticing. While the breadth of this study need not be explained, the results were summarized as the following: “with a cost to taxpayers of $500 million, there is no evidence that it improved retention” (Colarusso et al. 2010d, p. 26). Cash was simply not enough to convince talented individuals to stay.

The final example gives a successful strategy that demonstrates the sole issue talented individuals desire the most is purpose. This approach is a program called the Officer Career Satisfaction Program (OCSP). This program was offered to newly commissioned offers who would be able to obtain their “branch of choice, post of choice, or a guaranteed option to attend graduate school” in exchange for “an additional 3 years of service” (Colarusso et al. 2010d, p. 27). The results were dramatic in this approach. In the years of 2006 to 2009, the rate that officers increased their obligated service from five years to eight years rose from 47% to 69% (Colarusso et al. 2010d). A similar study found that 44% of young officers identified the job as their most important consideration, while only a mere 6% cared about deployment schedules (Colarusso et al. 2010b).

The conclusion of each of these examples demonstrates the importance of the RDM in terms of talent management. The key aspect highlighted is that proper talent management is attained when individuals find purpose in their work. The RDM helps to ensure that new Marines find purpose in the job assigned at the very onset of their career. This individual purpose will have an immense impact on the entire Marine Corps organization.

2. Personnel Assignment Optimization

The second part of the literature review is an analysis of two personnel optimization models that were crucial in developing the M-RDM. The first is a Marine Corps personnel assignment model that was created by a Marine NPS student. The second is a more recent multi-objective model which determines the optimal way to assign company employees to tasks that require varying amounts of risk.

a. Marine Security Guard Assignments

After exploring talent management to show the importance of assigning individuals to the right job, we now focus on methodologies to achieve optimal assignment. The research that aligns most closely with the M-RDM was a thesis conducted by Captain Maro Enoka in the OR department of NPS. This thesis is titled "Optimizing Marine Security Guard Assignments." We review this thesis because many aspects regarding optimal assignment of Marine Security Guards (MSG) are applicable to the assignment of recruits to an MOS.

The brief purpose of Enoka's assignment tool was to assign 1500 Marine Security Guards to 149 embassy detachments annually (Enoka 2011). The Marine Corps previously did this by hand, which required 1200-man hours per cycle (Enoka 2011). Enoka's thesis created an Excel-based optimization tool called the Marine Security Guard Assignment Tool (MSGAT) that not only decreased the amount of time required to make assignments but did an overall better job of talent management.

Like the M-RDM, MSGAT uses a multi-objective approach to achieve optimal MSG assignment. MSGAT also utilizes an integer linear program to provide optimal assignment of MSGs to fulfill many purposes. The first purpose is essentially to ensure the needs of the embassies are met. The bottom line is that every embassy needs to be properly manned and defended, and fulfilling this purpose always takes top priority. MSG assignment and MOS assignment share a mutual tenet that the needs of the Marine Corps will always come first.

The second objective of the MSGAT is to meet the desires of the individual Marine. Given the discussion of talent management, the desires of the Marine should undoubtedly play a vital role in optimal assignment because it will help each Marine find purpose in their work. The MSG optimization model provides assignment in a multi-objective fashion that balances both the hard requirements of the Marine Corps embassies, in addition to the desires of the individual Marines.

Another aspect of MSGAT that informed the development of M-RDM was the flexibility the MSGAT provided to the Marine Corps. MSGAT's objective function contains penalties and weight parameters that can be fine-tuned by the user to meet the needs of the Marine Corps in the moment. The objective function balances the cost associated with the unique attributes of each MSG, in addition to weight penalties regarding issues like goodness of fit (Enoka 2011).

The M-RDM similarly is created to balance optimal talent management with the needs of the Marine Corps. The Marine Corps needs to create the proper amount of newly trained Marines per MOS each year in order to meet the needs of the nation, while at the same time, realizing that utilizing the unique abilities of each individual undoubtedly makes the organization better. The multi-objective nature, in addition to the flexibility provided by the MSGAT, were crucial in developing similar attributes in the M-RDM.

b. Workers' Sensitivity to Risk

A more recent multi-objective personnel assignment model also aided in the development of the M-RDM. Lazzerini and Pistolesi (2018) describes a personnel assignment model that assigns workers at a manufacturing company to tasks in a multi-objective manner. The problem for the manufacturing company was an excess of work-related accidents and deaths. These accidents were caused by workers not taking the proper precautions when conducting tasks with large amounts of risk. Lazzerini and Pistolesi (2018) describes a model that takes into consideration multiple aspects when determining the optimal task to be assigned to each worker.

The objective function of their model considers three main aspects when determining optimal worker assignment. First, cost and dislike are minimized when assigning tasks to each worker. Those two minimization terms are beneficial to both the company and the individual employees. The company obviously wants to assign workers in a manner that incurs the smallest cost. Additionally, workers desire to be assigned the job that is most desirable. The third term in the objective function maximizes carefulness (Lazzerini and Pistolesi 2018). This predominantly addresses the issue at hand for the manufacturing company. Lazzerini and Pistolesi (2018) analyzes historical data and measure the carefulness of every employee. They utilize a combination of a worker's caution in addition to individual worker human factors to measure the extent of carefulness utilized to accomplish tasks of higher risk (Lazzerini and Pistolesi 2018). Therefore, the goal of the model is to assign workers who exhibit higher carefulness to tasks that require higher risk, since those workers will take the proper precautions in conducting those tasks and therefore lead to fewer work-related accidents.

Multiple aspects of this model are similarly utilized in creating the M-RDM. Lazzerini and Pistolesi (2018) utilizes three terms in their objective function, two minimizations and one maximization. This directly mirrors the objective function of the M-RDM in accomplishing enlisted talent management. The goal of minimizing deviations from staffing goals and the amount of time required to create fully trained Marines must be balanced with that of maximizing assignment to best fit jobs. Additionally, Lazzerini and Pistolesi (2018) utilizes weight penalties in the objective function to allow the manufacturing company the ability to decide how much carefulness should be weighted in the optimal job assignment. The exact same principal is utilized in the M-RDM, as described throughout Chapter III. Finally, Lazzerini and Pistolesi (2018) utilizes a mathematical approach to quantify something subjective such as individual worker carefulness. A similar method is utilized in the M-RDM to attempt and quantify exactly how good of a fit an MOS is for every recruit in a class. The integer program designed by Lazzerini and Pistolesi (2018) thus provides key insight and methodology utilized in creating the M-RDM.

E. M&RA CONCURRENT WORK

M&RA requires multiple OR data analysts to find solutions to difficult manpower problems discussed throughout the chapter. Most of these analysts are NPS graduates. A small cohort of these Marines have undertaken a large-scale project to modernize and adapt multiple systems and models currently being used at M&RA.

The main model currently under development that is pertinent to this thesis is the Enhanced Shipping Model (ESM). The primary purpose of the ESM is to decrease the amount of time it takes to turn a newly recruited civilian into a fully trained Marine. Civilians are recruited into the Marine Corps throughout the entire year and there are multiple stages along that path that lead to periods of waiting. Whether that be waiting to ship to boot camp, waiting to start basic combat training, or progressing along an MOS path, there is potential for a significant amount of dormant time.

One of the outputs of the ESM is to determine what types of MOSs should be produced at various times of the year which would create the minimum amount of time to create fully trained Marines. The ESM takes into consideration the different start dates of boot camp and MOS schools to determine which months should be utilized to create MOSs of each type. This example is discussed for two reasons. First, to show that M&RA is already conducting substantial efforts to improve talent management practices in alignment with the Commandant's priorities. Second, this thesis utilizes outputs from the ESM to achieve optimal talent management within the M-RDM. The context of the ESM is provided because both models plan to be implemented in conjunction at M&RA in the future.

II. CURRENT RDM

A. MARINE CORPS ENLISTMENT PROCESS

It is a long journey to turn a civilian into a fully trained Marine. We now describe the Marine Corps enlistment process in order to explain how the RDM fits into the larger context of Marine Corps manpower. As a civilian, an individual will go to their local Marine Corps recruiting station and begin the process to enlist in the Marine Corps. Based on a combination of desires by that individual and quota availability of that specific recruiting station, the individual will sign a contract into a grouping called a Program Enlisted For (PEF). Each PEF has a two-letter code designator and MOSs have a four-digit designator. A wide variety of MOSs are associated with each PEF. Some PEFs only have two MOSs, while others can have over twenty. By signing an enlistment contract, that individual has agreed to be assigned any MOS within their PEF grouping. Some example PEFs and their associated MOSs appear in Table 1.

Table 1. Examples of PEF and MOS Relationships

PEF	Description	MOSs	Contract Length
AF	Aviation Mechanic	6048, 6062, 6073, 6074, 6092, 6113, 6114, 6116, 6123, 6124, 6132, 6153, 6154, 6156, 6212, 6216, 6217, 6218, 6222, 6227, 6252, 6256, 6257, 6258, 6282, 6286, 6287, 6288	5 years
CJ	Logistics	0411, 0431, 0481, 2311	4 years
HZ	Reconnaissance	0321	5 years
CX	Combat Vehicles and Ordnance Repair	2131, 2141, 2146, 2147	4 years

During this recruitment process, every prospective recruit takes an aptitude test called the Armed Services Vocational Aptitude Battery (ASVAB). The ASVAB is a multiple-choice test that gives recruits a numerical score in four main categories: clerical (CL), electronics (EL), general technical (GT), and mechanical maintenance (MM). These scores are then used to determine MOS eligibility.

After formally enlisting in the Marine Corps, the individual will then start Marine Corps boot camp at either Marine Corps Recruit Depot (MCRD) San Diego or Parris Island. Boot camp is approximately 12 weeks long and encompasses the entire process of turning recruits into Marines. Throughout boot camp, recruits are evaluated and receive scores on various physical fitness tests. An example of a physical fitness test is the annual Marine Corps Physical Fitness Test (PFT) comprised of a three-mile run, sit-ups, and pull-ups. Additionally, all recruits are required to pass the "basic" swimming qualification and can test on the "basic plus," "intermediate," and "advanced" levels if desired.

A recruit's scores on ASVAB categories, in addition to their performance on physical fitness tests are recorded and utilized to determine MOS eligibility. Every MOS in the Marine Corps has specified minimum standards. These minimum standards are explicitly tied to the skills required to perform that job. For example, the MOS of administrative specialist requires an ASVAB clerical score of 100, while the MOS of transmissions system operator requires an ASVAB mechanical maintenance score of 105. All combat arms MOSs require minimum scores for each of the categories of the PFT. Another physical fitness example would be that a prospective reconnaissance Marine requires a "basic plus" swimming qualification. Additional examples appear in Table 2.

Table 2. Examples of MOS Minimum Eligibility Requirements

MOS	Description	EL	CL	MM	GT	Other
0321	Reconnaissance				105	B+ Swimming Combat-Arms PFT standards
1341	Electrical Technician	100		105		
2611	Cryptologic Cyberspace Analyst				105	Top Secret Clearance Eligible
6173	Helicopter Crew Chief			105	110	B+ Swimming Secret Clearance Eligible

The combination of a recruit's scores in physical fitness and aptitude categories will determine which MOSs they qualify for in their contracted PEF. At approximately boot camp training-day 60, the RDM will be run by MMIB to assign each recruit in the class an MOS based on their eligibility within the PEF, in addition to several other factors which will be described throughout the chapter.

After boot camp graduation, recruits officially earn the title of Marine and can be split into two main categories: infantry and non-infantry. All infantry Marines will go straight to their MOS producing school, while all non-infantry Marines have a short thirty-day course called Marine Combat Training (MCT). Following MCT, each non-infantry Marine then continues to every Fleet Learning Center (FLC) required in their specific MOS training path. For some MOSs this can just be one additional course after MCT, while for the more difficult jobs, the training path could require as many as four additional courses. Once a Marine successfully completes all courses required by the MOS training path, he or she formally receives the MOS and is assigned his or her first operational unit.

An additional piece of clarifying information worth noting is that each MOS assigned by the RDM belongs to one of two categories: those that are a one-to-one correlation with an MOS, and another type called a Training MOS (TMOS). A TMOS is a placeholder given to Marines that can receive any one of multiple MOSs associated with a single TMOS. In these cases, the FLC, and not the RDM, has final MOS designation authority. The RDM will simply assign a Marine the TMOS and a seat at the FLC, and the FLC will ultimately decide what final MOS that Marine will hold after completing training.

The following example demonstrates the relationship between all these designators and shows the path from turning a civilian into a fully trained Marine. A civilian enlists in the Marine Corps and signs a contract into the *BA* PEF which is Aviation Electronics Technician. This specific PEF has 3 TMOSs that correlate to 21 MOSs. This recruit attends boot camp at MCRD Parris Island in South Carolina. A few weeks before graduation, the staff at MMIB conducts the RDM run which assigns this recruit the TMOS of 6300. This Marine then graduates boot camp and goes on to 30 days of training at MCT in Camp Lejeune, North Carolina, since 6300 is a non-infantry MOS. He then goes to the first FLC associated with the 6300-training pipeline, which is a course in Pensacola, Florida. Based on his performance in that course, the training staff assigns him an MOS of 6326 which is Aircraft Avionics Technician for the MV-22 Osprey. After graduating MOS school, he receives orders to his first operational unit which is an Osprey squadron at Air Station New River in North Carolina. He is now a fully trained, operational Marine.

B. RDM FACTORS

M&RA creates goals and quotas based on their projections for the future five-year plan. This allows M&RA to plan for unknowns such as how many Marines will retire or reach the end of their contract in that timeframe, in addition to the amount of time it takes to turn newly recruited civilians into fully trained Marines as described in the previous section (USMC 2021).

The planning goal created by M&RA that is the catalyst for the RDM is called the Initial Classification Plan (ICP). The ICP is the target number of Marines per MOS that need to be created for a given year. The ICP considers all other projected factors, such as what MOSs need to be increased over time to meet Marine Corps mission sets, which

MOSs are being phased out of the Marine Corps, and historical data to determine which MOSs have the highest attrition rates.

If Marine Corps Recruiting Command hits their goals in successfully recruiting civilians, the RDM needs to ensure that those new recruits are properly assigned MOSs in accordance with the ICP. This concept generally answers the question of what MOS a specific recruit will be assigned if the recruit is eligible for multiple MOSs. Recruits are assigned with the goal of reaching the ICP target over the course of a year.

While the main factor of the RDM is ensuring that the proper number of Marines per MOS are assigned according to the ICP, the secondary factor considered is how long it takes for those fully trained Marines to arrive at an operational unit. For most MOSs, there are multiple training schools one must attend prior to becoming fully trained. Each of these courses have various start dates that generally align with graduation dates of the prior course. However, there is always expected to be idle time a Marine spends waiting to begin instruction. This status is known as Marine Awaiting Training (MAT). It is important to note that this is purely a secondary factor in the current model. Although it is a consideration, the main decision point for the RDM is to assign Marines to an MOS with the goal of meeting the ICP target.

C. RDM PURPOSE

Having explained exactly where the model fits in the Marine Corps manpower process, we now describe the purpose of the RDM in greater detail. While the end state of this entire process is to assign every recruit an MOS, the RDM does this as an implied secondary task. The true purpose of the RDM is to formally set a recruit on a path that may lead to one of several MOSs. In other words, the output of the RDM is the assignment of every recruit to an available seat at the first FLC of a given MOS training path.

Each course along a training path has an associated code called a Course Identification Code (CID). The output of the RDM is to assign each recruit an available seat at the first CID associated with a specific MOS training path. While the RDM does assign a recruit an MOS, it is important to note that this is accomplished by assigning each recruit an available seat at a CID.

One final clarification is that this assignment is to the first CID of an MOS producing school. It is assumed that every non-infantry Marine will attend MCT after boot camp. The RDM takes this into consideration and therefore assigns all non-infantry Marines to their first CID after finishing MCT. In the event a training path has multiple courses, it is the responsibility of the previous course to assign the recruit a seat at any follow-on course. The purpose of the RDM is purely to assign the recruit a seat at the very first CID and therefore along a path to an MOS and an operational unit.

D. CURRENT RDM PROCESS

The current RDM process is driven by assigning recruits an MOS based on CID seat availability. For every CID that is available to a given RDM iteration, there are multiple offerings of that course, each of which begins on different dates. The current RDM process is driven by the order in which it attempts to fill school seats at each of these CID course offerings.

For a given RDM run, each course offering of a CID is given a priority number that is defined by Marine Corps Training and Education Command (TECOM). The current algorithm then processes each of these CIDs sequentially by priority. Namely, every CID offering with priority one will be evaluated first. Every recruit that is qualified for an MOS taught at a CID offering with priority one will fill a seat until all available school seats have been taken. This process continues for every single course offering that has been given priority one, and so forth for all other priorities.

There are multiple instances where this may lead to a tie, however. A recruit could be equally qualified for two MOSs that are taught at CID course offerings with priority one. In the event of a tie, the current algorithm will utilize MAT time as a secondary tiebreaker. This is to say the current RDM will assign the recruit a seat at the CID course offering which incurs the least amount of time the recruit will spend in MAT.

Although the algorithm is more complex, this simple concept truly expresses the current RDM process in its entirety. Everything is driven by course offering seat availability and the priority number of those seats. The goal is to fill all the seats with the highest priority by qualified recruits. In the event of a tie, the model will send the recruit to the CID with the earliest start date.

E. ISSUES WITH THE CURRENT RDM

The current RDM successfully accomplishes the task that it was designed to fulfill, which is to assign an MOS path for every recruit in the Marine Corps. There are multiple issues with the current RDM though, which we now describe.

1. Outdated

The current RDM has been in place for nearly 40 years. It is written in a programming language called FORTRAN (Ryan 2021). While FORTRAN is a capable programming language, it has been outpaced over the past few decades by many other object-based languages. While these aspects within themselves are not a problem, they are highlighted to demonstrate how long this model has been in place, and how much time has elapsed without conducting any modernization to meet the current needs of the Marine Corps. The model has been steadily updated since its original creation, but at some point, minor fixes to an outdated model can only go so far. Modeling and optimization software has drastically improved over the past few decades, and the Marine Corps needs to leverage these innovations to best fit their current needs.

2. Extensive User Effort Required to Meet Initial Class Plan

The RDM was created to assign recruits to MOS paths with the intent of meeting the annual ICP. The manner that this is currently done requires much more effort by the user than it does by RDM automation. Currently, the RDM is run for a single graduating boot camp class at a time. There are approximately 100 Marine boot camp classes that graduate each year between MCRD San Diego and MCRD Parris Island. Due to this, MMIB needs to meet the overall annual ICP per MOS via these 100 separate RDM iterations.

The current RDM is "memoryless" in the sense that it purely looks at one class of recruits at a time and assigns CID course seats accordingly. It does not take into consideration what time of the year it is, how many recruits it has assigned to each MOS up to that point, and how many more recruits it needs to assign to make the annual quota. Therefore, the way the ICP targets are accomplished is purely due to cumbersome user efforts. The staff at TECOM updates the priority number of each MOS for every single RDM iteration according to the current state of M&RA. They do this based off their knowledge of the ICP target number and how far away they currently are from meeting that goal.

The following is a hypothetical example of this approach. In the month of September, M&RA is approaching the end of the fiscal year deadline which occurs in October. The staff at TECOM realize that the MOS of 0811 (artilleryman) is far behind its annual target. Therefore, in the upcoming RDM iteration, TECOM assigns every course offering to Artillery School in Fort Sill, Oklahoma a priority of one to fill as many of those seats with recruits who qualify for 0811 as possible. This would allow them to get back on track towards hitting the 0811 ICP target by the end of the month.

3. Extensive User Effort Required to Prioritize MOSs

The prioritization of MOSs within the Marine Corps changes constantly in order to meet current needs. There are two main reasons why MOS priorities may change. The first occurs when a specific community loses many individuals to competing civilian interests. This MOS becomes a high priority for the RDM because the model will need to fill these gaps in the organization. The second instance occurs when a specific MOS increases in importance due to the future operating picture of the organization. Similarly, the model needs to ensure to assign the proper number of recruits to this MOS to fulfill this amplified role in the future fight. Both examples demonstrate how MOS prioritization is fluid in an adapting organization like the Marine Corps.

The current RDM requires extensive user effort to update MOS prioritization. It requires an individual with complete knowledge of both the current situation and the future operating goal to manually update priority numbers for each course offering available to a given recruit class. These priorities need to be updated practically for every iteration of the model and gives a similar example to extensive user effort required to force the model to return a simplistic solution.

4. Rudimentary View of MAT Time

The current RDM considers time a Marine spends in MAT, but only as a tiebreaker when a recruit is equally qualified for two CIDs with the same priority. While MAT should never be the main consideration of the RDM, it needs to play a more important role than simply serving as a tiebreaker. Typical waiting times between ending recruit training and beginning MOS school have historically been greater than 100 days. A portion of this time is spent completing additional training outside the MOS training path and thus is not wasted. However, according to the OR analysts at M&RA, the current Marine spends an average of 40 days idle prior to arriving at their first operational unit (Ryan 2021). Idle time may be spent waiting a few days before beginning MCT or possibly waiting multiple weeks to begin a CID along a MOS training path. Given the salary of a Marine Corps private, this equates to roughly $2,320 wasted per recruit for over 30,000 recruits every year (Federal Pay 2020).

The staff at M&RA classifies time a Marine spends in MAT into two categories simply referred to as “good MAT” and “bad MAT” (Ryan 2021). An example of bad MAT would be the case where a recruit is equally qualified for two relatively common MOSs, one of which holds a slightly higher priority than the other. The slightly more important MOS incurs 60 days of MAT while the other MOS incurs 5 days. The RDM will always assign the recruit the MOS with higher priority, resulting in an assignment that incurs two months of MAT time. A human reviewing the assignment would rationalize that since they are both common MOSs, assignment to the slightly higher priority job does not justify two months of MAT time. This is an example of bad MAT because two months of MAT were incurred for no good reason.

An example of good MAT would be an extremely qualified recruit incurring two months of MAT time to fulfill a restrictive intelligence MOS. This uniquely qualified recruit may be the only member of the class who meets the minimum ASVAB scores and can qualify for a top-secret clearance. All pertinent agencies of the Marine Corps manpower process would agree that incurring months of MAT time to send a qualified recruit to a restrictive MOS is good MAT incurred.

The current model does not allow for a user to distinguish between good MAT and bad MAT. The model simply sees MAT time as equally relevant for every pairing. A commonsense approach would be able to notice when a uniquely qualified recruit is about to graduate and may be the only one over the past few weeks who qualifies for a restrictive MOS. Manpower would be happy to incur large amounts of MAT time for that assignment because it is not only a best use of individual potential, but also would help substantially in hitting the ICP target for that restrictive MOS.

5. No Consideration of Individual Potential

Every recruit that comes into the Marine Corps has strengths and weaknesses that should be best utilized to make the organization better as a whole. There currently is no aspect of the RDM that takes into consideration the unique qualifications, strengths, and weaknesses of every individual recruited into the Marine Corps. Certain recruits are objectively a better fit for some MOSs than others. An example of this would similarly be that recruit who is uniquely qualified for a restrictive MOS. Due to high physical and aptitude scores, this recruit is likely qualified for many other MOSs. The current RDM does not have any constraints in place to attempt and utilize this recruit's unique skillset to the maximum potential. The algorithm would purely assign this recruit to the first CID offering he is qualified for in accordance with the priority list delineated by TECOM.

6. Excessive Use of Manpower Hours

The first example of the current model requiring excessive manpower hours is the way it prioritizes CID offerings and MOSs. An individual at TECOM needs to be fully aware of the entire Marine Corps ICP picture and update course offering priorities weekly to ensure the current model is coming close to the annual target. While it will always be important to have user input in a model, this clearly requires an excessive amount of time and energy spent by the staff at TECOM to update parameters so frequently.

The second manner of excessive use of manpower hours is multiple instances where the current model requires the users to classify individual recruits by hand. An example of this would be recruits that enlist into the Marine Corps with an "open contract." An open contract is a specific PEF that signifies a recruit can receive any MOS across the entire

Marine Corps. The current model does not automatically classify open contract recruits according to CID priority. It simply leaves them as unclassified. Once the RDM output is complete for a given class, the Marines responsible for running the RDM must check which MOSs the open contract recruits are qualified for and try and assign them to the highest priority CID that has open seats remaining.

A final example of waste can be evidenced in those Marines that are assigned to combat arms MOSs. Examples of combat arms MOSs are infantry and artillery. To qualify for these MOSs, recruits must meet physical fitness standards that are not currently checked by the RDM. The RDM only checks for the aptitude scores required for each of these MOSs. The way this is currently being addressed is that the RDM will run on a recruit class only verifying MOS eligibility based on aptitude scores. If the RDM assigns a recruit to a combat arms MOS, then the staff at each MCRD will verify that each of those selected recruits did in fact meet the minimum physical fitness standards. Many times, it will be identified that the recruits did not meet the minimum physical standards, and they will either need to be run through the RDM again or reclassified by hand. In the worst-case scenario, this flaw leads to some recruits proceeding without being properly verified. TECOM has identified multiple instances in which a Marine will arrive at a combat arms CID and only upon arrival will the staff realize that the recruit did not actually meet the minimum physical standards to be there.

F. SOLUTIONS BY THE M-RDM

In a single word, the M-RDM is designed to provide M&RA with flexibility. Revisions and aspects addressed in the M-RDM will be discussed in the exact order of the issues that were identified in the previous section.

1. Modernized

The M-RDM is written in Python, which is a much more relevant object-based programming language. M&RA is currently undertaking a massive overhaul to transition models from legacy to modern programming languages to better enable the entire organization to shift to cloud-based services. A Python based M-RDM supports the current work being conducted by the M&RA OR Analysts. The M-RDM additionally utilizes an integer linear programming formulation that will be discussed at length in the following chapter. This formulation was created specifically to meet each of the needs of all pertinent agencies who have vested interest in talent management and the output of the model.

2. Automates the Initial Class Plan

Achieving ICP target numbers needs to remain the primary purpose of the M-RDM. The M-RDM works in conjunction with the ESM to automate the process required to create MOS target numbers per recruit class. The targets for each class are specifically created to obtain the annual ICP over the course of all recruit classes from a given year. While this provides a much better solution, the M-RDM will always require a human in the loop similar to the current RDM. Subject matter experts will have a much better understanding of the larger context than any model. Given this stipulation, the M-RDM is substantially more efficient than the current model. The M-RDM absolves TECOM from manually updating all course offering priorities based solely on their knowledge of previous MOS assignments and current distance from achieving the ICP.

3. Minimal Effort to Update MOS Prioritization

This thesis does not aim to dictate which MOSs the Marine Corps should prioritize. Based on all factors that encompass good talent management described in Chapter I, we conclude that only M&RA can determine how MOSs should be prioritized. The M-RDM provides M&RA the flexibility to determine the importance of any MOS at any given moment. When that determination is made by subject matter experts, the effort required to input those priorities into the M-RDM is minimal relative to the previous RDM.

4. Progressive View of MAT Time

The M-RDM allows M&RA the flexibility to determine exactly how important MAT time is for any given iteration. The current RDM views all MAT time equally and only utilizes time incurred as a tie breaker when a recruit can be assigned multiple MOSs. If at certain points during the year, the ICP targets seem to be on track, then the M-RDM allows M&RA the flexibility to incur more MAT time to fill restrictive MOSs. In a completely different scenario, there may be a situation where certain MOSs lost many more

Marines than M&RA was projecting over the course of a year. In this case, the amount of MAT time incurred per iteration could be significantly decreased to allow trained Marines to reach the fleet as fast as possible.

5. Maximum Use of Individual Potential

The M-RDM attempts to assign each recruit to the job that is the best use of their specific skill set. It does so by taking into consideration the goodness of fit in assigning a recruit to an MOS. Goodness of fit scores are created to assign recruits the ideal job that they are best qualified to hold. The purpose of this attribute in the M-RDM is to make the overall organization better by uniquely utilizing the skillset of each individual recruit.

6. Minimal Use of Manpower Hours

In addition to not requiring TECOM to manually set all MOS priorities, the M-RDM addresses the other issues of excessive manpower required by the RDM. The M-RDM automatically checks potential combat arms recruits to ensure they are meeting minimum physical fitness standards. Additionally, the M-RDM automatically assigns an MOS to any recruit who is an open contract, in addition to all recruits who did not qualify for any MOS in their original contracted PEF. The M-RDM assigns these open contract and reclassification recruits in alignment with the exact same objective priorities utilized to assign every other recruit.

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III. M-RDM METHOD

A. INTRODUCTION

The M-RDM utilizes an integer linear program to optimally assign recruits to an available CID seat and therefore an MOS. The objective function of the M-RDM considers all aspects of talent management pertinent to the Marine Corps discussed in Chapter I. The model allows M&RA the flexibility to find the best fit MOS and the acceptable amount of MAT time incurred all under the overarching tenet that the needs of the Marine Corps are paramount. The manner the M-RDM formulation achieves this optimal assignment can be broken up into two parts: data calculation and optimization.

B. CALCULATED DATA

The model utilizes a few key pieces of information calculated on a given recruit class to determine optimal MOS assignment. The results of these calculations will become inputs to the optimization model.

1. *ELIGIBLE* Set

The first step is to determine all possible MOSs a given recruit is eligible to receive. Only after determining full MOS eligibility can the best fit MOS be decided. The output of this first computation is to create a list of pairings for an entire recruit class that lists every MOS each recruit is eligible to receive. This is accomplished through a few steps.

Initially, a recruit's eligibility is only looked at for each of the MOSs in the contracted PEF. This eligibility is determined based on individual scores and minimum MOS requirements, as demonstrated in Table 2. The Marine Corps assigns recruits to PEFs in quantities that will ideally meet the needs of the Marine Corps; therefore, it is crucial that the primary goal is to assign a recruit an MOS in their contracted PEF. For each recruit, the data points shown in Table 3 are compared to minimum MOS eligibility standards delineated in NAVMC 1200.1 (USMC 2020b).

Table 3. Recruit Data Points

Citizenship Status	Age
Driver's License Status	Height
Swim Qualification	EL Score
Security Clearance Eligibility	MM Score
High School Math Experience	CL Score
Eye Vision	GT Score
Color Vision	PFT scores

There are only two cases where a recruit's eligibility will be determined for every MOS in the Marine Corps. The first case involves those recruits who signed an Open Contract, which is an enlistment contract stating that the recruit can be assigned any MOS in the Marine Corps if they meet minimum requirements. The second case is those recruits who do not qualify for any MOS in their original contracted PEF. In this case, their eligibility will similarly be determined for every other MOS in the Marine Corps since those recruits will need to be reclassified from the original PEF. Both cases exemplify improvements from the current RDM which requires intensive labor for individuals at MMIB to classify Open Contract recruits and ineligible recruits by hand. The result from these calculations is the set *ELIGIBLE* which is a list of eligible recruit, MOS pairings.

2. Goodness of Fit Scores

Marine Corps agencies agree that goodness of fit should be utilized to determine optimal MOS assignment. It is difficult to quantify something as subjective as the goodness of fit in assigning a given recruit to a specific MOS, however. Moreover, it is difficult to quantify how much better of a fit one MOS is from another. This research utilizes the talent management ideas described in Chapter I to make a claim that a good fit MOS for each recruit is an MOS which allows each individual to find purpose in their work. The assertion is that an individual will find purpose in their work when they possess the unique abilities to excel at the required job, while at the same time, not be overqualified to the point that they feel underutilized or not challenged.

We implement this idea by comparing each recruit's individual ASVAB scores to the minimum requirements for each MOS. To balance a recruit's qualification for a job, we aim for a recruit's ASVAB score to be 10% above the minimum requirement. This embodies the idea that the recruit's abilities are well above a minimum threshold, allowing them to excel in the skills required for the job. At the same time, the 10% target will penalize recruits who may be overqualified and therefore a better fit for an MOS with higher eligibility requirements. In the event an MOS requires multiple ASVAB scores, the goodness of fit score for each of those categories is calculated independently and then averaged to create an overall goodness of fit score in assigning the recruit that MOS. The following formulation denotes how the goodness of fit score $gf_{r,m}$ utilizes an absolute value to reward recruits for being close to 10% above the minimum, while simultaneously penalizing recruits who are potentially overqualified. The output for this calculation is a goodness of fit score for each recruit, MOS pairing in the *ELIGIBLE* set.

$r \in R$	Recruits
$m \in M$	MOSs
$s \in S$	Categories of the ASVAB that lead to MOS minimum scores
$s \in ASVAB_m$	Set of skills s required for MOS m
$minimum\_score_{s,m}$	Minimum score in skill s required for MOS m
$recruit\_score_{r,s}$	Recruit $r's$ score in skill s

$$target\_score_{s,m} = 1.1 \cdot minimum\_score_{s,m}$$

$$gf_{r,m} = \frac{\sum_{s \in ASVAB_m} 1 - \frac{\left|recruit\_score_{r,s} - target\_score_{s,m}\right|}{target\_score_{s,m}}}{\left|ASVAB_m\right|}$$

3. MOS Target Numbers

The M-RDM aims to ensure the achievement of MOS target numbers through each of the individual model iterations over the course of a year. The current RDM faces heavy limitation due to memoryless features that require excessive manpower hours to correct and attempt to achieve target MOS assignment numbers. This aspect of talent management needs to be the cornerstone of the M-RDM as the single most important piece in ensuring the needs of the Marine Corps are met.

The M-RDM achieves this goal by utilizing the concurrent work of the ESM described in Chapter I Section E. The primary goal of the ESM is to determine what time of the year to create certain MOSs in order to minimize MAT. While MAT is only a portion of the M-RDM, the key is that the ESM identifies a manner to create the proper amount of MOSs over the course of a year. The M-RDM utilizes this key data output to determine a baseline target number for each MOS per iteration given a recruit class boot camp graduation date. Although this approximation will never be a perfect solution, it is a much better baseline to determine an estimated number of recruits of each type of MOS that need to be created. The flexibility of other aspects of the M-RDM described throughout this chapter can be utilized as a fiscal year progresses. This allows for informed target numbers to be generated for each iteration but additionally enables M&RA the ability to change penalty parameters accordingly to drive different solutions to meet talent management and staffing goals of the organization.

We now explain the methodology for creating this target number in further detail. The output from the ESM utilized in the M-RDM is a master data frame that includes a few key pieces of information. An example of this data frame is shown in Table 4.

Table 4. ESM Master Data Frame

PEF	MCRD Start Date	MCT Start Date	MOS Selected	MOS School Begin	Gender
CB	7 October	6 January	0111	6 February	Female
CB	7 October	6 January	0111	6 February	Male
CP	20 April	3 August	1361	8 November	Male
MT	20 July	3 November	3521	7 December	Male

While the Table 4 gives the column headers and example information, it is a very small picture of the overall data frame produced by the ESM. The actual data frame is approximately 30,000 rows long which directly equates to the roughly 30,000 recruits the Marine Corps must acquire each year.

Consider a single row of the data frame in Table 4. Each row correlates to an individual with a specific MOS that the Marine Corps needs to create (recruit) at a given point in the year in order to minimize MAT time and to hit the overall yearly target numbers. To illustrate by a few examples, consider the first row of Table 4. The row shows that an 0111 female Marine should be recruited in the month of October so she could start boot camp on 7 October, begin MCT on 6 January, and begin 0111 MOS school on 6 February. Namely, the Marine Corps' goal is to recruit a civilian female in the month of October who is eligible and interested in signing a contract into the PEF associated with 0111.

In the last row, the ESM output is stating that a male 3521 should be recruited in the month of July in order for him to attend boot camp on 20 July and eventually 3521 MOS school on 7 December. This method similarly progresses for an entire year equating to the optimal time to create recruits of a certain MOS to meet target numbers and minimize the time it takes to become fully trained given MOS school start dates.

In the context of the M-RDM, this data frame can be utilized to create rough target numbers per iteration given the date of the boot camp class. The target number per iteration is calculated in two steps. The first step is to determine how many recruits of each type of MOS need to be created per boot camp class. This is done as a simple search of this master data frame that totals how many times a given MOS appears for a specific MCRD start date. The second step involves determining how many total individuals need to be assigned that MOS over the course of a year. Then a simple fraction is calculated to determine what percentage of the overall target number per MOS needs to be created by the current boot camp class. This percentage is then taken from the overall yearly target numbers.

The following example illustrates this process in the context of MOS 0111. Assume the M-RDM iteration is about to be run by MMIB on the boot camp class that started on 7 October. The ESM master data frame will be searched to calculate how many 0111's the

ESM has determined to create from the 7 October boot camp class. Then the ESM data frame will be searched to calculate how many 0111's need to be created over the course of the entire year. The two numbers are divided, which results in 5% of the yearly 0111's being produced by the 7 October boot camp class. 5% of the overall 0111 yearly target is taken and this becomes the MOS 0111 target number for the M-RDM on this given iteration.

$$MOS\ Target\ Percentage = \frac{Number\ of\ MOS\ appearances\ on\ given\ ship\ date}{Total\ Number\ of\ MOS\ appearances\ in\ data\ frame}$$

$$MOS\ Target\ Number = MOS\ Target\ Percentage \times MOS\ Annual\ Target$$

4. MAT

The final piece of calculated data that will be input into the optimization model is MAT time per CID course seat. For the purposes of the M-RDM, MAT is simplified to encompass the total number of days between a recruit graduating boot camp and beginning the first day of MOS school. Most recruits will go to mandatory MCT before arriving at their first MOS school. Attending further mandatory training is not considered MAT and therefore not a waste of money or assets. However, since MCT is a universal requirement for most recruits to attend before arriving at MOS school, it can therefore be stated that decreasing the number of days before beginning MOS school will similarly decrease the number of days a recruit will spend idle in MAT. Throughout the remainder of this thesis, the number of days between a recruit finishing boot camp and beginning MOS school will simply be referred to as MAT.

MAT time is therefore a simple calculation where the result is the number of days between finishing boot camp and sending a recruit to a specific CID offering. MAT time is only associated with a course offering because for the purposes of this model, each recruit for a given RDM iteration will begin MAT day zero at the same time. For the vast majority, that would mean that they would all graduate boot camp on the same day, and therefore the MAT clock would begin from that day onward until they begin the first course on an MOS path. This is a simple calculation that is purely taking the number of days in between boot camp graduation and the course offering start. The resultant difference in days therefore becomes the amount of MAT time that will be incurred when assigning a recruit to that specific course offering.

C. M-RDM FORMULATION

The goal of the M-RDM is to optimally assign every recruit in the Marine Corps to an available course seat and an MOS in accordance with talent management principles. We now describe the integer linear program that accomplishes this.

1. M-RDM Formulation

Indices and Sets :

$r \in R$	Recruit
$m \in M$	MOS
$c \in C$	Course Identification Code (CID) Offering
$(r, m) \in ELIGIBLE \subseteq R \times M$	Recruit r is eligible for MOS m
$(m, c) \in TAUGHT \subseteq M \times C$	MOS m is taught at CID offering c

Input Parameters :

$MAT_{r,c}$	MAT time for assigning recruit r to CID offering c
$gf_{r,m}$	Goodness of fit for assigning recruit r to MOS m
$avail_c$	Available school seats for CID offering c
$target_m$	Target number of recruits assigned to MOS m
$\lambda_m^{shortfall}$	Penalty per recruit under target for MOS m
$\lambda_m^{overage}$	Penalty per recruit over target for MOS m
λ_{MAT}	Penalty for incurred MAT time
$\lambda_{goodfit}$	Penalty for goodness-of-fit score

Decision Variables :

$X_{r,m,c}$	Assign recruit r to MOS m taught at CID offering c [binary]
$SHORTFALL_m$	Number of recruits below target for MOS m
$OVERAGE_m$	Number of recruits above target for MOS m

M - RDM Formulation :

$$\min z = \sum_{\substack{(r,m)\in ELIGIBLE,\\ c:(m,c)\in TAUGHT}} X_{r,m,c}\left(\lambda_{MAT} MAT_{r,c} - \lambda_{goodfit}\, gf_{r,m}\right) + \sum_{m}\left(\lambda_m^{shortfall} SHORTFALL_m + \lambda_m^{overage} OVERAGE_m\right)$$

$$s.t. \sum_{(m,c)\in TAUGHT:(r,m)\in ELIGIBLE} X_{r,m,c} = 1 \qquad \forall r \in R \quad (3.3.1)$$

$$\sum_{(r,m)\in ELIGIBLE:(m,c)\in TAUGHT} X_{r,m,c} \le avail_c \qquad \forall c \in C \quad (3.3.2)$$

$$\sum_{\substack{r:(r,m)\in ELIGIBLE,\\ c:(m,c)\in TAUGHT}} X_{r,m,c} = target_m - SHORTFALL_m + OVERAGE_m \qquad \forall m \in M \quad (3.3.3)$$

$$X_{r,m,c} \in \{0,1\} \qquad (3.3.4)$$

$$SHORTFALL_m, OVERAGE_m \ge 0 \qquad \forall m \in M \quad (3.3.5)$$

2. Objective Function

The objective function of the M-RDM is explicitly designed to contain terms for each of the three tenets of talent management. Each of these three terms is penalized accordingly based on the input parameters determined by the user, namely, MMIB. This feature allows the flexibility for the Marine Corps to tailor their specific talent management needs over any length of time. Penalties can be changed every iteration, every few months, or remain constant for an entire fiscal year. It is important to note that the optimization model is a minimization. This is to ensure the model is penalized and rewarded accordingly for any given recruit assignment according to the talent management terms.

The first talent management principle seen in the objective function is the MAT component. The amount of MAT time incurred for assignment is multiplied by the scalar MAT penalty inputted by the user. As that penalty increases, the formulation will consequently penalize additional days of MAT incurred by any recruit assignment.

The second term is the goodness of fit term. This term is negative to allow for goodness of fit to be viewed as a reward in terms of the overall objective minimization.

The model accrues rewards by assigning recruits to an MOS that gives a higher goodness of fit score.

The final term in the objective function reflects the needs of the Marine Corps. This term penalizes MOSs that do not receive the required number of recruits, as well as those that receive too many. These terms are separate in order to allow for different penalty values. Additionally, both decision variables are indexed by MOS to allow for an added feature of tailoring to the specifics needs of the Marine Corps at any given time. While the model utilizes a single penalty value for both MAT and goodness of fit, having the model penalize the overage and shortfall from a target per MOS allows for the Marine Corps to prioritize MOSs for any given period of time, which is not taken into consideration by the current RDM. While the ideal is to be as close to the target as possible, allowing for decision variables and penalties to be tailored to every specific MOS allows the Marine Corps the most amount of flexibility in determining MOS prioritization.

To illustrate by an example, assume for an upcoming iteration the target goal is to assign ten recruits to a ground intelligence MOS. Given the current state of the fiscal year, the subject matter experts at M&RA know that they have been falling short of the overall intelligence numbers. Therefore, for this specific iteration, the staff will heavily increase the shortfall penalty for ground intelligence, and substantially decrease the penalty associated with the overage for ground intelligence. The combination of these two penalty assignments will force the model to address the ground intelligence shortage.

While the model has the flexibility to tailor penalties for shortfall and overage per MOS, each does not need to be hand-crafted. At the beginning of a fiscal year when M&RA is working with a fresh slate, the organization may decide to place every shortfall and overage penalty per MOS to the same value and have the model assign recruits more heavily based on MAT time and goodness of fit scores. Then as the year progresses, shortfall and overage penalties for a few key MOSs can be tailored accordingly as demonstrated in the previous example.

3. Constraints

The model utilizes five constraints to ensure that assignments are made according to the input parameters. Constraint 3.3.1 ensures that every single recruit receives exactly one assignment to an MOS and a seat at a course offering. Constraint 3.3.2 ensures that the total number of recruits assigned to a course offering does not exceed the number of seats available at that course offering. Constraint 3.3.3 calculates the overage and shortfall values for each MOS based on the assignments made. This is combined with Constraint 3.3.5 which ensures that the shortfall and overage decision variables per MOS must be positive. Finally, Constraint 3.3.4 ensures that each recruit, MOS, course offering pairing needs to be binary, where a value of one correlates to an assignment in the final optimal solution, and an assignment of zero correlates to that recruit not being assigned to that MOS, course offering pairing.

4. Model Feasibility

An aspect of the model that cannot be seen in the formulation is a simple step that was taken to ensure the model is feasible, i.e., every recruit is assigned an MOS and available school seat. While the model already determines eligibility for open contracts and required reclassifications, there may be a recruit who does not meet the minimum standards for any MOS in the Marine Corps. Another example would be a case where there are two recruits who only meet the standards for a single MOS, but there is only one school seat available.

A placeholder MOS of “9999” is created specifically to address such issues. The MOS is initialized to have no minimum standards, so every recruit in a class is automatically eligible. Additionally, a placeholder CID offering is created for MOS 9999 that had unlimited school seat availability. The rest of the input parameters associated with this placeholder MOS and CID offering are created specifically to ensure the model only utilizes this assignment as a last resort. Namely, a substantial amount of MAT time would be incurred for any recruit assigned to this placeholder CID, the goodness of fit score associated with the 9999 MOS has a large negative value, and the target number of assignments for the 9999 MOS is zero.

This allows for an MOS that every recruit can be assigned for in the event there is no other feasible pairing, but overall, the model will only utilize this assignment as a last resort. In the event a recruit does get assigned this placeholder MOS and course offering, MMIB would need to determine exactly why that occurred on a case-by-case basis.

IV. M-RDM RESULTS AND ANALYSIS

A. INTRODUCTION

We now exercise the M-RDM on an actual recruit dataset obtained from MMIB. This dataset includes contracted PEF and all relevant individual scores used to obtain MOS eligibility for 667 Marine recruits. The individual ASVAB scores are similarly utilized to calculate goodness of fit values for every MOS each recruit is eligible to receive. Additionally, MMIB provided the CID seat availability and course offering start dates that were open to this boot camp class. From this second data file, we calculate the MAT time incurred for every CID course offering. Finally, the MOS target numbers for this recruit dataset were calculated utilizing the boot camp start date and the ESM master data frame described in the previous chapter.

The first step to analyzing the model is simply to verify the model is working as designed. The optimal solution returned for a given iteration should reflect the relative importance of the objectives, as represented by the penalty parameters. Section B demonstrates this model verification. First, we consider a baseline instance of equal values for each penalty. From this baseline, penalty parameters are then incrementally increased to allow specific measures of performance to be compared to the baseline model. They key figures of merit throughout this chapter are the average number of MAT days per recruit assignment, the average goodness of fit score for each recruit assignment, and the total number of MOSs that were short and over the target amount for the iteration.

The next section of this chapter directly compares the performance of the RDM and the M-RDM. Direct comparisons between the two models can be made because the dataset provided my M&RA includes the MOS assignments on the recruit dataset by the RDM. With these MOS assignments, the same key figures of merit can be compared between the two models.

Another theme discussed throughout this chapter is the nature of a multi-objective model. The M-RDM is designed to balance all three main aspects of talent management. Therefore, there is not a single optimal solution that should be presented to M&RA for a given recruit class. Rather, a portfolio of efficient solutions is generated using multiple different penalty parameters. This allows M&RA the flexibility to utilize the model to achieve talent management in the manner they see fit.

B. MODEL VERIFICATION

The following section details how the M-RDM was verified to be working as designed. The process involved running a baseline output treating all penalty parameters as the same, and then deviating from that baseline to confirm the model is penalizing assignments correctly.

1. Baseline Model

The M-RDM was run on the test recruit dataset with every possible penalty parameter input at a value of one. Table 5 depicts the resulting measures of performance from this baseline output.

Table 5. Results of Baseline Output

MAT Penalty λ_{MAT}	GoodFit Penalty $\lambda_{goodfit}$	Short Target Penalty $\lambda_m^{shortfall}$	Over Target Penalty $\lambda_m^{overage}$	Avg MAT per recruit (days)	Avg GoodFit per recruit (scores)	# MOSs under target	# MOSs over target
1	**1**	**1**	**1**	**99.879**	**0.941**	**37**	**5**

Recall that the shortfall and overage penalties are indexed per MOS. For simplicity, we set these penalties equally for each MOS. This standard output can then be used to compare results from deviations in the input penalties as demonstrated throughout the chapter. The same measures of performance for each of the next trial runs are then compared to this baseline output.

2. Computational Data

The computational data of the model is now analyzed after successful completion of the baseline iteration. It is important to examine computational data to help quantify how large the problem is, in addition to how long it may take the average Marine Corps computer to conduct an iteration of the model on a standard recruit dataset. Table 6 shows how large the model becomes when run on this standard 667 recruit dataset.

Table 6. M-RDM Computational Data

Decision Variables	Integer Decision Variables	Constraints
52,083	51,684	1,102

Most of the decision variables for the model are integer, which result from the number of binary variables required for each possible recruit, MOS, course offering pairing. The optimization model is implemented using Python's Pyomo package and solved with the COIN-OR branch and cut (CBC) Solver Version 2.10.3 for mixed integer linear programs. Utilizing a computer with 8 GB of RAM and a CPU operating at 2.11 GHz, the model solves in approximately 15 seconds.

3. Model Confirmation

After the baseline iteration, we incrementally increase the penalty parameters to verify that the model accurately accounts for penalties. Four trials are conducted, each associated with increasing the size of one penalty at a time and leaving the others at the baseline level. We utilize this approach because to clearly show how increasing one penalty changes the optimal assignment from the baseline model.

Table 7. M-RDM Model Confirmation

Trial	MAT Penalty λ_{MAT}	GoodFit Penalty $\lambda_{goodfit}$	Short Target Penalty $\lambda_m^{shortfall}$	Over Target Penalty $\lambda_m^{overage}$	# Recruits assigned differently from baseline	Avg MAT per recruit (days)	Avg GoodFit per recruit (scores)	# MOSs under target	# MOS over target
Baseline	**1**	**1**	**1**	**1**	**-**	**99.879**	**0.941**	**37**	**5**
1	**1**	**1**	**1**	**+100**	**52**	**100.891**	**0.940**	**35**	**2**
2	**1**	**1**	**+100**	**1**	**194**	**104.324**	**0.931**	**32**	**2**
3	**1**	**+100**	**1**	**1**	**345**	**100.06**	**0.952**	**39**	**6**
4	**+100**	**1**	**1**	**1**	**234**	**99.86**	**0.941**	**37**	**5**

Table 7 concisely demonstrates that the penalty parameters, and therefore the model, work as designed. Each of the four trials should be compared to the baseline. The yellow portions per row are specifically highlighted to illustrate which penalty and aspect of the model is being tested for a given trial. An additional column is added to show how many recruits were assigned differently from the baseline solution. This encompasses both cases where a recruit is assigned to a different course offering of the same CID, or to a different MOS altogether.

The following will utilize trial one as an example. Every input penalty was kept at a value of one except for the MOS overage penalty. Every single overage penalty per MOS was given a value of 100 in this trial. This would heavily penalize the model for assigning recruits in a manner that placed any single MOS over the target number. As seen in the results from trial one, only two MOSs were assigned above the target number, significantly decreasing the baseline result of five MOSs. This output demonstrates that the model is working as designed. When treating all penalties the same, the optimal solution resulted in five MOSs being over the target. When the overage penalty is substantially increased, the model avoids assigning MOSs over the target, resulting in only two going above the target number.

The remainder of the trials show the exact same result. When a single penalty parameter is substantially increased, the resultant measure of performance improves from the baseline trial run. The number of MOSs assigned under the target decreases from the baseline in trial two. The average goodness of fit per MOS assignment increases from the baseline in trial three. Finally, the average amount of MAT days per recruit decreases in trial four. Each of the four main penalty parameters is working properly, demonstrating that the M-RDM is running as designed.

Another important aspect to note is how the other measures of performance change when a single penalty parameter is increased. An improvement in one measure of performance generally comes at the cost of the other measures of performance. For example, in trial three the goodness of fit penalty was increased and the average goodness of fit score per recruit assignment increased, but only at the detriment of incurred MAT time.

This balance perfectly demonstrates why talent management is such a difficult goal to achieve in an organization like the Marine Corps. Optimal assignment is a zero-sum game, where improvements in one measure of performance likely lead to deteriorating values in other measures of performance. There is a finite number of available CID seats, which in the context of trial three would mean sacrificing MAT time to allow more optimal MOS assignments based on goodness of fit scoring.

4. Score Distribution

In addition to looking at average measures of performance, we now conduct a more detailed analysis of specific recruit assignments. Figure 3 shows the distribution of recruit MAT assignments for each of the five trials demonstrated in Table 6.

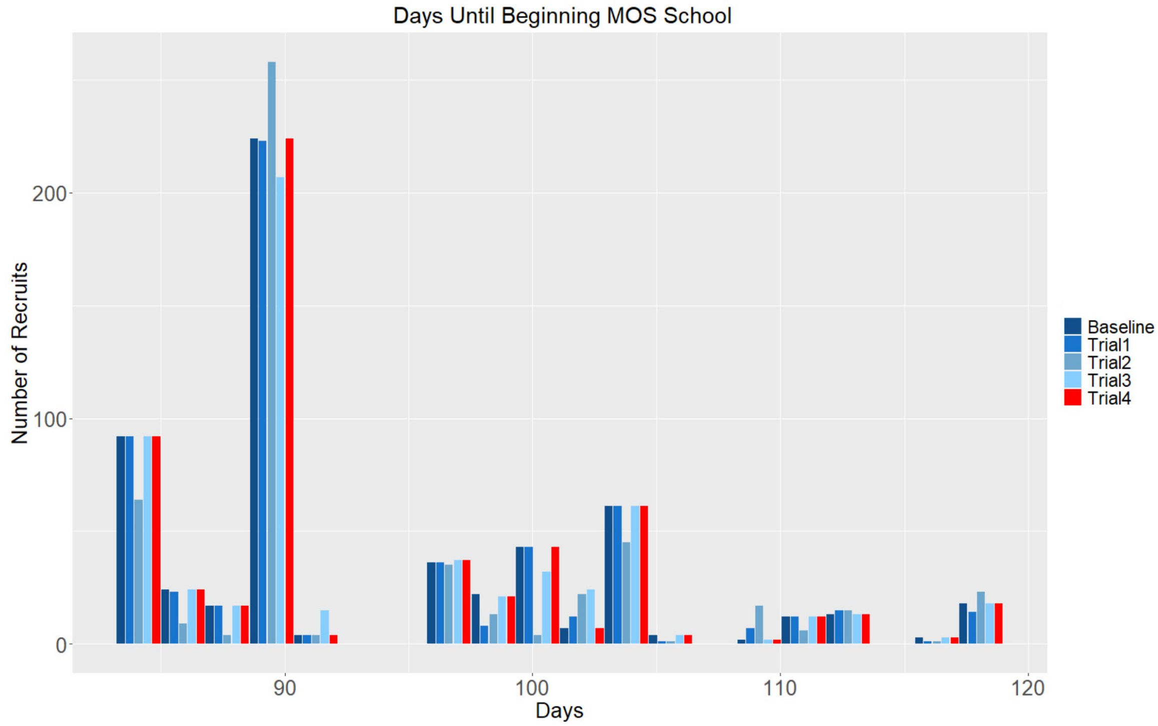

Figure 3. Distribution of Days before Beginning MOS School

Figure 3 provides insight as to how the model assigns recruits in accordance with the penalties. Trial 4, considered the "MAT trial," leaves all penalties at the baseline except for increasing the MAT penalty to 100. As seen in Table 6, the increased MAT penalty successfully decreased the average amount of MAT time per recruit assignment in the optimal solution. Figure 3 demonstrates that this improvement in trial four is not accomplished by simply increasing the number of recruits that incur a small amount of MAT time. The average decrease is achieved by slightly decreasing those recruits who were incurring large amounts of MAT days.

A different result is evident in the average goodness of fit scores, however, Figure 4 provides further detail into results of each of the four model runs in terms of goodness of fit scores.

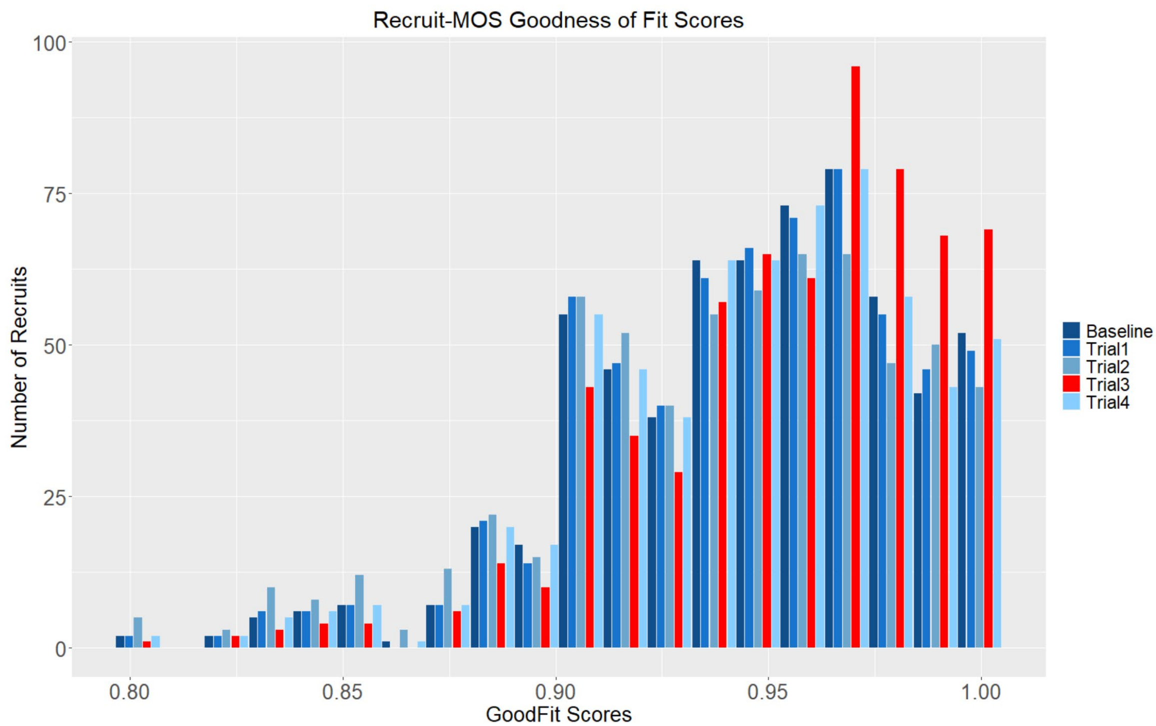

Figure 4. Distribution of Recruit Goodness of Fit Results

Trial 3, considered the "goodness of fit trial," was the only trial that increased the goodness of fit penalty. Figure 4 demonstrates a much different result than previously seen for MAT. In this instance, the model increases the average goodness of fit per recruit by increasing the number of recruits with a high value greater than 0.95. The baseline model resulted in 331 recruits receiving an MOS above this metric, while increasing the goodness of fit penalty in Trial 3 resulted in an additional 68 recruits receiving an extremely good fit MOS. This also gives further explanation to there being 345 different assignments in Trial 3 compared to the baseline. At least 68 recruits received a different MOS altogether, which likely caused so many other assignments to shift in order to make availability while still striving to meet the MOS target numbers.

The two figures shown in this section demonstrate how all assignments are interconnected. Due to the finite number of MOSs and CID offerings, the model needs to sacrifice certain areas in order to improve others all under the constraints of attempting to accomplish the target numbers. In each iteration, the target numbers per MOS are relatively being accomplished with roughly 30 being short and approximately 5 being over. However, each case uses vastly different assignments to accomplish that target. More discussion on achieving MOS target numbers for this specific dataset will be given in Sections C and E.

5. MOS Specific Penalties

In each of the five trials described in the previous sections, the shortfall and overage penalties were equal for all MOSs. As described in Chapter III, a key feature that provides flexibility to M&RA is the ability to tailor overage and shortfall penalties per MOS. This would allow the combination of human domain expertise and the optimization model to work towards optimal talent management. The purpose of this section is to confirm that the model is working as designed in the context of MOS specific penalties.

MOS 1345, Engineer Equipment Operator, served as the test MOS. Similar to the previous sections, we compare the performance between two trials: the standard baseline, and a second trial confirming that the shortfall penalty is functioning properly. The results of this comparison are shown in Table 8.

Table 8. MOS Specific Penalty Confirmation

MAT Penalty λ_{MAT}	GoodFit Penalty $\lambda_{goodfit}$	*1345* Short Penalty $\lambda_{1345}^{shortfall}$	Other MOS Short Penalty $\lambda_m^{shortfall}$	MOS Over Target Penalty $\lambda_m^{overage}$	# Recruits assigned differently from baseline	Avg MAT per recruit (days)	Avg GoodFit per recruit (scores)	# Recruits assigned to MOS 1345
1	**1**	**1**	**1**	**1**	**-**	**99.879**	**0.941**	**8**
1	**1**	**+300**	**1**	**1**	**70**	**100.43**	**0.944**	**33**

The first row shows a detailed look into the baseline model run in the context of the 1345 MOS. The target for this boot camp class is to assign 33 recruits to the 1345 MOS. The baseline model, when giving the 1345 MOS a shortfall penalty of 1, assigns 8 recruits to this MOS and therefore does not meet the target. The highlighted red cell denotes the target as not being met.

The second iteration leaves all other MOS shortfall penalties set to 1 but increases the shortfall penalty of the 1345 MOS to 300. This large penalty results in the model fulfilling the target of 33. This also results in 70 overall different assignments from the baseline, with a slight increase in overall MAT time per recruit. However, the model properly takes into consideration this penalty and ensures to exactly hit the 1345 target.

The M-RDM gives M&RA the flexibility to fulfill any desired purpose in regard to MOS target numbers. In the event a specific MOS is far below the intended annual target goal towards the end of a fiscal year, then that shortfall penalty to that specific MOS should be increased dramatically. On the other hand, if the model assigned many more recruits at the beginning of the year than expected, the overage penalty for a specific MOS should be significantly increased for the remainder of the year. This proof of concept successfully demonstrates that the MOS specific shortfall and overage penalties are being accounted for in the model exactly as designed.

C. M-RDM AND RDM COMPARISON

After confirming the M-RDM works as designed, we now compare the modernized model's performance to that of the legacy RDM. The recruit dataset received from MMIB contains the MOS that each recruit was assigned by the legacy model. With this information, calculations are then made to compare two key metrics of the M-RDM and the RDM: average MAT and average goodness of fit scores per recruit assignment.

1. MAT Comparison

The dataset obtained from MMIB contains the MOS and CID offering assigned to each of the 667 recruits by the RDM. We combine this information with the CID start dates to calculate the amount of MAT incurred for each of the 667 recruits. We now compare averaged MAT times between the RDM and M-RDM shown in Figure 5.

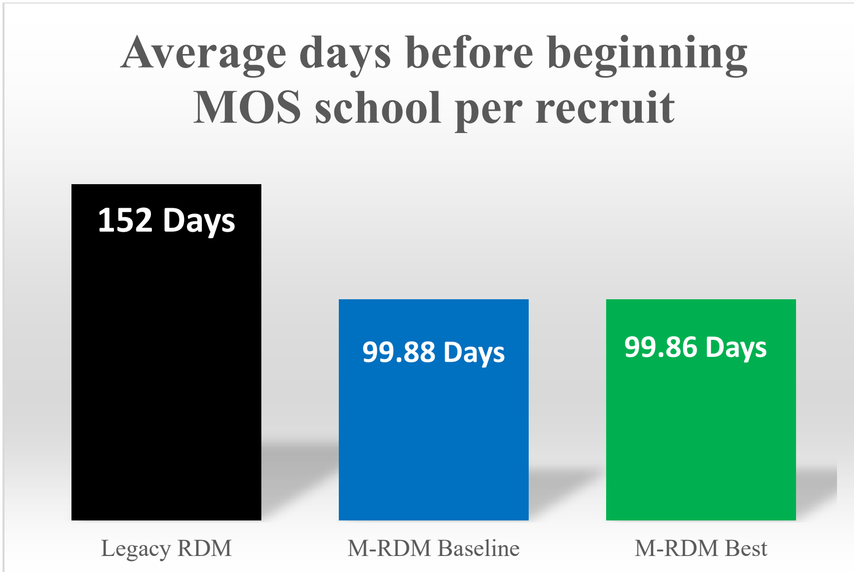

Figure 5. M-RDM vs. Legacy RDM MAT Comparison

Figure 5 shows vast improvement in performance by the M-RDM compared to the RDM. In the RDM assignment, each recruit was incurring on average 152 days of MAT. The baseline run of the M-RDM, which treated all penalties equally, resulted in the average recruit only incurring 99.88 days of MAT. The lowest average MAT observed from the M-RDM runs was Trial 4 as can be seen in Table 6. This resulted in each recruit on average incurring 99.86 days of MAT. In summary, the M-RDM achieves a 34% decrease in average MAT compared to the legacy RDM assignments.

2. Goodness of Fit Comparison

We now take a similar approach to compare average goodness of fit scores between the two models. It is important to note that the legacy model does not account for goodness of fit whatsoever. Goodness of fit scores in the legacy assignments were retroactively calculated utilizing the same formulation described in Chapter III. Namely, the distance from a recruit's score to a target of 10% above the MOS minimum was calculated for each of the assignments by the legacy model. Figure 6 shows average scores and similarly compares them to the performance of the M-RDM.

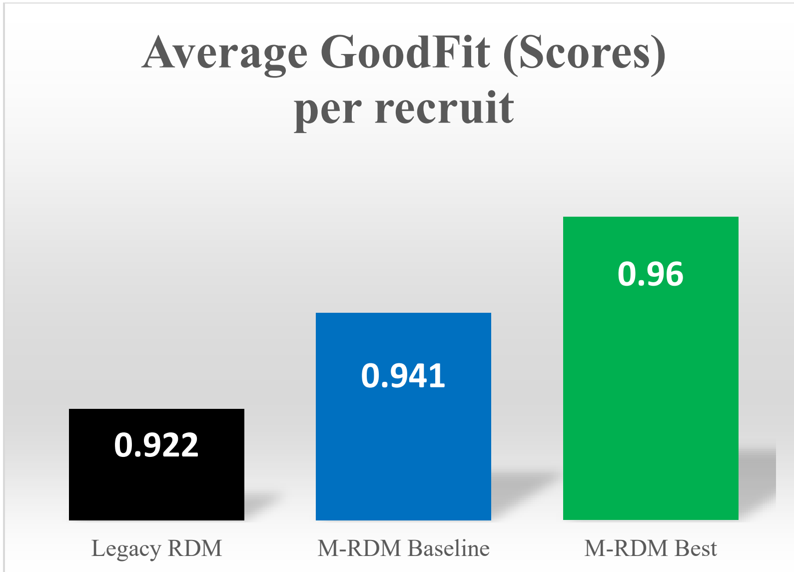

Figure 6. M-RDM vs. Legacy RDM Goodness of Fit Comparison

Upon initial glance, it appears as if the best M-RDM performance is not substantially better than the legacy model, which is neither considering nor even attempting to maximize goodness of fit. Further explanation is required to demonstrate that a seemingly small numerical improvement by the M-RDM is a substantial upgrade from the RDM.

Recall that minimum MOS eligibility requirements of the standardized ASVAB determine goodness of fit scores. To be assigned an MOS, a recruit needs to meet the minimum standard. The target score is 10% above that minimum standard. Therefore, a recruit who has the exact minimum score to be eligible is already at the threshold of receiving a 0.909 goodness of fit score. The following demonstrates how that score was calculated.

MOS 0111 requires a minimum CL score of 105
Assume the assigned recruit has the exact minimum score

$$minimum\,score = 105$$
$$recruit\,score = 105$$

$$target\,score = 1.1 \times 105 = 115.5$$

$$goodfit\,score = 1 - \frac{|105 - 115.5|}{115.5} = 0.909$$

This example demonstrates the scale at which goodness of fit scores should be viewed. Returning to Figure 6, initial response would be that the best M-RDM average performance of 0.96 is not remarkably better than the legacy performance of 0.92. Goodness of fit scores could have been calculated in larger scales to attempt and make the numbers stand out more, but ultimately the relative difference would remain the same. One should look at goodness of fit performance in the context of a minimally eligible recruit receiving a goodness fit of approximately 0.91 and a maximum score being approximately 1.0. Under this context, a 4% increase demonstrated in the M-RDM is substantial. The legacy RDM obtains average goodness of fit scores of 0.92 which are barely above the minimum, whereas the optimal M-RDM performance of 0.96 is relatively close to the maximum score of 1.0.

These recruit scores and minimum eligibility scores are also discussed in the context of the ASVAB, which is an armed-services wide standardized test. Small deviations in scores on that test correlate to a substantial difference in performance. To utilize another more common example, consider the perspective of the American College Testing (ACT). If a company advertised that they could increase a high school student's performance on the ACT by 4%, they would likely be an extremely profitable company in gaining aspiring college students. This is not to say that M-RDM is increasing recruit performance on the ASVAB, but simply demonstrates how small percentage differences correlate to substantial improvements in performance.

The final point to make regarding goodness of fit scores is that the inclusion of goodness of fit by the M-RDM is alone a substantial improvement from the legacy model in terms of achieving optimal talent management. Chapter V includes a section of future work which details exactly how M&RA intends to incorporate goodness of fit with the M-RDM in the near future with a separate program. The goodness of fit calculation utilized throughout this thesis is predominantly a place holder until that program is operational. The base code that is incorporated in the M-RDM allows for an easy transition to that future program M&RA intends to use. In conclusion, the M-RDM incorporates goodness of fit which is already a substantial improvement from the current model. Additionally, when utilizing the same metric to compare goodness of fit results, the M-RDM vastly outperforms the current model in conducting optimal assignments.

3. Achieving Target MOS Numbers

We now compare how each model performed in the third aspect of talent management, which is achieving the needs of the Marine Corps. This comparison requires specific adjustments to the M-RDM which will be explained in depth. These adjustments are made because the research team received incomplete datasets from M&RA. Further explanation to this issue will be given in Section E of this chapter.

It is impossible to determine how the RDM performed in achieving MOS target numbers because the target numbers the legacy model was attempting to achieve are unknown. Therefore, it cannot be determined how accurately the RDM made MOS assignments in accordance with its goal. To adjust for this deficiency, we conservatively assume that the RDM was 100% accurate in achieving its target. Although extremely unlikely, assuming the RDM output achieved its target with perfect accuracy allows for the RDM assignments to become the input targets for an M-RDM iteration.

To utilize a specific example to explain this relationship, consider MOS 0231, which is given to Intelligence Specialists. The RDM assigned 15 recruits to MOS 0231. We assume that the target the RDM was striving to achieve was 15 recruit assignments to MOS 0231. Therefore, the RDM made recruit assignments perfectly in accordance with its target. With this information, we now make 15 the input target number of MOS 0231 assignments for the M-RDM. We repeat this for all other MOS assignments by the RDM, and we now have target numbers for every MOS. This will allow for a direct comparison of the two models on the same metric. Ideally, the M-RDM will be able to achieve the exact same number of assignments per MOS but do so in a manner that either decreases MAT time or improves goodness of fit scores.

Unfortunately, it is impossible for the M-RDM to make assignments in the exact same quantities as the RDM. The main reason for this is due to incomplete datasets alluded to previously. Specifically, the recruit dataset received from M&RA is from a recruit class in November 2013. Some recruits in this dataset signed PEF contracts and received MOSs that no longer exist in 2021. The minimum MOS eligibility requirements received from M&RA are from the current year of 2021. Therefore, it is unknown what scores a recruit would need to have in order to be eligible for these previous MOSs that no longer exist in the year 2021.

Further adjustments are made to attempt and align the M-RDM and RDM assignments as close as possible for this analysis. Every recruit in the RDM assigned an MOS that no longer exists in 2021 was given the infeasibility MOS of 9999. In total, this equates to 120 recruits receiving the MOS of 9999. Similar to all other MOSs, this now becomes the input target number of MOS 9999 assignments by the M-RDM. Although the intended purpose was to create this dummy MOS as a last resort, forcing the M-RDM to make 120 dummy assignments will allow for a more direct comparison to the RDM. It essentially decreases the dataset from 667 recruits to 547 recruits when forcing the M-RDM to make 120 dummy assignments. Only the 547 recruits will be utilized in the model comparison.

With this additional constraint, the goal for the M-RDM is to assign 547 recruits to MOSs in the same quantities as the RDM and 120 recruits to MOS 9999. Even with this imposed constraint, the M-RDM could not achieve the exact same quantities as the RDM. This is likely caused by the cascading nature of decreasing the eligible pool by 120 recruits. Due to a multitude of differences between the two models, it is not feasible for M-RDM to make MOS assignments in the exact same quantities as RDM. In lieu of making the exact same MOS assignments as M-RDM, we set upper bounds for the *SHORTFALL* and

OVERAGE decision variables to force the M-RDM to make those assignments as closely as possible.

The closest performance of the M-RDM was to accurately assign 477 of the 547 recruits in the same manner as the RDM. This encompasses both examples where the M-RDM assigned either more or less recruits than the input RDM target. The total difference between the RDM and M-RDM MOS assignments equates to 12.79% error. While this is not exact, these assignments by the M-RDM and RDM are as close as possible given the limitations of the dataset provided and are substantially closer to each other than any other comparison. The average amount of days until beginning MOS school, and the average goodness of fit scores for these two assignments are similarly compared.

The RDM assigned recruits in a manner that achieved on average 152 days between finishing recruit training and beginning the first day of MOS school. The M-RDM did so in a manner that resulted in 142 days on average, a 7% decrease. The RDM additionally made assignments that gave each recruit on average a goodness of fit score of 0.922. The M-RDM made assignments that gave each recruit an average score of 0.93, a 1.08% increase.

In summary, the main purpose of this section was to attempt and compare the effectiveness of both models in achieving target goals of the Marine Corps, the final tenet of talent management. Although the M-RDM was not able to make MOS assignments in the exact same quantities as the RDM for a direct comparison, it is also a large assumption to believe the RDM met its target goal with 100% accuracy. Regardless of these dataset shortfalls, the impact and superior performance of the M-RDM can concisely be stated in its use of automation. Forcing the RDM to meet the target needs of the Marine Corps is the single aspect which requires the most human labor by M&RA. Automating approximate target goals, combined with the precision of *OVERAGE* and *SHORTFALL* penalties per MOS, will achieve better target performance over the course of the year, in addition to saving countless manpower hours in its implementation.

D. ACHIEVING OPTIMAL TALENT MANAGEMENT

The results of this chapter demonstrate the flexibility that the M-RDM provides to M&RA. The model properly accounts for penalties and assigns recruits to an MOS and available CID seat accordingly. While the penalties are working properly, the nature of a multi-objective model is such that there is no single optimal solution, but instead a family of efficient solutions. This notion accurately reflects the dilemma posed to the Marine Corps in terms of talent management. There is not a straightforward answer to define exactly how the Marine Corps should balance MAT, goodness of fit, and needs of the Marine Corps in order to achieve optimal talent management. The answer to that problem is something that should be decided only by the subject matter experts within the organization and will likely be situation dependent. It is not within the purview of this thesis to define exactly how the Marine Corps should manage the enlisted force of the organization.

The purpose of the portfolio of results demonstrated in this chapter is to fully explore the range of optimal solutions available to the Marine Corps via this model. The Marine Corps does not need to have a clear definition of how to specifically achieve talent management in the organization in perpetuity. The answer will likely change drastically given the current status of the organization and the future operating environment. Regardless of the current context, all the results described throughout this chapter demonstrate that the M-RDM can meet the exact needs of the Marine Corps in any given situation. Simple fluctuation in penalties can derive vastly different optimal solutions, therefore meeting the continuous talent management needs of a complex organization.

E. DATA LIMITATIONS

The purpose of this section is to explain limitations to full model analysis due to the nature of the datasets received from M&RA. It is important to note that we were not able to obtain a complete data set during the course of this thesis and instead relied upon multiple M&RA organizations to build a notional data set for analysis purposes. For example, the test recruit dataset utilized was from a boot camp class that graduated on November 13th, 2013. The MOS target numbers for the iteration were created utilizing the

ESM master data frame that generated quotas based on fiscal year 2020. Additionally, the PEF codes and associated MOSs were utilized from the current year of 2021. Some of the PEFs this specific recruit class signed contracts for in 2013 no longer exist in 2021. These examples delineate a few of the issues of the datasets provided by M&RA. The small deviations between MOS targets and PEF contracts resulted in 15 of the 667 recruits being assigned to the "dummy MOS" 9999 in every instance. This was predominantly because most of these 15 recruits had contracts into a PEF that no longer existed. Although a relatively minor problem, the base of the code and model is functioning properly as demonstrated throughout the chapter. Obtaining current data files in all categories would add even more fidelity to the results of the model.

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V. CONCLUSION AND RECOMMENDATIONS

A. CONCLUSION

This thesis presents the Marine Corps with an optimal enlisted MOS assignment tool called the Modernized Recruit Distribution Model (M-RDM). The M-RDM is a Python-based integer linear program that optimally assigns recruits to an available school seat and therefore along an MOS training path to become a fully operational Marine.

Prior to the creation of the M-RDM, M&RA had been using a FORTRAN-based model that had been in place for nearly 40 years. The legacy model successfully assigns recruits to an MOS but does so in a manner that solely attempts to fill school seats. The previous model's ability to assign enough recruits to the various MOSs annually in accordance with the needs of the Marine Corps requires excessive use of manpower hours, and inefficiencies in this process leads to deviations from sound talent management principles.

Optimal talent management in an organization like the Marine Corps is a difficult goal due to its conflicting nature. The base tenet of Marine Corps talent management is to ensure that the required demands are met in order to allow the organization to fulfill its role in the national defense strategy. While this aspect will always be the top priority, there is undoubtedly a large advantage to maximizing the unique abilities of every individual in the organization. Leveraging the unique skillset of each individual will allow every Marine to achieve higher levels of performance, therefore increasing the effectiveness of the entire organization. Additionally, every military organization constantly operates in a world of uncertainty. It cannot be guaranteed when or where the next conflict may arise. Rapidly delivering fully trained Marines to deploying units similarly needs to be a priority to ensure the Marine Corps can meet its warfighting role at any moment. These competing aspects all need to be considered when discussing optimal talent management within the enlisted force of the Marine Corps.

The purpose of this thesis is not to determine exactly how the Marine Corps can best achieve talent management in the Marine Corps. Rather, the goal is to provide the

Marine Corps with a flexible tool that allows the Marine Corps to decide fluidly how to best achieve talent management within the organization. The M-RDM is formulated to specifically include each aspect of talent management: meeting the needs of the Marine Corps, finding the best fit MOS leveraging the unique skills of every individual, and accounting for the time it takes to create fully trained Marines. The flexibility built into the M-RDM allows for M&RA to determine how important each aspect of talent management is in a continuous manner.

Our analysis results confirm that the model operates exactly as it is designed. Should the Marine Corps determine that the current need is to minimize the amount of time it takes to create fully trained Marines, then they can increase the MAT penalty accordingly to expedite the process. On the other hand, if the Marine Corps believes it is experiencing retention issues and wants to prioritize finding the MOS that allows each individual the ability to find purpose in their work, then the goodness of fit penalty can be increased. Finally, the model can be adjusted to emphasize specific MOSs in the event the Marine Corps needs to fill certain gaps or ensure the annual target numbers are as close to exactly achieved as possible. In every measurable aspect, the M-RDM vastly outperforms its legacy counterpart.

We anticipate that the M-RDM will save countless hours of manpower effort that was required by the RDM. It takes into consideration all three major aspects of talent management that were not considered fully in the previous model. Finally, it allows the Marine Corps the ability to decide what exactly is important to meet the current manpower needs, overall creating better talent management in the enlisted force.

B. IMPLEMENTATION

This research aims to create an M-RDM for M&RA to fully employ. As of May 2021, M&RA is still undergoing its large-scale effort to modernize models and transition them to cloud-based services. This research substantially aids M&RA in its ongoing modernization efforts to produce a model that will provide a vast improvement from the current method and make a substantial impact across the entire organization.

While M&RA continues to modernize its entire command, further progress on the M-RDM will provide a more fully operational model ready to be employed once cloud services are available. Additional research through the NPS OR department will continue to refine and edit the M-RDM to provide an operationally ready product to the organization, ready to be used on every graduating boot camp class throughout the Marine Corps. We now discuss further work that will be done on the model.

C. FUTURE WORK

The NPS OR department plans to do further research and continue to refine the M-RDM. While the model is operational and produces results as designed, there are multiple other aspects that need to be added and tested to deliver a product to M&RA that can truly help shape the talent management picture of the Marine enlisted force.

1. User Interface

The current M-RDM is a single Python script. The data calculations are done via Python and the integer linear optimization model is implemented via Pyomo. To conduct the data calculations, ten separate CSV files are being read in by the Python code. Subsequent data objects are created which in turn become Pyomo objects utilized in the optimization model. To change the penalty parameters in the optimization model, the Pyomo code needs to be updated by hand to run a given iteration for specific penalty parameters.

Future work may allow the M-RDM script to be untouched while input parameters would be able to be updated via a more user-friendly interface, such as an Excel spreadsheet or another similar type of system. This would allow for anyone to run the model by inputting some simple penalty parameters rather than working with the Python script. This will be substantially better for MMIB to allow the M-RDM Python script to go untouched while refined penalty parameter edits could be made in an easily read format. Additionally, the output of the optimization model could similarly be placed in a much more readable format within a separate sheet of the Excel file, allowing for anybody to see exactly to which CID and MOS every recruit in a class was assigned.

2. Annual MOS Targets

The results described throughout this thesis were constructed utilizing many different datasets obtained throughout multiple agencies within M&RA. The current method of utilizing the ESM master data frame to obtain approximate target numbers per MOS for a given iteration makes intuitive sense. As discussed throughout this thesis, however, meeting the needs of the Marine Corps will always be the underlying task of the M-RDM.

The current model accurately assigned recruits from a single boot camp class to an available CID seat according to target numbers made from the ESM master data frame. However, further research may integrate the M-RDM and ESM in conjunction with a forecasting approach to more accurately determine appropriate targets for each individual boot camp class, given annual targets.

3. Penalty Parameters

In this thesis, M-RDM penalty parameters were updated and modified purely with the intent of ensuring the model was operating as designed. The results described in Chapter IV indicate that the model is in fact utilizing penalty parameters properly. Similar to the yearly MOS targets described in the previous section, a simulation of an entire fiscal year should be conducted to determine what penalty parameters optimally achieve MOS assignment. While the entire purpose of the model is to provide M&RA flexibility, an outline or guide of what recommendations for penalty parameters to be utilized throughout different times of the year would be extremely beneficial to the organization. A simulation of an entire fiscal year would allow for analysis of when M&RA may be more aggressive in striving for high goodness of fit scores or incur MAT time. On the other hand, perhaps analysis will determine that leaving penalty parameters roughly the same for an entire year allows for best results in hitting MOS target numbers. The flexibility aspect will always be available to M&RA to shift priorities in line with the Marine Corps. Further analysis on what specific values for penalty parameters would be a great starting point for the organization, however, as this model plans to be implemented for a long period of time.

4. Identifying Uniquely Qualified Recruits

A simple aspect that should be implemented in a finalized M-RDM is the ability to identify uniquely qualified recruits. Historical data could be analyzed to determine what scores per category of the ASVAB would correlate to a recruit who is one of a kind. The model could then put this recruit in a separate category and similarly check for MOS eligibility across the entire Marine Corps, as opposed to solely the contracted PEF. Perhaps the goal should then be to send this recruit to the most restrictive MOS, or the one that leads to the highest possible goodness of fit score, not taking into consideration MAT time incurred. This would truly accomplish a key talent management practice of making the best use of highly qualified individuals in the organization. It is important to note that the M-RDM will still only be able to identify what this uniquely qualified recruit's best fit MOS would be. Manpower work would be required in the event this MOS is not in the original contracted PEF, as this recruit would need to be personally approached and asked if he or she is interested in signing a different contract and being assigned the best fit MOS.

5. MCOSM

The goodness of fit scores calculated in the M-RDM are based around the talent management practice that individuals excel when they find purpose in their work. The assertion is that a recruit will find purpose when he has the skills to excel in a job, while at the same time, not being overqualified to the point where he feels underutilized and not challenged. This is put into practice by calculating goodness of fit scores utilizing a target of 10% above the minimum ASVAB requirement and calculating a recruit's goodness of fit score according to the distance from that target. The result is a single goodness of fit value for every recruit, MOS pairing in the *ELIGIBLE* set.

M&RA currently has a much more advanced plan to implement this idea in the future. This is called Marine Corps Occupational Specialty Matching (MCOSM). The idea is to identify the best fit MOS for each recruit prior to even signing a PEF contract and enlisting. This process entails prospective recruits taking a test that is essentially the equivalent to a career matching test in the civilian sector. It is important to note that this is separate from the ASVAB. While the ASVAB tests intellect and skillset, MCOSM intends on identifying what individuals find interesting and what career paths seem to be most in line with their skillset and desired goals. The results of this test will then be a single score for every MOS in the Marine Corps delineating how good of a fit that MOS is for each recruit. This essentially accomplishes the same thing as the current goodness of fit score, but does so in a much more thorough manner.

We designed the current goodness of fit calculation with the knowledge that the Marine Corps plans to implement MCOSM in the future. It will be a seamless transition to replace the current calculated goodness of fit scores with the results of the MCOSM examination, therefore allowing for goodness of fit to continue to be utilized in the M-RDM objective function and even better attain talent management within the enlisted ranks of the Marine Corps.

6. Persistence

The final aspect that should be included in the M-RDM prior to operational use is the idea of persistence. Incorporating persistence will allow for the M-RDM to be run multiple times on a single boot camp class with the added ability to reassign Marines who cannot fulfill the MOS assignment from the original iteration. A simple modification to the formulation of the integer linear program will save countless manpower hours to allow for the model to reassign Marines to a different MOS, as opposed to checking Marine MOS eligibility and CID seat availability by hand. The following updates would be made to the M-RDM formulation to account for this idea.

Indices and Sets :

$(r,c) \in INCUMBENT \subseteq R \times C$ — Recruit r was previously assigned to CID offering c

Input Parameters :

$\lambda_{reassign}$ — Penalty for reassigning a previously assigned recruit

Decision Variables :

$REASSIGN$ — Number of recruits whose assignments has changed

Objective Function :

$$\min z = \sum_{\substack{(r,m)\in ELIGIBLE, \\ c:(m,c)\in TAUGHT}} X_{r,m,c}\left(\lambda_{MAT} MAT_{r,c} - \lambda_{goodfit} gf_{r,m}\right) + \sum_{m}\left(\lambda_{m}^{under} SHORTFALL_{m} + \lambda_{m}^{over} OVERAGE_{m}\right) + \lambda_{reassign} REASSIGN$$

Constraints :

$$REASSIGN = \sum_{(r,c)\in INCUMBENT} 1 - X_{r,m,c}$$

The added *INCUMBENT* set represents the recruit, CID pairings from the original iteration of the M-RDM. Then by adding another penalty parameter and decision variable associated with reassignments, persistence can easily be included in the objective function. This formulation simply penalizes every additional reassignment that the model would make from the inputted incumbent solution. The idea of persistence would be a simple addition to the M-RDM formulation that would allow further flexibility to M&RA, in addition to saving multiple manpower hours in the event that a small subset of recruits from a given boot camp class need to be reassigned from the original solution.

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