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A Decision-Support System for the Deployment Tasking Process of U.S. Air Force Civil Engineer Officers

Kenneth A. Neal

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THESIS

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Abstract

The Armed Forces frequently deploy their personnel to expeditionary locations around the world. For example, the Air Force tasks its personnel to deploy based on a six-month rotational cycle. In the current tasking process, the deployment makes its way down from combatant commanders to squadron commanders through the chain of command. The commander then has a few days to select an individual from their unit to fill the tasking. The commander may consider an individual's dwell time, home-station position, and upcoming significant life events; however, because commanders have little time and information, minimum requirements selection criteria often become the driving force. Additionally, the commander must select an individual in isolation from other taskings, and the search space is restricted to one unit, leaving no opportunity to optimize the process. This thesis presents and evaluates a prototype decision-support system for the deployment tasking process of Air Force civil engineer officers. The prototype system extends beyond the minimum requirements selection criteria to optimize an officer's professional qualifications and personal preference considerations across the entire enterprise while considering home-station manning constraints. Finally, this research uses past deployment tasking data to examine the feasibility of utilizing the decision-support system on the current tasking process.

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Kenneth A. Neal

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List of Acronyms

ADES	Personnel Assignment Decision-Support System
AEF	Air Expeditionary Force
AETF	Air Expeditionary Task Force
ARHRL	Air Force Human Resources Laboratory
AFI	Air Force Instruction
AFMC	Air Force Material Command
AFSC	Air Force Specialty Code
BOPAP	Bi-Objective Personnel Assignment Problem
CCDR	Combatant Commander
CGO	Company Grade Officer
COMAFFOR	Commander Air Force Forces
CPI	Continuous Process Improvement
DAV	Deployment Availability
DRRS	Defense Readiness Reporting System
DSS	Decision-Support System
FAM	Functional Area Manager
GA	Genetic Algorithm
GFM	Global Force Manager
GFMAP	Global Force Management Allocation Plan
GO	General Officer
HAF	Headquarter Air Force
JFC	Joint Forces Commander

JOPES	Joint Operations Planning and Execution System
JPEC	Joint Planning and Execution Community
LEED	Leadership in Energy and Environmental Design
LSS	Lean Six Sigma
MAJCOM	Major Command
MIS	Management Information System
NDS	National Defense Strategy
NIMP	National Intern Matching Program
OPLAN	Operation Plan
PE	Professional Engineer
PII	Personally Identifiable Information
PMP	Project Management Professional
PSORK	Particle Swarm Optimization with Random Key
SIPRNET	Secret Internet Protocol Router Network
SME	Subject Matter Expert
SPEA	Strength Pareto Evolutionary Algorithm
SQL	Structured Query Language
TPFDD	Time Phased Force Deployment Data
TS	Tabu Search
UJTL	Universal Joint Task Listing
UMD	Unit Manning Document
VEGA	Vector Evaluated Genetic Algorithm
WPES	War Planning and Execution Systems

A DECISION-SUPPORT SYSTEM FOR THE DEPLOYMENT TASKING PROCESS OF U.S. AIR FORCE CIVIL ENGINEER OFFICERS

I. Introduction

Background

The Armed Forces frequently deploy their personnel to expeditionary locations around the world. For example, the United States Air Force tasks its personnel to deploy based on a six-month rotational Air Expeditionary Force (AEF) cycle (Smith, 2019). Because of the high personnel turnover at deployed locations, expeditionary assignment matching is an intricate and laborious process. Arguably, expeditionary assignment matching is more demanding than home-station assignment matching as personnel typically rotate every six months versus every two to four years. Additionally, factors such as injuries or pregnancies limit an individual's availability in the deployment tasking process.

The deployment tasking process includes three key groups—the personnel to be tasked to deploy, the expeditionary positions to be filled, and the commanders and detailers responsible for selecting and matching the personnel to expeditionary positions. The current deployment tasking process matches personnel to expeditionary positions based on their rank and Air Force Specialty Code (AFSC) (Parker, 2012). Although home-station squadron commanders may consider factors such as an individual’s skill level, time on station, and deployment tempo band, they are applied neither deliberately nor systematically (Parker, 2012). Except for a squadron commander’s judgment, only minimum requirements criteria are considered in selecting personnel for deployment

taskings (Parker, 2012). Parker (2012) asserted that in some ways, "the current process is more akin to rolling dice than following a deliberate procedure" (p. 68).

In response to the aforementioned problem, this thesis investigates a prototype decision-support system (DSS) for the deployment tasking process of Air Force civil engineer officers. First, this research extends beyond minimum requirements selection criteria to optimize an officer's professional qualifications and personal preference considerations. Furthermore, this research considers an officer's home-station manning constraints. The extensions are then combined with a Management Information System (MIS) to form a prototype DSS capable of matching civil engineer officers to deployment taskings while optimizing an individual's professional qualifications and personal preferences in addition to considering the officer's home-station manning. Finally, this research uses ten years of civil engineer officer deployment data from Dyess Air Force Base to explore the feasibility and challenges of utilizing the prototype DSS on the current process.

Problem Statement

There is evidence to support the claim that the current deployment tasking process of Air Force civil engineers is not optimal. First, there is a consensus among civil engineer subject matter experts (SME) that the current process is not ideal. The civil engineer Global Force Managers (GFM) and the late Dean of the Air Force Civil Engineer School have vocalized frustrations with the process (Ohlemacher & Mackenstadt, 2020). Additionally, recent data from the Air Force Personnel Center (AFPC) demonstrates that an attempt to automate the deployment tasking process of civil engineers is not optimal as their fiscal year 2021 civil engineer deployment tasking cycle

left approximately 800 taskings unfilled (Ohlemacher & Mackenstadt, 2020). As a result, civil engineer GFMs had to source the taskings individually, which took six months to complete (Ohlemacher & Mackenstadt, 2020). Furthermore, civil engineer SMEs agree that sourcing conferences, a manual process conducted in the past with all Major Command (MAJCOM) civil engineer GFMs in one room, was more effective than the current fragmented process (Ohlemacher & Mackenstadt, 2020). Finally, published literature in *Air and Space Power Journal* asserts that the current approach is not optimal. In his 2012 publication, titled "Support the Combatant Commander, Develop the Force, or Roll the Dice," Kevin Parker outlined three possible courses of action for improving the current deployment tasking process beyond minimum requirements selection criteria:

1. Support the combatant commander by selecting the most qualified personnel for the expeditionary positions.
2. Develop the force by selecting the personnel that would grow the most from the experience of the expeditionary positions.
3. Roll the dice by focusing on neither approach and maintain the status quo by continuing to select personnel for expeditionary positions based on minimum requirements criteria.

The first component of this research focuses on proposing a solution to the first course of action as presented by Parker (2012), supporting the combatant commander by selecting the most qualified personnel for the expeditionary positions.

Additionally, evidence supports the claim that U.S. Air Force civil engineer officer retention is negatively related to the number of deployments. Riddel (2010) and Connell (2012) surveyed civil engineer officers and found evidence contrary to their

theses' hypotheses that civil engineer officer retention is positively related to the number of deployments. As a result of previous deployment studies on civil engineer officers, the second component of this research considers personal preference considerations such as the amount of time since an individual added a dependent and the amount of time since an individual's last deployment.

Motivation

An article in *The Atlantic* titled "Why Our Best Officers Are Leaving" stated that "a criticism of military personnel systems is it treats each employee as an interchangeable commodity rather than a unique individual with skills that can be optimized" (Kane, 2014, p. 84). Additionally, a Rand Corporation study on *Air Force Personnel Research* found that "the 1991 disestablishment of the Air Force Human Resources Laboratory (AFHRL) has left a void in Air Force personnel research and development" (Sims et al., 2014, p. 19). Moreover, the Air Force Chief of Staff (CSAF), General Charles Brown, Jr., launched action orders titled *Accelerate Change or Lose*. The first tenant of his action orders charges the Air Force with a "people-first approach by identifying attributes of Airmen the Air Force needs and reviewing personnel and talent management systems to meet the identified needs" (*CSAF Releases Action Orders*). The quotations mentioned above articulate the motivation for this research best by revealing what military personnel systems do not do well and why personnel management research is needed. Additionally, the citations show the emphasis placed on personnel management by the current Air Force leadership and the need to develop systems capable of optimizing an individual's qualifications to meet the Air Force's needs.

Air Force civil engineer officers have a moderately high operations tempo, a 1:2 deploy-to-dwell ratio, and they possess unique, potentially underutilized individual qualifications, which make them good candidates for a case study in personnel management research (*AEF evolves*). To be an Air Force civil engineer officer, one must have an accredited engineering degree. However, the range of engineering degrees is substantial, which provides the potential to supply combatant commanders with diverse engineering skillsets tailored for their expeditionary engineering positions. In addition to diverse engineering backgrounds, civil engineer officers have a wide variety of professional qualifications such as Professional Engineer (PE) licenses, a Project Management Professional (PMP) license, a Leadership in Energy and Environmental Design (LEED) certification, and Lean Six Sigma (LSS) certifications.

Research Objectives

This research will attempt to develop a deliberate, systematic methodology for the current deployment tasking process of U.S. Air Force civil engineer officers by providing a prototype decision-support system capable of matching officers to expeditionary positions by maximizing an officer's professional qualifications while maximizing an officer's personal preference considerations to provide combatant commanders with the most qualified officers who ideally desire to be there. Additionally, this research will attempt to apply a realistic constraint variable by considering an officer's home-station officer manning percentage. Finally, this research will try to use real-world data to examine the feasibility and challenges of utilizing the prototype DSS developed in this research on the existing deployment tasking process. To help address the objectives

mentioned above, this research will also attempt to answer the following investigative questions:

1. Why is a decision-support system needed to assist assignment detailers and squadron commanders in matching personnel to deployment taskings?

2. In addition to individual qualifications, what other factors could be considered in a deployment tasking decision-support system?

3. Which personnel assignment models are suitable to optimize individual qualifications while also considering personal preference considerations?

4. What challenges and limitations are associated with implementing a new deployment tasking methodology on the current process?

Methodology

The primary research methodology follows the Personnel Assignment Decision-Support System (ADES) developed by Korkmaz et al. (2008). However, this research departs from their ADES by utilizing different qualifications and preference criteria and applying a different matching algorithm. Moreover, Korkmaz et al. (2008) did not configure or test their ADES in a military personnel assignment environment, nor did they specify how or what system they used for their Management Information System (MIS). The DSS configuration developed in this research is for a military personnel environment and presents a specific MIS.

Assumptions/Limitations

When military personnel are matched to expeditionary positions, it becomes classified information. Consequently, this research was primarily conducted using simulated data representing Air Force civil engineer officers to prevent any claims or misinterpretation of classified or personally identifiable information. Additionally, this research used U.S. geographic regions to mimic major commands (MAJCOM) and U.S. cities to represent home-station locations in the DSS validation process. Moreover, this research assumed that all of the simulated candidates to be matched to the expeditionary positions are civil engineer officers, eliminating the need for an AFSC specific sorting function. This study excluded general officers (GO) and colonels as it assumed the deployment taskings for the ranks of colonel and above would be managed on a case-by-case basis for the foreseeable future due to the low number of deployments for the civil engineer officers in those ranks. Furthermore, the MIS developed in this research includes effective and expiration dates for professional licenses, certifications, and training courses; however, they were assumed to be current during the matching procedure to eliminate the need for a date verification function.

A limitation of this study is that it only considers ordinary, rotational deployment taskings. In the real-world, special assignments exist, such as joint, special operations, and classified taskings. Another limitation of this study is that it does not consider input variables from the Defense Readiness Report System (DRRS) which is a Secret Internet Protocol Router Network (SIPRNET) web application for commanders to report the deployment readiness and availability of their personnel.

Implications

The implications of this deployment tasking DSS provides Air Force leaders with a prototype tool that can be used to extend beyond minimum requirements selection criteria when matching personnel to deployment taskings, specifically civil engineer officers in this research configuration. Additionally, the prototype DSS demonstrates the capability to score every civil engineer officer against each deployment tasking, which allows a decision-maker to quickly identify and notify backup candidates during the tasking process so that short-notice taskings could be reduced. Moreover, this prototype DSS's novelty provides Air Force leaders with the capability to quickly visualize the entire solution space via heatmaps to identify and assess training shortages, gaps, and overall health of the force, which the Air Force could use to deliberately and systematically tailor training programs. Finally, this research fosters an environment of Continuous Process Improvement (CPI) in Air Force academia for solving personnel assignment problems by including talent management considerations as charged by "Action order A: Airmen" in the CSAF's action orders *Accelerate Change or Lose*. A CPI culture on personnel management problems can have strategic, operational, and tactical level impacts. On a strategic level, allowing military personnel to input personal preference considerations regarding the deployment tasking process can increase trust and transparency on systems that affect their lives for six months or more, increasing retention. On an operational level, selecting the most qualified personnel to serve the combatant commanders on rotational deployments can improve the downrange commanders' capabilities. A DSS can provide some automation to the deployment tasking process on a tactical level, saving assignment detailers time, thus saving money.

Thesis Organization

This thesis presents an in-depth literature review, research methodology, analysis and results, and a conclusion in the chapters that follow. The literature review in Chapter 2 provides an evaluation of human decision-making, a thorough examination of the current deployment tasking process, an overview of the personnel assignment problem, a brief history of personnel management research in the U.S. Air Force, and an examination of personnel assignment models and decision-support systems. Chapter 3 presents the methodology for the prototype deployment tasking DSS, followed by the analysis and results in Chapter 4. The final chapter provides concluding comments, research contributions, recommendations for action, recommendations for future research, and a summary.

II. Literature Review

Chapter Overview

This chapter evaluates human decision-making and the current deployment tasking process to understand better how a DSS could support the current process. Additionally, this chapter provides a brief overview of the personnel assignment problem and personnel management research in the Air Force to understand the problem's historical context. Finally, this chapter presents an in-depth examination of personnel assignment models and decision-support systems to determine an appropriate DSS construct and an assignment matching algorithm for this research.

Human Decision-Making

Humans make an innumerable number of decisions every day. In general, humans perform well on object recognition, grammar acquisition, and speech comprehension and will outperform artificial, computer-based systems attempting to replicate those tasks (Cosmides & Tooby, 1994). However, despite the human brain's intricacies, cognitive limits exist, which cause boundaries to human decision-making due to information quantity (Miller, 1956) and time constraints (Hahn et al., 1992). The limitations caused by cognitive constraints demonstrate that human rationality is bounded (Simon, 1955). As a result of bounded rationality, humans must either guess or perform simplified approximations when they reach their cognitive limits (Simon, 1955).

Information Overload

Eppler and Mengis (2004) found that the quality of human decision-making is "positively correlated with the amount of information he or she receives" (p. 1119). However, a maximum amount of information is reached when the decision quality begins

to decrease in response to additional information (Robards, 2011). This maximum is described as the point of information overload and has been studied in detail by the consumer research industry (Robards, 2011). In consumer research, decision complexity is typically quantified by the "number of brand choices and the number of attributes describing each brand" (Robards, 2011, p. 16).

Jacoby et al. (1974) conducted a consumer study using laundry detergent, which provided evidence supporting their hypothesis that information overload affects decision-making. Their test subjects were given a survey at the beginning of the study to determine their individual needs regarding laundry detergent. Then, they gave their test subjects a list of detergent brand names to choose from based on varying amounts of information about each brand. Jacoby et al. (1974) determined the quality of their test subjects' decisions based on their ability to select the detergent brand that met their needs from the initial survey the test subjects completed. Jacoby et al. (1974) found a curvilinear relationship between the amount of information given to the test subjects and their ability to select a laundry detergent brand that best suited their needs. Their test subjects' decision quality was poor when the amount of detergent information was low and high; however, the decision quality was best when the amount of detergent information was intermediate.

Time Constraints

Hahn et al. (1992) built upon the research of Jacoby et al. (1974) by hypothesizing that time pressure played an important role in decision quality in addition to information overload. Hahn et al. (1992) also focused on exploring the interactions between information overload and time pressure on decision quality. To test their hypothesis,

Hahn et al. (1992) recruited students from two high schools and asked them to decide which colleges they would like to attend or which employers they would like to work for if they were not going to college. Then, they gave the students a three-part questionnaire. The first part asked the students to rate the importance of different potential colleges or employers' attributes on a nine-point scale (Hahn et al., 1992). The second part of the questionnaire presented the students with 10 alternatives, either colleges or employers, and they were asked to rank their top two choices (Hahn et al., 1992). Hahn et al. (1992) varied the number of college or employer attributes to research information overload at intervals of 3, 6, 12, or 20 attributes per alternative. Hahn et al. (1992) imposed time limits on the number of details the student was given per college or employer to induce time pressure. The time limits were 80, 140, 260, and 420 seconds for the 3, 6, 12, 20 attribute groups, respectively (Hahn et al., 1992). Hahn et al. (1992) gave their control group no time constraints. The third part of their questionnaire asked the students questions about their plans after graduation, the degree of time pressure they felt on a three-point scale and the degree of eagerness in reading the options on a three-point scale. Hahn et al. (1992) found that timed students' decision quality increased for 3 to 12 attributes. However, past 12 attributes, the students' decision quality decreased (Hahn et al., 1992). For the untimed students, decision quality did not decrease regardless of the number of attributes (Hahn et al., 1992). Hahn et al. (1992) found support for their hypothesis that information overload is dependent on the factor of time pressure. Additionally, without time pressure, they found that the students could use the 20 attributes without a decline in decision quality. Given an unlimited amount of time, 20 attributes for 10 alternatives were not enough to show the effects of information overload

in their experiment. Nonetheless, Hahn et al. (1992) introduced the concept that time constraints play a role in human decision-making in addition to the amount of information.

Assignment Decision Complexity

When assignment decisions are to be made, and there are multiple criteria to be considered for each assignment, the matching process quickly becomes complicated for assignment detailers (Robards, 2011). The magnitude of assignment decisions refers to the number of objects needing assignment, and the complexity refers to the number of criteria to be considered in making the assignment (Robards, 2011). Some examples of assignment decisions include projects to students (Harper et al., 2005), referees to games (Scarelli & Narula, 2002), court cases to judges (Yang & Dean, 1993), and personnel to positions (Toroslu, 2003; Toroslu & Arslanoglu, 2007; Korkmaz et al., 2008; Huang et al., 2009). Preferences may exist on one side of the assignment or both sides of the assignment, depending on the assignment type (Robards, 2011). For example, in assigning students to projects, the students may have preferences on the project they could get assigned, but the projects themselves do not have choices (Robards, 2011). However, in assigning personnel to positions, both the personnel and the position owner may have preferences, which adds multiple complexity levels to the assignment decisions (Robards, 2011).

Analysis of the Current Deployment Tasking Process

Deployment Planning and Rotational Construct

There are two deployment planning processes used by the joint planning and execution community (JPEC) (AFI 10-403). The first process is crisis action planning,

driven by current events during emergencies and time-sensitive situations and initiated by the Secretary of Defense (AFI 10-403). The second process is deliberate planning, which occurs in response to threats identified by combatant commanders and national guidance (AFI 10-403). Rotational AEF operations are based on a predetermined timeline following the Joint Global Force Management (GFM) schedule (AFI 10-403). Moreover, the Air Force outlines its deployment planning process in Air Force Instruction (AFI) 10-403. The AEF rotational construct is the Air Force's methodology for meeting the combatant commander's existing and emerging requirements.

Global Force Management

Global Force Management (GFM) ensures that force assignments, apportionment, and allocation methods are aligned with the National Defense Strategy (NDS) (AFI 10-401). For rotational force requirements, combatant commanders (CCDR) submit their requirements through a multi-step process ending with a Secretary of Defense approved Global Force Management Allocation Plan (GFMAP) (AFI 10-401). The GFMAP officially allocates rotational forces to the combatant commanders (AFI 10-401). However, the GFMAP may be adjusted or suspended by the Secretary of Defense in the event of an emerging crisis (AFI 10-401).

AEF Schedule

AFI 10-401 outlines the AEF rotational construct, which consists of two six-month cycles that align with GFM cycles. The first six-month cycle coincides with the beginning of the fiscal year in October and goes through April (*AEF evolves*). The second six-month cycle begins in April and goes to October (*AEF evolves*). Before each new AEF cycle, functional area managers (FAM) revalidate deployment tempo bands with

their respective areas and realign forces as needed (AFI 10-401). The Air Force's goal for FAMs is to align to the least exhausted deployment tempo band to minimize the risk of burnout to the force (AFI 10-401). Each year, the FAMs establish a new 24-month AEF schedule (AFI 10-401). The AEF schedule encompasses time for home-station training, deployment preparation, and a deployment vulnerability window (AFI 10-401). Only one block of people from each deployment tempo band is vulnerable at a given time (AFI 10-401).

Air Force War Planning and Execution Systems (WPES)

AFI 10-401 outlines the Air Force's War Planning and Execution Systems (WPES), shown in Figure 1. The Air Force Personnel Center (AFPC) provides oversight on Time Phased Force Deployment Data (TPFDD) sourced using the Air Expeditionary Force (AEF) scheduled assets (AFI 10-401). TPFDD is a U.S. Department of Defense (DoD) term for the database portion of an Operations Plan (OPLAN) in the Joint Operations and Planning and Execution System (JOPES) (AFI 10-401). The two types of TPFDDs are requirements-driven TPFDDs and capabilities-driven TPFDDs (AFI 10-401). A requirement driven TPFDD is associated with a written Operation Plan (OPLAN) (AFI 10-401). A capability driven TPFDD, on the other hand, is used for organizing, training, equipping, and sustaining air and space forces to meet defense strategy requirements (AFI 10-401). A TPFDD contains the time phasing of forces by dates to specific destinations called routing data (AFI 10-401). JOPES is a next-generation database application used as a part of the Global Command and Control System (GCCS), shown in Figure 1 (AFI 10-401).

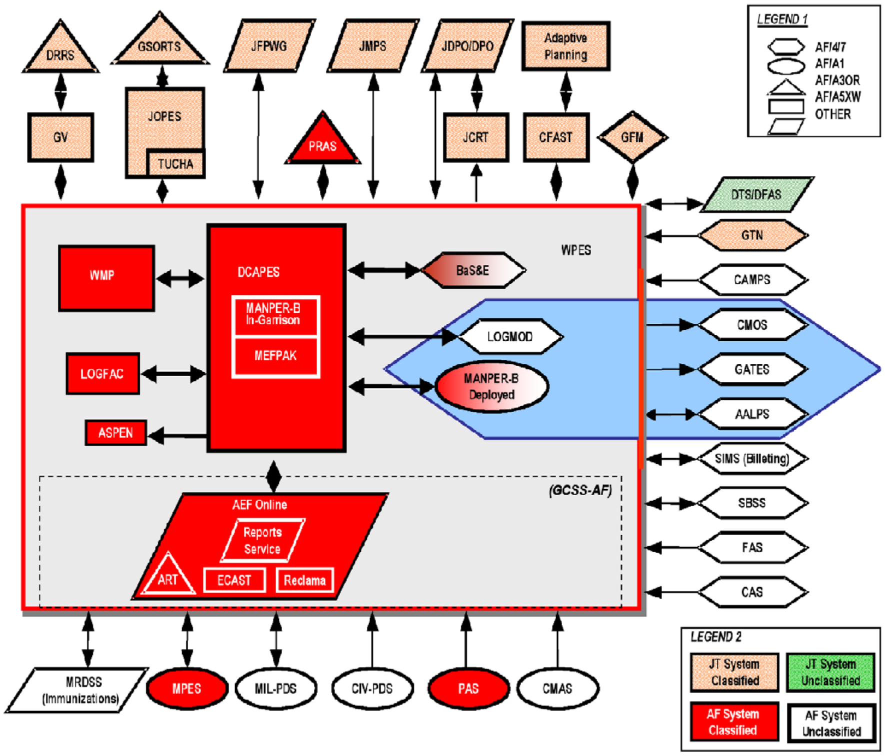

Figure 1. War Planning & Execution Systems Adapted from (AFI-401)

Deviations, Waivers, Reclamas, and DAV Codes

The Air Force's rotational AEF construct is structured around Airmen, deploying for a baseline of 179 days (AFI 10-401). Headquarters Air Force (HAF) A3 and A5 must approve and review all deviations to this construct (AFI 10-401). The supporting organization must submit the deviation request through their MAJCOM (AFI 10-401). Functional areas must request a two-hit waiver if anticipated requirements cannot be met within the two, 6-month AEF cycle construct (AFI 10-401). A reclama is a process to request duly constituted authority to reconsider its decision or its proposed action (AFI 10-401). Furthermore, deployment availability (DAV) codes exist to identify an

individual’s current medical, legal, and administrative status for deployment eligibility. An example of a DAV Code is shown in Table 1 below.

Table 1. Example DAV Code Adapted from (*DAV Code Table*)

Code	**Description**	**Applies To:**	**Update Method**	**Corresponding AAC/ALC**	**Source Doc**	**Availability Determination**	**Governing Guidance**
28	Unable to hand-carry or possess firearms/ammunition	Total Force	Auto	None/ T (Firearms/Ammunition Disqualification)	N/A - DAV is updated by ALC "T" update	Available except for deployments to locations that require weapons/ammunition possession or qualification unless DAV "28" expires before the first movement of the deployment	AFI 31-207

Line Remarks

Deployment taskings use line remarks as the methodology for identifying the combatant commander's requirements to ensure personnel tasked to deploy meet their requirements before arriving downrange (AFI 10-403). Additionally, the line remarks may include information such as recommended equipment (AFI 10-403). Some examples of line remarks for civil engineer deployment taskings are shown in Table 2.

Table 2. Example Line Remarks Adapted from (*Line Remark Lookup Tool*)

Line Remarks	Description	Last Updated
AW	SUB ANY CIVIL ENGINEER OFFICER AFSC	10/15/2004
CDW	REQUIRES ENGINEERING AND INSTALLATION (E-I) EXPERIENCE OF AT LEAST ONE YEAR. SUBSTITUTION PERMITTED OF FULLY QUALIFIED E-I MEMBERS OF ANY AFSC INCLUDED IN THE E-I SERIES OF UTCS (6KQXX) OR ASSIGNED TO AN ENGINEERING INSTALLATION SQUADRON PROVIDED THE MEMBER IS MISCAP-QUALIFIED AND THE TASKED COMMANDER AND THE AFFOR/A67 DEEMS THE SUBSTITUTION WILL NOT DEGRADE THE TEAM'S MISSION CAPABILITY. MEMBERS WILL BE ISSUED THE FOLLOWING EQUIPMENT (WITHOUT DUPLICATION OF PREVIOUSLY ISSUED ITEMS STILL WITHIN WEAR/USAGE GUIDELINES OR IF MANDATED BY ANOTHER LIST FOR DEPLOYMENT): - 2 Pairs of steel/composite toe Safety Boots - 1 ea., ANSI Z87+ Eye Protection (Wiley-X or similar with clear/smoked lenses) - 1 pair each, Mechanix style Protective/Work Gloves (Substitutes authorized if they provide manual dexterity) - 1 ea., Ballistic Hearing Protection (i.e., Ear Defenders) - 2 ea., Neck Gaiter or Sand Scarf (OCP or Tan) - 1 ea. Balaclava - 1 ea., Eye Protection Wiley-X Goggles - 2 Thermal (Top/Bottom) (Tan) and/or OCP Gore-Tex (if deployed between 1 October - 31 March) - 3 ea., Combat Shirts (ACS shirts) - 2 ea., Rolling Duffle Bag(s) - non-military print (North Face Rolling Thunder 30" or similar) - Small personal flashlight (Sure-Fire or similar type) - 1 ea., Multi-tool (Gerber or similar type) - 1 ea., Head Lamp with Red Lenses - 1 Camelback hydration system	06/18/2020
CES	MUST COMPLETE SECURITY ENGINEERING COURSE SPONSORED BY THE US ARMY CORPS OF ENGINEERS/PROTECTIVE DESIGN CENTER. COURSE INFORMATION AND POC LISTS CAN BE FOUND AT https://pdc.usace.army.mil/training/secengg.	07/23/2015
CKC	REQUIRES CIVIL ENGINEERING PROJECT PROGRAMMING EXPERIENCE OR GRADUATE OF AFIT MGT 423.	09/12/2006
FAO	MEMBER IS REQUIRED TO ATTEND THE 3 DAY AFIT COURSE WMGT 401 (EXPEDITIONARY ENGINEERING) AT WRIGHT PATTERSON AFB PRIOR TO DEPLOYMENT. MEMBER MUST REGISTER FOR THE CLASS ON THE AFIT WEBSITE (NIPR) AT http:\\www.afit.edu\cess\Course_Desc.cfm?p=WGMT%20401 OR CONTACT AFIT COURSE DIRECTOR AT DSN: 785-5654 EXT 3538. RENTAL CAR AUTHORIZED. INDIVIDUALS DEPLOYING AS THE BASE CIVIL ENGINEER OR AS THE DEPUTY BASE CIVIL ENGINEER HAVE THE OPTION TO ATTEND THE COURSE. TDY IS UNIT FUNDED. "ZA" ESP CODE AUTHORIZED.	02/06/2012

Current Deployment Tasking Process Flow

In the current deployment tasking process, the deployment tasking makes its way down from the combatant commanders to an individual's squadron commander through the chain of command structure shown in Figure 2 (Rueda, 2008). Then, the squadron commander has a few days to select an individual to fill the deployment tasking (Parker, 2012). The squadron commander's only information about the tasking is the location, in-place date, duration, required AFSC, required rank, and line remarks (Parker, 2012). If only one Airman is available and meets the tasking's minimum requirements, the choice is easy (Parker, 2012). However, if more than one Airman meets the deployment tasking's minimum requirements, the squadron commander must select an individual based on their judgment (Parker, 2012). The squadron commander might consider an individual's dwell time, home-station position, upcoming or recent significant life events such as a wedding, birth of a child, or professional military and civilian education timelines (Parker, 2012). However, because the Air Force gives squadron commanders little time and information to make selections for a deployment taskings, minimum requirements selection criteria often become the driving force in the selection process (Parker, 2012). Additionally, the decision is made in isolation from other decisions as deployment taskings filter down from the MAJCOM intermittently throughout the deployment planning cycle (Parker, 2012). Because squadron commanders make deployment tasking selections in isolation from other taskings and the search space is restricted to one unit, there is no opportunity to optimize the system (Parker, 2012).

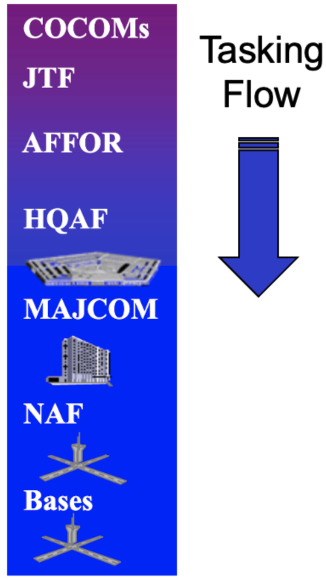

Figure 2. Deployment Tasking Process Flow (Rueda, 2008)

Civil Engineer Doctrine

The Air Force civil engineer organization is a total force that includes regular Air Force, Air Force Reserve, Air National Guard, and civilians (Annex 3-34). Unlike the Army and the Navy, Air Force Doctrine Annex 3-34, Engineer Operations, requires active-duty civil engineers to support home-station and expeditionary engineer requirements. During deployments, civil engineer forces are part of an Air Expeditionary Task Force (AETF), commanded by a commander, Air Force forces (COMAFFOR), and follow command relationships affecting all Air Force forces (Annex 3-34). Civil engineer units performing regional operations are generally attached to an AETF and report directly to the COMAFFOR (Annex 3-34). However, Air Force civil engineers may be placed under the tactical control of a joint force engineer command structure if established by the Joint Forces Commander (JFC) (Annex 3-34).

Deployment Process Challenges for Civil Engineers

In addition to the challenges faced by FAMs in filling rotational AEF civil engineer requirements, the Air Force civil engineer organization at large is not represented in the Joint Force Sufficiency Analysis (Hurst, 2020). Air Force civil engineers' capabilities are not visible to the combatant commanders in the Universal Joint Task Listing (UJTL) (Hurst, 2020). Furthermore, the AEF rotational tasking structure was designed around "iron" forces, meaning that units deploy as a package (Hurst, 2020). These packages include the Army's Brigade Combat Teams, the Navy's Carrier Strike Groups, the Marine Expeditionary Forces, and the Air Force's Air Expeditionary Wings (Hurst, 2020). However, the AEF rotational tasking structure was not designed for combat support functions like civil engineers as they do not deploy as force packages (Hurst, 2020). As a result, combat support functions are disconnected from the "iron" packages and have differing deploy-to-dwell rates than operational functions (Hurst, 2020). This disconnect leads to decreased personnel availability as the AEF rotational tasking process attempts to fill the combatant commanders' combat support requirements (Hurst, 2020).

Consequently, the current AEF rotational deployment tasking process models are not the most effective means to provide combat support functions to the combatant commander to meet evolving mission requirements (Hurst, 2020). Based on data from the Air Force civil engineer organization, constraints to the current deployment tasking process or any new model proposed can be summarized in the following points (Hurst, 2020):

1. Civil engineers will always be in high demand.
2. The availability of engineers will be based on the squadron's Unit Manning Document (UMD) authorizations.
3. Squadron manning will most often be less than 100%.
4. The available capacity will be affected by multiple factors, such as deployment availability (DAV) codes, posture coding, and manning vacancies.

Deployments and Civil Engineer Officer Turnover Intentions

Riddel (2010) investigated potential factors that influence the turnover intentions of Air Force civil engineer company-grade officers (CGO). One of the elements he examined was the relationship between deployments and civil engineer officers' turnover intentions. During his initial interviews, Riddel (2010) found that perceptions of the deployed jobs of Air Force civil engineer CGOs were considerably higher than those of home-station positions. Riddel (2010) found that the officers' operations tempo was negatively related to their turnover intentions. Thus, the higher the number of deployments the civil engineer CGOs had, the less likely they were to separate from the Air Force. This statistical relationship was the opposite of Riddel's (2010) hypothesis; however, for many of the officers surveyed, deployments were opportunities to do more exciting and meaningful work than their in-garrison jobs. Moreover, Riddel (2010) found a positive relationship between job satisfaction with operations tempo and job satisfaction with the number of deployments. Thus, the higher the operations tempo and the greater the number of deployments the officer had completed, the higher the likelihood that the officer's job satisfaction would be high. The survey results by Riddel (2010) reinforced

his interview findings that Air Force civil engineer CGOs preferred their deployed job over their in-garrison job and that deployments were beneficial to their intentions to remain in the Air Force.

Connell (2012) reexamined factors that influence turnover intentions of Air Force civil engineer CGOs using a different model than Riddel (2010). The purpose of the research by Connell (2012) was to determine if turnover intentions differed among subgroups within the population of Air Force Civil Engineer CGOs. Connell (2012) divided Air Force Civil Engineer CGOs into subgroups based on gender, age, number of deployments, marital status, and Professional Engineer (PE) licensure. Connell (2012) found a significant difference between single civil engineer CGOs and married civil engineer CGOs. Additionally, Connell (2012) found that the turnover intentions of civil engineer CGOs under the age of 30 significantly differed from those who were 30 years of age or older. The other groups Connell (2012) tested showed no significant differences in turnover intentions. The research conducted by Connell (2012) added to Riddel's (2010) analysis by determining that marital status and age are significant factors in determining the turnover intentions of Air Force civil engineer CGOs.

The Personnel Assignment Problem

Since 1965, research professionals have studied the optimal allocation of resources (Niknafs et al., 2013). A recurring resource problem in many organizations is the efficient distribution and utilization of personnel (Trippi et al., 1974). In the military, personnel assignment problems are especially challenging due to the “magnitude and frequency of personnel turnover” (Trippi et al., 1974, p. 111). Niknafs et al. (2013) first identified a military personnel assignment problem in a publication by Trippi et al.

(1974). Trippi et al. (1974) studied a personnel assignment problem in the U.S. Navy by examining the feasibility of using a computer-based system to match enlisted members to assignments. They used a network flow model based on the assignment's transportation cost, the assignment's required skill set, and the members' skills and preferences. Klingman and Philips (1984) examined a network flow model to match U.S. Marine Corps enlisted members to assignments based on the priority of the position, the cost of assigning the member to the position, the utility of position, and the desirability of the position to the member. Liang and Thompson (1987) used a network flow model to assign U.S. Navy enlisted members to assignments while "minimizing moving costs, maximizing individual preferences, balancing manning between the Pacific and Atlantic fleets, and minimizing the gap between an individual's available date and a job's vacancy date" (p. 247). B.R. Feiring (1993) analyzed the personnel assignment problem in a military context by describing the challenge of "determining a number that measures the 'fit' of an individual in a position" of U.S. Air Force enlisted personnel (p. 503).

In the mid-1990s, personnel assignment methodologies began evolving from network flow models to tabu search (Laguna et al., 1995), genetic algorithms (GA) (Herrera et al., 1999; Toroslu & Arslanoglu, 2007), particle swarm optimization (Lin et al., 2010; Lin et al., 2012), fuzzy goal programming (Shahnazari-Shahrezaei et al., 2013), and machine learning (Chishimba & Kunda, 2018). However, despite the numerous personnel assignment methodologies, Gates and Nissen (2002) found that large government organizations such as the military still heavily rely on assignment detailers to match personnel to assignments. Gates and Nissen (2002) revealed that "hierarchical job assignments rely upon the cognitive process of centralized, administrative professionals

to match individual capabilities and job requirements and to reflect both the job's relative priority and the individual's job preferences" (p. 5).

Additionally, the literature described personnel assignment problems within the broader context of two-sided matching problems where the objects to be matched belong to two distinct groups. The two-side matching problem was found dating back to 1962. Gale and Shapley (1962) examined matching college applicants to the admissions offices' quotas while considering the applicants' ranked order of college preferences. However, in practice, the documented use of the two-sided matching problem has been used since 1951 by the National Intern Matching Program (NIMP), which matches medical students to residency programs (Robards, 2011). In a military context, two-sided personnel assignment matching studies are limited. Robards (2001 & 2011) examined applying a two-sided matching process to match U.S. Navy enlisted personnel to assignments. Korkmaz et al. (2008) studied analytical hierarchy process (AHP) and two-sided matching to assist personnel assignment detailers. They developed a personnel assignment decision-support system (ADES) to match personnel to positions based on an individual's competencies and personal preferences. Additionally, Korkmaz et al. (2008) noted that although they designed their ADES for use in the military, they did not configure or test it in a military environment.

Despite numerous studies, the main characteristics of personnel assignment and two-sided matching problems remain the same throughout literature and can be summarized in the following four points (Herrera et al., 1999):

1. The objects under consideration are finite, such as teams, jobs, or employees;
2. The objects must be assigned-selected on a one-to-one basis to other objects;

3. The results of each assignment-selection can be expressed in terms of payoffs, such as the cost of profits; and
4. The objective is to assign-select objects so that the total cost is minimized or the total profit is maximized.

Personnel Management Research in the Air Force

The U.S. Air Force's interest in personnel management research grew from its success of the aviation psychology program that identified potential Airmen after World War II (Sims et al., 2014). Several organizations conducted personnel management research in the Air Force from 1949, focusing on training, selection, classification, and manpower planning (Sims et al., 2014). In 1968, the Air Force Human Resources Laboratory (AFHRL) was established as an Air Force Systems Command Laboratory in response to the Air Force's Scientific Advisory Board's recommendation (Sims et al., 2014). AFHRL was headquartered at Brooks Air Force, Texas, and served as a central organization for manpower, personnel, and training research and development (Sims et al., 2014). By 1972, AFHRL comprised 365 people, 13 percent holding PhDs and 27 percent having master's degrees, and an annual budget of approximately $12 million (Sims et al., 2014).

In 1983, AFHRL was assigned to the Aerospace Medical Division then was combined into the Armstrong Laboratory in 1991 (Sims et al., 2014). In 1997, four other Air Force laboratories were combined with Armstrong Laboratory and the Air Force Office of Scientific Research to form the Air Force Research Lab (AFRL) (Sims et al., 2014). In 1998, AFRL halted funding for manpower and personnel research conducted by its Human Effectiveness Directorate (Sims et al., 2014). Still, it continued funding for

personnel research databases and proposed funding contractor positions to fill in the gap of expertise in personnel management research (Sims et al., 2014). However, the contractor positions were reassigned to meet other AFRL priorities, leaving its personnel research databases unmaintained (Sims et al., 2014).

The Rand Corporation study, *Air Force Personnel Research,* found that since the 1991 disestablishment of AFHRL, "the Air Force has not had another organization solely dedicated to personnel management research and as a result, advanced personnel management practices have not been a priority for many years" (Sims et al., 2014, pp. 18-19). Additionally, the study concluded that a consequence of the absence of an organization focused on personnel management research is that there is no organization to serve as a central resource for personnel research consumers. Furthermore, the study noted a second-order consequence of having a lack of in-house personnel management research expertise and data sharing is "attributable to the loss of coherent organization memory, dispersion of endeavor, and the overall deprioritization of the human resource mission" (Sims et al., 2014, p. 19).

Personnel Assignment Models

Network Flow Models

As learned earlier in the chapter, the first published models for solving personnel assignment problems were primarily network flow models. When analyzed using a network flow model, the personnel assignment problem becomes a special case transportation problem with a bipartite structure where each node's supply or demand is one (Bisschop, 2006). A schematic diagram consisting of nodes is developed using lines or arrows to form the network (Bisschop, 2006). The lines with arrows represent the flow

and are called arcs (Bisschop, 2006). When an arrow represents the network model's flow, the flow is considered restricted, called a directed network model (Bisschop, 2006). In a personnel assignment problem context, the first set of nodes in the network model represent the personnel candidates to be assigned (Klingman & Phillips, 1984). The second set of nodes represents the positions to be filled (Klingman & Phillips, 1984). If a person is eligible for a position, an arc is drawn connecting the two nodes (Liang & Thompson, 1987). A coefficient is then assigned to each arc, which denotes the assignment's associated benefit or cost (Liang & Thompson, 1987). Network flow models are essentially linear programming models and can be solved as a linear programming problem; however, in practice, network flow models can be solved quicker by unique network algorithms (Bisschop, 2006). The advantages of network flow models are high computational efficiency and reduced data preparation, whereas a disadvantage is poor fidelity (Krishnan et al., 2015).

Tabu Search Models

Tabu Search (TS) is a metaheuristic method based on heuristic search processes that create lists of solutions in the search space (Zhou et al., 2013). The TS algorithm searches a potential solution's neighbors to find an improved solution (Hasan et al., 2020). Suppose a solution visited within the algorithm's short-term memory violates a predefined rule (Zhou et al., 2013). In that case, the solution is marked as "tabu" so that there is no chance the solution will be repeated in the search process (Zhou et al., 2013). Laguna et al. (1995) used neighborhoods defined by ejection chains in their TS model for the personnel assignment problem, which "consists of multiple dynamic tabu lists and a strategic oscillation element that allows searching paths to cross the capacity-feasibility

boundary" (p. 179). If a solution is considered infeasible, the best neighbor is chosen, which is the one that reduces the infeasibility the most (Laguna et al., 1995). The TS model's value is that its short-term memory may find solutions superior to conventional, unassisted search methods; however, it does not have long-term memory structures required to solve highly complex problems (Malek et al., 1989). Because of its lack of long-term memory structures, TS models are often paired with other methods such as ant colony optimization, genetic algorithms, and simulated annealing (Laguna et al., 1995).

Genetic Algorithms

Genetic algorithms (GA) were developed in 1975 by J.H. Holland (Kaur & Chhabra, 2017). Genetic algorithms successfully solve multi-objective optimization problems by taking a complex problem and representing it in a simple vector, called a chromosome (Kaur & Chhabra, 2017). The chromosome represents one possible solution to the problem (Kaur & Chhabra, 2017). The closer the chromosome gets to the optimal solution, the better the quality of the chromosome (Kaur & Chhabra, 2017). The basic code structure of a GA is as follows (Toroslu & Arslanoglu, 2007):

```
Generate an initial population of chromosomes
WHILE stopping condition has not been reached DO
BEGIN
    Select chromosomes by using a selection technique
    Apply crossover with crossover probability and create offspring
    chromosomes
    Mutate chromosome with mutation probability
    Go to the next generation with the new population
```

END

It is crucial to preserve the chromosomes' diversity as a simple mutation, or unfit chromosome may produce a very fit chromosome in the next generation (Toroslu & Arslanoglu, 2007). The most commonly used selection techniques are roulette wheel, tournament, rank selection, and elitism (Toroslu & Arslanoglu, 2007).

Single objective optimization problems are much easier to solve than multi-objective ones (Toroslu & Arslanoglu, 2007). Consequently, three fitness-assignment methods have been developed to simplify multi-objective GAs (Toroslu & Arslanoglu, 2007). The first fitness-assignment method is aggregation, which combines all objectives into a scalar value (Toroslu & Arslanoglu, 2007). The most commonly used aggregation method is the weighted sum (Toroslu & Arslanoglu, 2007). Weighted sum aggregation normalizes the fitness function's coefficients to reduce bias towards a specific objective (Toroslu & Arslanoglu, 2007). The second fitness-assignment method is population-based non-Pareto, which treats objectives independently versus combining them into a scalar value (Toroslu & Arslanoglu, 2007). The most commonly used population-based non-Pareto method is Vector Evaluated Genetic Algorithm (VEGA) (Toroslu & Arslanoglu, 2007). VEGA combines equal size sets of chromosomes in the mating pool according to one objective in the problem (Toroslu & Arslanoglu, 2007). Then, VEGA conducts crossover and mutation operations in traditional GAs (Toroslu & Arslanoglu, 2007). The third fitness-assignment method is Pareto based techniques, which treat each objective of the problem as a vector where the vectors' dimension corresponds to the objectives (Toroslu & Arslanoglu, 2007). Instead of producing a single optimal solution, Pareto-based techniques generate multiple sets of solutions to the problem (Toroslu &

Arslanoglu, 2007). The most commonly used Pareto-based method is the Strength Pareto Evolutionary Algorithm (SPEA) (Toroslu & Arslanoglu, 2007). SPEA maintains two separate populations through multiple generations (Toroslu & Arslanoglu, 2007). One population contains dominated solutions, and the other includes the non-dominated solutions (Toroslu & Arslanoglu, 2007). A clustering technique is then used to prune the non-dominated population within boundaries before genetic operations are applied (Toroslu & Arslanoglu, 2007).

Herrera et al. (1999) proposed using genetic algorithms to solve assignment-selection problems with a fitness function that evaluates verbal information quantified by linguistic variables. In assignment-selection problems, the input variables used in the decision-making processes may be hard to quantify, such as “opinions, thinking, beliefs, notions, feelings, etc.” (Herrera et al., 1999, p. 327). Herrera et al. (1999) developed fuzzy sets theory to handle the inherent uncertainty in the decision-making processes of assignment-selection problems (Herrera et al., 1999). Herrera et al. (1999) recommended that the first step determine which positions a company wants to recruit and which positions they can fill with existing employees. Then, they suggested that managers prioritize the job vacancies using a linguistic label of importance with nine categories from essential to unnecessary. Furthermore, Herrera et al. (1999) recommended that links be made between the positions since they are not independent of one another. The goal of the fuzzy set’s optimization model is to maximize candidate levels in the skills needed for the vacant positions and maximize the relationships among candidates for linked positions (Herrera et al., 1999).

Although GAs provide a potential method for personnel assignment selection models, they do not guarantee a global optimum solution to a problem; however, they are good at “finding acceptably good solutions to problems quickly” (Herrera et al., 1991, p. 331). Moreover, GAs are well suited to solve problems where the decision space is “discontinuous and poorly understood” (Herrera et al., 1991, p. 331). Conversely, personnel assignment problems may often be well defined and well understood (Robards, 2011).

Two-Sided Matching

Literature alternatively described personnel assignment problems within the larger context of two-sided matching models. Two-sided matching models match objects belonging to one group to objects in another group (Robards, 2011). Two-sided matching can be categorized into one-to-one matching problems and many-to-one matching problems (Robards, 2011). In the context of the personnel assignment problem, a one-to-one matching relationship indicates that one assignment is to be matched with one person. Moreover, a many-to-one matching relationship means that many assignments are to be matched with one person. Except for the marriage market, two-sided matching problems are generally many-to-one as most organizations have many job assignments and typically assign employees to only one position at a given time (Robards, 2011). The desired outcome of a two-siding matching model is measured in terms of stability (Robards, 2011). A stable matching outcome occurs if the two-siding matching algorithm does not force an object into an unacceptable assignment (Robards, 2011). Conversely, an unstable matching result occurs when the two-sided matching algorithm forces one or more objects into an unacceptable assignment (Robards, 2011). If an object in one group

wants to match to an object in another group and they are both assigned to other, non-preferred partners, they are called blocking pairs because they want to be matched but did not match (Robards, 2011). In this scenario, the blocking pair could withdraw from the matching process and organize a match external to the model; however, by definition, a stable two-sided matching outcome is one that has no blocking pairs (Robards, 2011).

A deferred-acceptance algorithm has been proven to produce stable matches in a two-sided matching model for both one-to-one and many-to-one matching problems (Robards, 2011). However, the deferred-acceptance algorithm does not handle complexities such as couples seeking assignments close to each other and medical residency programs seeking to have an even number of positions filled (Robards, 2011). In response to these complexities, the instability-chaining algorithm was developed to consider an entire set of assignments while introducing one object at a time and resolving any instability before introducing another object into the algorithm (Robards, 2011). One advantage of using two-siding matching algorithms is that they "consider the preferences on both sides of the market" (Robards, 2011, p. 8). Additionally, two-sided matching algorithms "provide alternative results when preference list ties are broken," thus, "enabling alternative outcomes to be explored by the decision-maker" (Robards, 2011, p. 8). One disadvantage of two-sided matching algorithms is that all participants may not be matched without complete preference lists. Furthermore, "there is no mechanism to ensure high priority positions are filled" (Robards, 2011, p. 8).

Particle Swarm Optimization

Lin et al. (2012) suggested the use of a particle swarm optimization (PSO) algorithm combined with a random-key encoding scheme (named PSORK) to solve bi-

objective personnel assignment-selection (BOPAP) problems. A BOPAP is used to match potential candidates' abilities to the requirements of available positions (Lin et al., 2012). The smaller the difference in the employees' ability levels, the better their overall performance (Lin et al., 2012). The goal of a BOPAP is to maximize the employees' ability scores while minimizing the differences between the scores (Lin et al., 2012). However, a BOPAP requires that the number of candidates exceeds the available positions (Lin et al., 2012).

In particle swarm optimization, every particle can move its location in the search space, like a bird flying in the sky (Lin et al., 2012). Each particle remembers its best location from experience (Lin et al., 2012). When a particle moves, it retains its best location and all the other particles' best location in the swarm (Lin et al., 2012). Weights can be applied to the swarm to increase or decrease a particle's one-step movement distance (Lin et al., 2012). Confidence coefficients are applied to the swarm based on how much a particle believes in its experience (Lin et al., 2012). Additionally, confidence coefficients are applied to the swarm based on the particle's belief in its neighbor's experience (Lin et al., 2012).

Lin et al. (2012) proposed a PSORK algorithm that combines a virtual space array containing real numbers from a randomizing function with particle swarm optimization. The PSORK algorithm compares each particle's solution to a randomized encoding function to slow down the swarm's convergence speed (Lin et al., 2012). By slowing the convergence speed, Lin et al. (2012) observed the potential for an increase in the solution quality of a BOPAP by maintaining diversity in the swarm during the evolution process. Some advantages of particle swarm optimization models include "short computational

time and efficiency in solving problems presenting difficulty in finding accurate mathematical models, fast convergence, and few parameters to adjust" (Abdmouleh et al., 2017, p. 274). A disadvantage of particle swarm optimization is that it "can be difficult to define initial design parameters and can converge prematurely and be trapped into a local minimum especially with complex problems" (Abdmouleh et al., 2017, p. 274).

Fuzzy Goal Programming

Shahnazari-Shahrezaei et al. (2012) proposed using fuzzy goal programming to solve a multi-objective, multi-skilled manpower scheduling problem. In scheduling problems, the employers' objectives and employees' preferences are often vague, which leads to the fuzzy nature of the problem (Shahnazari-Shahrezaei et al., 2012). The end goal of a manpower scheduling algorithm is to output an "equitable allocation of working hours or shifts to employees considering work regulations, legal constraints, employers' objectives, and employees' preferences" (Shahnazari-Shahrezaei et al., 2012, p. 5424). Shahnazari-Shahrezaei et al. (2012) proposed using a fuzzy goal programming model to achieve the goal mentioned above. As a result of a manpower scheduling algorithm using fuzzy goal programming, human resource departments can shift their focus from employee scheduling to other activities such as job planning, training, and hiring new employees (Shahnazari-Shahrezaei et al., 2012).

The idea behind fuzzy goal programming is to model the fuzzy parameters as imprecise numbers (Shahnazari-Shahrezaei et al., 2012). The most common way to do this mathematically is to use triangular and trapezoidal numbers (Shahnazari-Shahrezaei et al., 2012). Shahnazari-Shahrezaei et al. (2012) used the max-min operator to develop a two-phased approach to convert their fuzzy model into two single-objective linear

programming models to solve a multi-objective, multi-skilled manpower scheduling problem (Shahnazari-Shahrezaei et al., 2012).

Machine Learning Techniques

Similarity learning falls into the category of supervised machine learning in data science to determine the amount of similarity or dissimilarity between data sets (Gupta, 2018). Two objects with a high similarity value denote that they are near each other or live-in close neighborhoods (Lüthe, 2019). The primary similarity-based metrics are Pearson's correlation, Spearman's correlation, Kendall's Tau, cosine similarity, and Jaccard similarity (Lüthe, 2019). Pearson's correlation is used to explore the relationship between quantitative, continuous variables such as age and blood pressure (Lüthe, 2019). Spearman's correlation is calculated similarly to Pearson's correlation; however, it is used for non-parametric data when the data does not follow normal or binomial distributions (Lüthe, 2019). Spearman's correlation detects monotonic relationships between two variables, whereas Pearson's detects linear relationships (Lüthe, 2019). Kendall's Tau is like Spearman's correlation in that it is used for non-parametric data. Still, it has smaller variability for larger sample sizes, often making it more advantageous than Spearman's correlation depending on the data quantity (Lüthe, 2019). The cosine similarity metric determines the cosine of the angle between two vectors and is often used in text analysis to assess document similarity (Lüthe, 2019). Jaccard similarity is like cosine similarity; however, Jaccard similarity is more computationally expensive than cosine similarity (Lüthe, 2019). It compares all objects in one group to all the other groups' objects to detect the similarity between the two groups (Lüthe, 2019). Although the Jaccard similarity metric or Jaccard index value is a simple, supervised machine

learning technique, it is used in sophisticated machine learning techniques such as object detection tasks in computer vision (Uniqtech, 2020) and medical image segmentation (Bertels et al., 2019).

In the context of the personnel assignment problem, Chishimba and Kunda (2018) used the Jaccard similarity function to match teaching applicants to suitable teaching positions based on a school's educational needs to "maximize the output" from the available teaching applicants (p. 17). Chishimba and Kunda (2018) first analyzed the teacher's competencies to create a "list of teaching applicants and the subjects that the applicants are qualified to teach to find out which applicants best align with the set of subjects that schools request" (p. 21). Then, they filtered the applicants, as some teachers were chosen for a specific location or age category (Chishimba & Kunda, 2018). After Chishimba and Kunda (2018) filtered the teaching applicants, they scored the applicants against the teaching positions using the Jaccard similarity function. Finally, they assigned the teaching applicants to the school based on the highest Jaccard score. An advantage of using machine learning techniques is that they are "easier to adapt to evolving business needs since the models can easily be trained with the data that suits an organization's current needs" (Chishimba & Kunda, 2018). However, a disadvantage of machine learning techniques is that one "cannot always provide adequate supervision to information" (Joy, 2020).

Decision-Support Systems

A decision-support system (DSS) is an interactive, computer-based system or group of subsystems intended to help decision-makers use technology, data, knowledge, and models to identify and solve problems, complete decision process tasks, and make

decisions (Power). Bühner & Kleinschmidt (1988) and Constantopoulos (1989) presented the first DSSs in a personnel assignment problem context. Bühner and Kleinschmidt (1988) proposed a decision-support architecture for personnel assignment scheduling within a production cell organization to help companies adopt flexible manufacturing systems to increase productivity. They developed production worker qualification profiles with information such as how many mistakes workers make and the degree of satisfaction a worker has with their job assignment. Then, they developed feasible job assignments based on production goals and bottlenecks. The researchers proposed using a linear model to compute optimal personnel assignments from the information stored in both the personnel information system and the production data system.

Additionally, Constantopoulos (1989) presented a decision-support system for assigning a large number of personnel to jobs based on multiple criteria to provide flexibility and usefulness for managing diverse employees with various educational backgrounds, ages, and previous employment. The goals of the decision-support system developed by Constantopoulos (1989) were to provide "data management capabilities with predefined, user-definable statistics of personnel data, and prepare a rational personnel assignment plan with the means for easy alterations of imposing restrictions and repeating the procedure" (p. 356). The decision-support system framework presented by Constantopoulos (1989) consisted of calculating a utility index for each assignment, defining an ordinary or default assignment for when no special conditions apply, and special assignment capable of handling exceptional cases. Then, Constantopoulos (1989) used his decision-support system to assign personnel to jobs based on a network flow model.

Korkmaz et al. (2008) coined the acronym for their personnel assignment decision-support system (ADES), which focused on assigning personnel to job assignments while considering an individual's competencies and personal preferences. Robards (2011) found that assignment detailers attempting to match personnel to assignments without using a decision-support system overestimated their performance abilities. Furthermore, Robards (2011) discovered that it is probable that the quality of human decisions will be degraded unless aided by a decision-support system in making assignment decisions where cognitive limits are reached.

Summary

This chapter examined human decision-making and thoroughly analyzed the current deployment tasking process. Additionally, it presented an overview of the personnel assignment problem and personnel management research in the U.S. Air Force to understand the problem's historical context. Finally, this chapter examined personnel assignment models and decision-support systems to determine an appropriate matching algorithm for the DSS developed in this research. However, despite the significant contributions of the personnel assignment models and decision-support systems examined in this chapter, there was no reported research that focused on: (1) a military deployment tasking process and (2) visualizations of the entire personnel assignment solution space. Accordingly, a decision-support system capable of extending beyond minimum requirements criteria in selecting military members for deployment taskings and visualizations of the whole personnel assignment solution space is needed to overcome these limitations in existing research. The next chapter presents this research's methodology.

III. Methodology

Chapter Overview

This chapter presents the research methodology for the decision-support system (DSS) construction, personnel management information system (MIS), data simulation, matching framework, matching criteria, matching algorithm, decision-support system formation, validation, matching visualizations, and test subjects. This research was conducted using quantitative research methodology to develop a prototype decision-support system capable of achieving the objectives presented in the first chapter.

DSS Construction

As learned in the previous chapter, Robards (2011) found that it is probable that the quality of human decisions will be degraded unless aided by a decision-support system in making assignment decisions where cognitive limits are reached. Additionally, it was learned that when assignment decisions are to be made, and there are multiple criteria to be considered for each assignment, the matching process quickly becomes a complicated process for assignment detailers (Robards, 2011). Because this research's objectives constituted a series of complex personnel assignment decisions, it was determined that a decision-support system was needed to match civil engineer officers to deployment taskings.

The overall research methodology for the DSS developed in this study was proposed by Korkmaz et al. (2008), as shown in Figure 3. The ADES developed by Korkmaz et al. (2008) considered both an individual's professional qualifications and personal preferences in matching personnel to assignments. However, this research departs the ADES developed by Korkmaz et al. (2008) by utilizing the Jaccard similarity

function to match civil engineer officers to expeditionary positions. Korkmaz et al. (2008) used EP match as their two-sided matching algorithm. Moreover, Korkmaz et al. (2008) did not develop actual personal preferences. Nonetheless, the ADES by Korkmaz et al. (2008) was an invaluable reference for developing the methodology to achieve the research objectives identified in the first chapter.

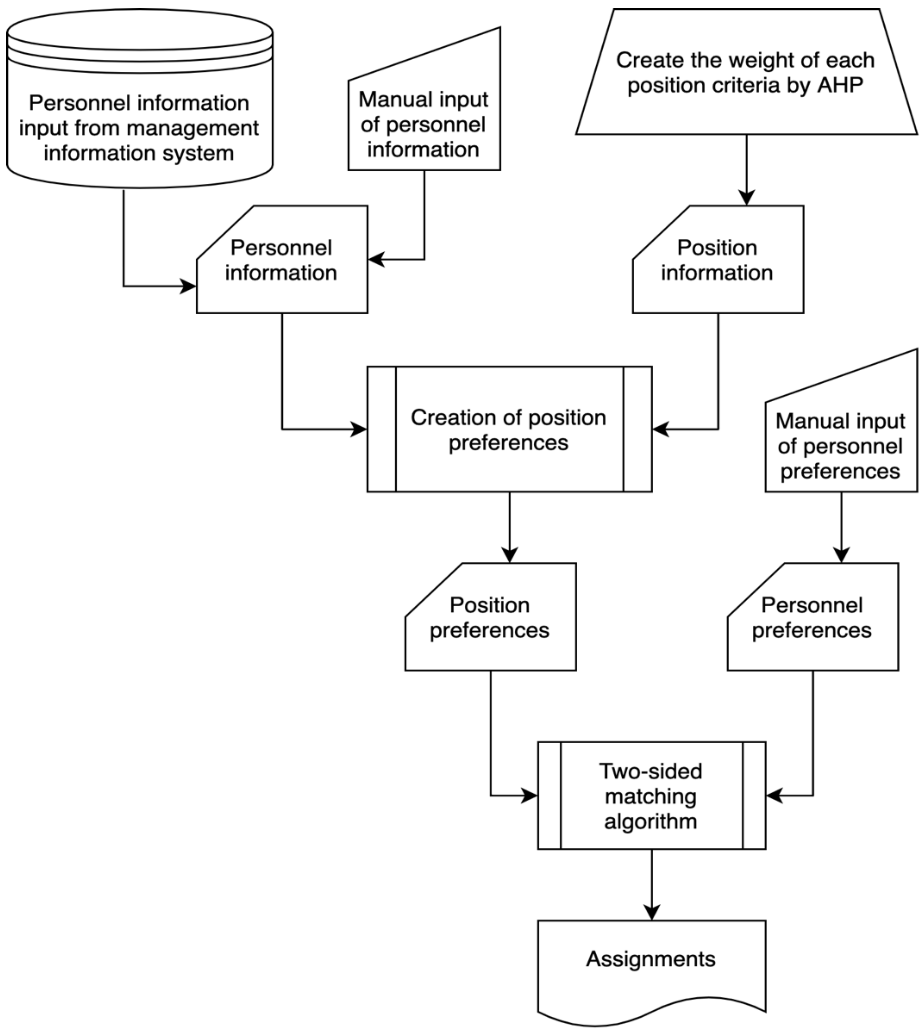

Figure 3. Personnel Assignment DSS (ADES) Adapted from (Korkmaz et al. 2008)

Using the ADES by Korkmaz et al. (2008) as a guide, a DSS was developed and configured for the problem presented in this research. The prototype DSS in Figure 4 was constructed for use in the context of the objectives in this research to match civil engineer officers to deployment taskings while optimizing individual qualifications, personal preference considerations, and constraints.

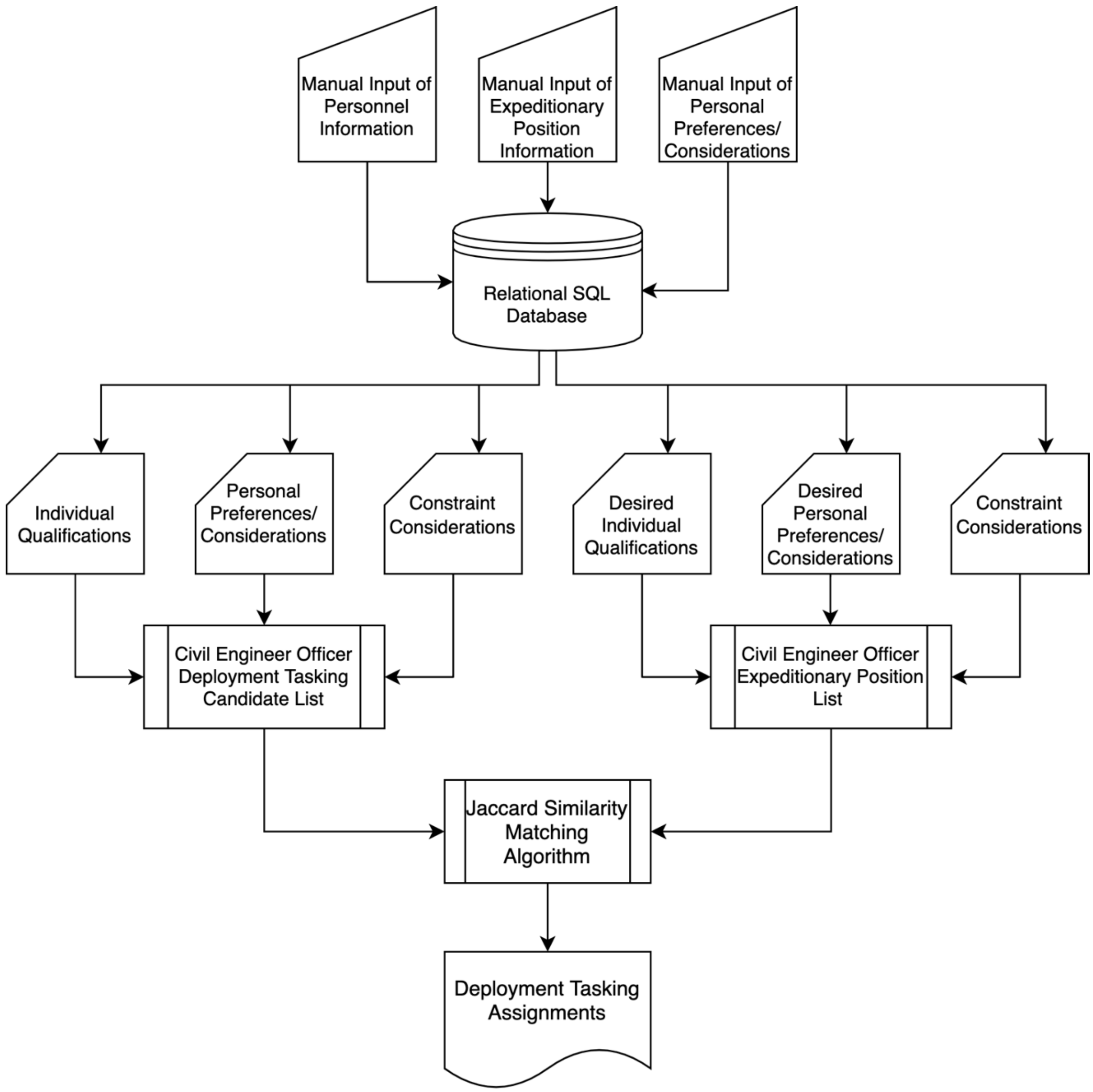

Figure 4. Civil Engineer Officer Deployment Tasking Decision-Support System (DSS)

The civil engineer officer deployment tasking DSS begins with the manual input or import of personnel and expeditionary information from multiple data systems into a relational structured query language (SQL) database, which serves as the personnel management information system (MIS). The information in the database can then be sorted and queried according to the objectives and constraints to develop information lists in preparation for the matching procedure. Once information lists of the civil engineer officers and the expeditionary positions have been created from the database's information, the matching algorithm can be executed. The matching algorithm compares the two lists or data frames using the Jaccard similarity function to compute a Jaccard similarity score between each civil engineer officer and the deployment tasking. The officer with the highest Jaccard similarity score for each tasking is then matched to the respective deployment tasking. If an officer is matched to more than one tasking, the officer is selected for the tasking he or she scored the highest. If an officer is matched to more than one tasking and has the same Jaccard similarity score for each tasking, the officer is selected for the first tasking. The second tasking is then reevaluated and matched with the next officer with the next highest Jaccard similarity score. By compiling a list of the matching algorithm results, an optimized list of deployment taskings is produced.

Personnel Management Information System

Relational databases organize data into tables linked to common data fields ("Relational Databases," n.d.). Additionally, relational databases establish relationships between entities using the common fields included in a table called relations (Hoffer et al., 2011). Once the database's tables are populated with data and the relations between

the tables are completed, the relational SQL database has a powerful querying ability that enables the retrieval of entirely new data to gain new insights for making better decisions or identifying new opportunities ("Relational Databases," n.d.). Furthermore, a database management approach provides a systematic method for creating, updating, storing, and retrieving data and enables users to share data across multiple databases and computational applications (Hoffer et al., 2011). Some of the advantages of using a database approach include data consistency, data sharing, data quality, data accessibility, and improved decision-support (Hoffer et al., 2011). Whether simulating data or extracting real-world data, one must have a location and methodology to store information. In the design of the relational SQL database for the DSS, an entity-relationship diagram was developed. For readability, a collapsed version of the entity-relationship diagram is shown in Figure 5.

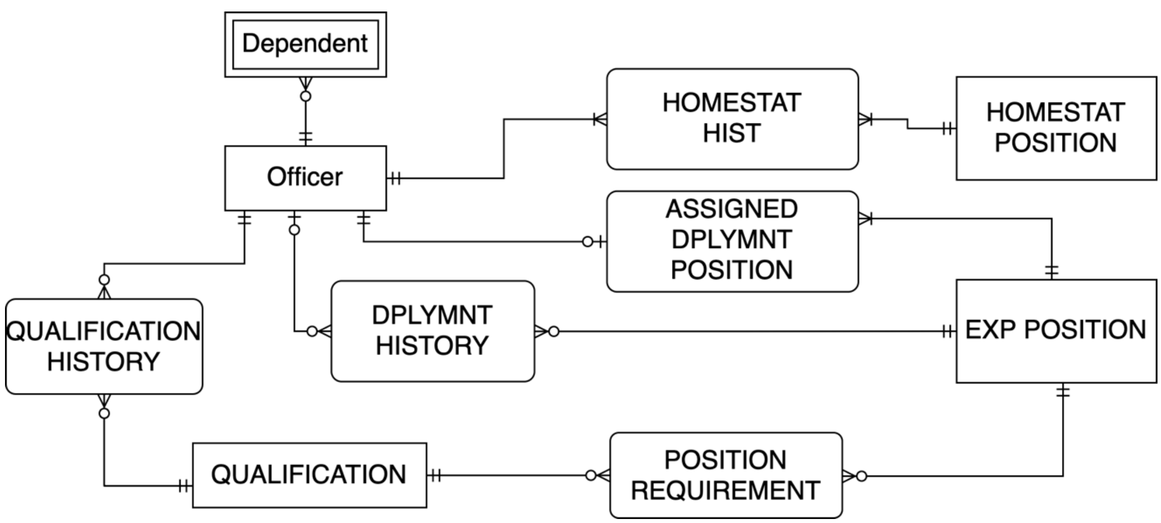

Figure 5. SQL Database Collapsed Entity Relationship Diagram

The primary entities of interest in this DSS are officer and expeditionary position. The database's primary entities are represented with sharp-cornered rectangles, shown on

the collapsed entity-relationship diagram's ends in Figure 5. In database design, business rules must be determined to develop the relationships or cardinalities between the entities. For example, a business rule in this research is that an officer must be assigned to a home-station first before being considered for a deployment tasking. Because of this business rule, an officer must have a home-station. If the officer does not have a home-station, they cannot be input into the database. Thus, the home-station requirement is mandatory. This business rule ensures the consistency and accuracy of the data. A single, perpendicular mark is made on the connecting line next to the entity of interest to indicate a mandatory requirement in an entity-relationship diagram. Because military members frequently move home-stations, an officer may have more than one home-station history. Consequently, crow’s feet are added to the perpendicular mark to indicate that an officer may have one-to-many home-station records; however, the officer must have at least one home-station to exist in the database. The double perpendicular lines next to the officer entity indicate that an officer’s home-station history belongs to only one officer. Because an officer may or may not have been on deployment, crow’s feet with a circle are used to indicate that an officer in the database may have zero-to-many deployments. The perpendicular line with the zero indicates that a deployment history is optional; however, if the officer has a deployment history, it belongs to one officer as indicated by the officer entity's double perpendicular lines. The entity-relationship diagram in Figure 5 was completed according to the entities of interest in this research, then collapsed for readability. After the database design was completed, the database tables were constructed according to the entity-relationship diagram. The database tables are shown in the appendix.

Data Simulation

There are restrictions with accessing a host of Department of Defense (DoD) data systems with personally identifiable information (PII) shown in Figure 1 in Chapter 2. However, upon reviewing literature in the information science field (Korkmaz et al., 2008; Robards, 2011), simulated data was deemed an appropriate methodology for developing a prototype personnel assignment DSS as personnel data is primarily discrete and deterministic. Additionally, the names of individuals to be tasked to deploy and the expeditionary positions can be represented by numerical values and are not essential to the personal assignment DSS's success. Furthermore, demographic information such as gender, age, and ethnicity was not crucial to achieving either the objectives or constraints of the DSS. However, the data fields for demographic information were included in the SQL database development as demographic information may be of interest to a decision-maker.

The relational SQL database was populated with 6,988 simulated civil engineer officers containing ten real-world attributes. Each officer was assigned a six-digit number representative of an individual's DoD identification number to serve as the primary key for the database's officer entity. Additionally, each officer was assigned a first name, last name, and rank ranging O-1 through O-6. The rank distribution was determined from current Air Force demographic data. For visualization purposes, a histogram of the rank distribution of the officers in the database is shown in Figure 6.

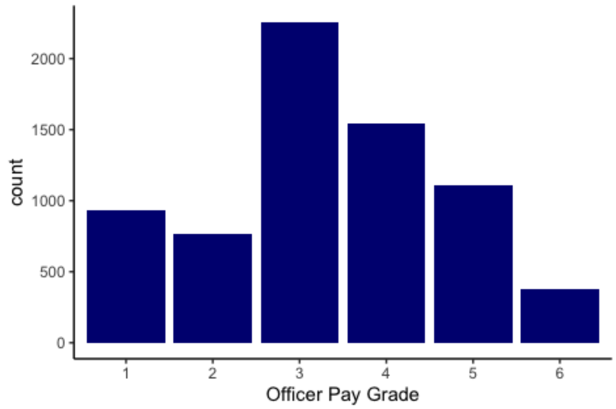

Figure 6. Pay Grade Histogram of Simulated CE Officers in Database

Next, the simulated officers were assigned various attributes using real-world civil engineer officer professional certifications, training qualifications, education qualifications, and home-station positions. The tables for each of the possible attributes of the officers in the database are shown in the appendix. It was determined that 6,988 civil engineer officers would be too excessive and unrealistic in developing a prototype deployment tasking DSS, so the number of officers was reduced to 250 based on the military personnel assignment model developed by Liang and Thompson (1987). Liang and Thompson (1987) demonstrated their military personnel assignment model by matching 250 U.S. Navy enlisted members to assignments. Because it was assumed the deployment taskings for the ranks of O-6 and above would be managed on a case-by-case basis, the officers in the rank of O-6 were removed from the 250 officers, which brought the number down to 226.

Korkmaz et al. (2008) assigned ten personnel to ten positions to demonstrate their ADES capability. However, to present sufficient analysis for each possible civil engineer officer ranks O-1 through O-5, it was determined that 20 expeditionary civil engineer

officer positions were needed. Based on general knowledge of expeditionary civil engineer positions, 20 deployment taskings were developed to be as realistic as possible while avoiding the appearance of classified information. The position descriptions and respective qualifications are referenced in the appendix.

Personnel Matching Framework

In a DSS, it is crucial to identify the system users and the system boundary. Figures 7, 8, and 9 visually display the deployment tasking DSS users, the system boundary, and the matching framework developed and utilized in this research. The first objective of this research aims to match civil engineer officers to deployment taskings by extending beyond minimum requirements selection criteria and applying desired qualifications selection criteria in the matching process, shown in Figure 7.

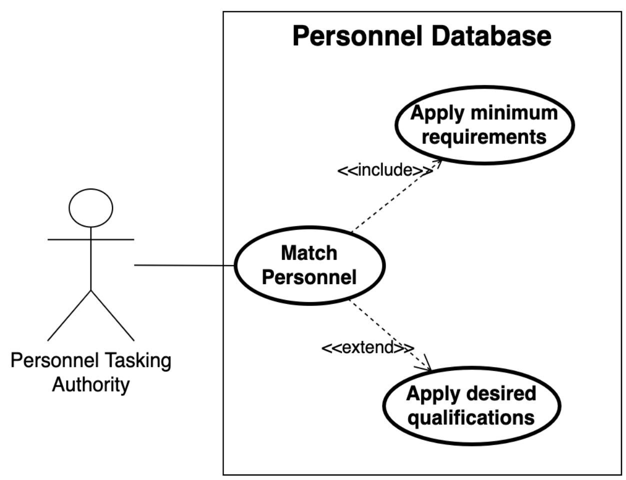

Figure 7. Matching Framework Objective 1

The second objective of this research is to match civil engineer officers to deployment taskings by extending beyond minimum requirements selection criteria and applying

desired qualifications and personal preferences selection criteria in the matching process, shown in Figure 8.

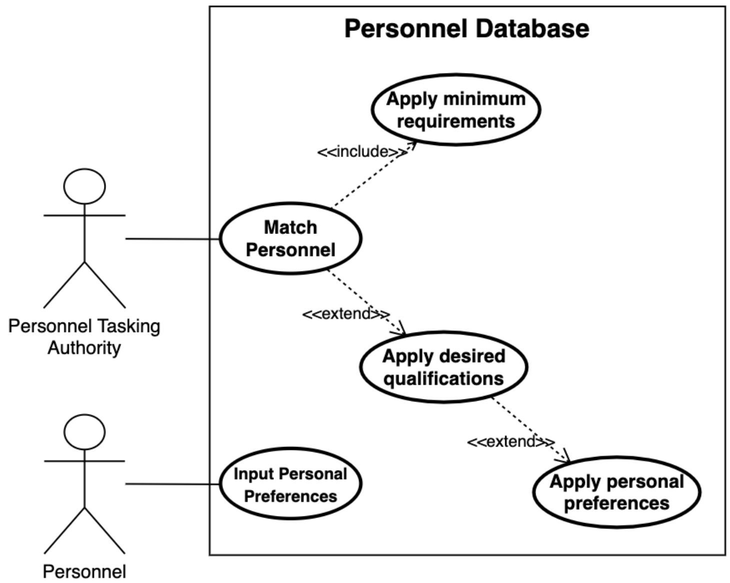

Figure 8. Matching Framework Objective 2

Finally, by adding a constraint extension to the matching framework, the final goal of this research is to match civil engineer officers to the deployment taskings while extending beyond minimum requirements selection criteria and applying desired qualifications, personal preferences, and a home-station manning constraint in the matching process, shown in Figure 9.

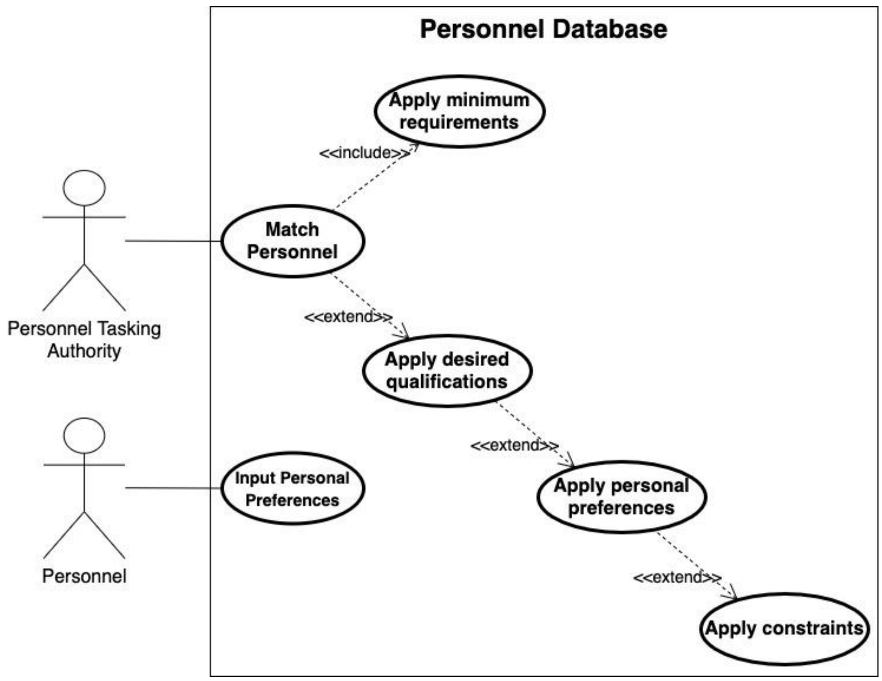

Figure 9. Matching Framework Constraint 1

To better understand each matching objective's impact and constraint on the prototype deployment tasking DSS, it was determined that three progressive matching simulations were needed to demonstrate capability and analyze the performance of the cumulative extensions of the matching framework shown in Figures 7, 8, and 9.

Matching Criteria

A prototype modeling methodology was used as the matching criteria were selected based on known information. Before acceptance, a prototype model's requirements can be updated or changed ("What is a Prototype Model," n.d). However, a prototype model's primary goal is to provide a system with overall functionality based on known information ("What is a Prototype Model," n.d.). It is known that to be an Air Force civil engineer officer, one must have an accredited engineering degree and that the

range of engineering degrees is substantial. In addition to diverse engineering backgrounds, civil engineer officers also have a wide variety of professional qualifications such as Professional Engineer (PE) licenses, a Project Management Professional (PMP) license, a Leadership in Energy and Environmental Design (LEED) certification, and Lean Six Sigma (LSS). Moreover, Parker (2012) described some criteria that squadron commanders informally use in selecting individuals for deployment taskings such as “dwell time, home-station duties, and timing of significant life events (wedding, childbirth, attendance at professional military education school, etc.)” (p. 69).

In the current deployment tasking process, only two minimum selection requirements formally exist for the expeditionary positions, rank, and AFSC (Parker, 2012). Although other requirements may exist in the line remarks attached to the tasking, they are neither applied systematically or deliberately. Furthermore, line remarks are most often completed in response to the deployment tasking rather than used as criteria to be considered in the deployment tasking process. To deliberately and systematically select officers for deployment taskings, this research recommends that the prototype DSS compare officers against deployment tasking criteria based on the officers' known qualifications. Textual notes are not an optimal format for a matching algorithm development; therefore, the matching criteria considered in the prototype DSS were assigned numerical values such as a training course number and a home-station position number. Five professional qualification criteria were selected based on known civil engineer officer qualifications shown in Figure 10 to achieve the first objective of this research to match the most qualified civil engineer officers to the expeditionary positions.

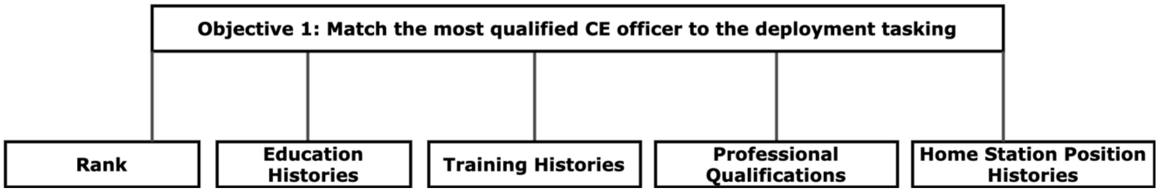

Figure 10. Matching Criteria Objective 1

In response to research by Riddel (2010), Connell (2012), and Parker (2012), as discussed in Chapter 2, it was determined that civil engineer officers' personal preferences should be considered in a prototype deployment tasking DSS. Following the ADES format as developed by Korkmaz et al. (2008) and the preference consideration examples outlined by Parker (2012), five preference criteria were chosen based on known information shown in Figure 11 to achieve the second objective of this research.

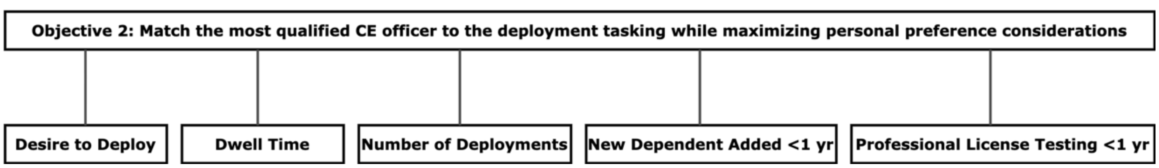

Figure 11. Matching Criteria Objective 2

An officer's dwell time and the number of deployments are numerical criteria. However, the other criteria considered were assigned numerical values to be effectively used by a matching algorithm. An individual's desire to deploy was represented on a 1-to-9 Likert scale, and binary, yes-no values represented the other two personal considerations.

Finally, it was determined that a prototype deployment tasking DSS should have the ability to consider real-world constraint criteria. If a prototype deployment tasking DSS was accepted and entered real-world test trials, constraints would be unavoidable. As learned in Chapter 2, civil engineer squadron manning is often less than 100 percent.

In response to manning shortages, a constraint variable was added to the matching criteria to be considered by prototype DSS in the third extension of the matching process. An important consideration in a matching algorithm development is flexibility. Although the 11 matching criteria chosen in this research were based on known information, they may not be all-encompassing. Air Force leaders and civil engineer officers could have different criteria to consider a real-world test trial of the prototype deployment tasking DSS.

Matching Algorithm

During the initial phase of this study, a GA and its application to the personnel assignment problem was the leading algorithm under consideration for the prototype DSS. However, as learned in Chapter 2, GAs are well suited to solve problems where the solution space is "discontinuous and poorly understood" (Herrera et al., 1991, p. 331). As the problem was described in the first chapter, the research objectives are well defined, and the number of officers in the solution space is determinate; thus, a GA does not offer a significant advantage over other optimization techniques. Although computational efficiency is gained by using a GA, decision-makers could benefit from a computationally expensive visualization of the entire solution space. Moreover, recent research conducted by Chishimba and Kunda (2018) has demonstrated the use of a supervised machine learning technique to solve a personnel assignment problem.

The Jaccard Similarity Function

The Jaccard similarity function is well-suited to achieve the research objectives to match the most qualified officer to the deployment tasking while considering personal preferences and a constraint variable. As learned in Chapter 2, the Jaccard similarity

function is a simple, supervised machine learning technique that measures the similarity between two data sets (Gupta, 2018). The basic Jaccard function is shown mathematically in Equation 1 and visually in Figure 12. Additionally, Figure 13 simplistically demonstrates how this research uses the Jaccard function to match civil engineer officer candidates to deployment taskings as candidate (a) matches to position (p) and candidate (b) matches to position (q) based on each of the three candidates' Jaccard similarity scores. When compared to the two positions to be filled, candidate (a) had the highest Jaccard similarity score for position (p), and candidate (b) had the highest Jaccard similarity score for position (q); thus, they matched to the respective taskings for which they scored the highest. Candidate (c) had the lowest Jaccard similarity scores, so they did not match to either tasking.

$$J(A,B) = \frac{|A \cap B|}{|A \cup B|} = \frac{|A \cap B|}{|A| + |B| - |A \cap B|} \tag{1}$$

$$0 \leq J(A,B) \leq 1$$

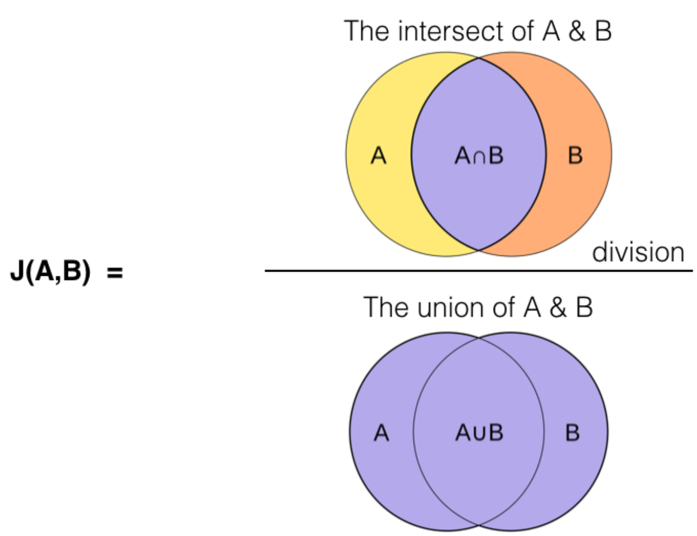

Figure 12. Jaccard Similarity Diagram

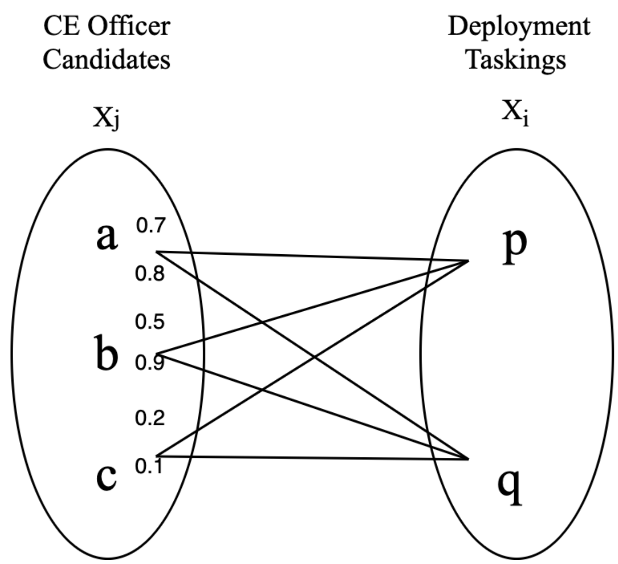

Figure 13. Matching Function Example

Utilizing the Jaccard similarity function to score civil engineer officers against potential deployment taskings eliminates the need for fuzzy, linguistic measures or utility values commonly used in personnel assignment problem studies. Utility values are used to score personnel based on their perceived utility for a particular assignment. However, the Jaccard similarity score measures the amount of similarity the officer has compared to the tasking requirements and preferred preferences. Customizing the Jaccard similarity function for this research problem, the basic code structure for the Jaccard similarity score is shown in Equation 2.

$$Jaccard\ Similarity\ Score \rightarrow Jaccard(i, j) \tag{2}$$

Where:

i = civil engineer officer candidate
j = deployment tasking

Moreover, the Jaccard similarity function can be used on text strings (Gupta, 2018). Text recognition ability could provide some comparative functionality on the

current deployment tasking process as requirements beyond required rank and AFSC are stored in line remark text. Furthermore, the Jaccard similarity function can handle large quantities of variables. The Jaccard similarity function performs better the more criteria that it has to compare (Rees, 2019). Additionally, the Jaccard similarity function can be weighted. When used in its standard form, the Jaccard similarity function gives all the criteria the same importance (Veerappa & Letier, 2011). However, in decision-making, some requirements may be more important than others. Weights for the criteria to be considered can be selected by a decision-maker (Veerappa & Letier, 2011). A weight vector is then multiplied by the Jaccard similarity function to weight variables according to the decision-maker's preferences (Veerappa & Letier, 2011). The ability to handle uncertainty was an important factor in developing the prototype deployment tasking DSS developed in this research. Uncertainty exists as military leaders move positions or retire, and the deployed positions evolve and change duties over time. As a result, the selection criteria for the expeditionary positions can vary. Therefore, a matching function that is expandable and able to be weighted was an important consideration in this research. As with any model selection, there may be disadvantages. A disadvantage of the Jaccard similarity metric is that "data sparsity decreases the performance and quality of any recommender systems" (Saranya et al., 2016, p. 5).

DSS Formation

When developing a prototype model, it is recommended to avoid hard coding the data into the computational analysis system as data changes rapidly (Simmons, 2018). However, when a computational software program like R Studio is linked to a living SQL database, the two interconnected systems become a powerful decision-making tool. In

this research, R Studio was linked to the relational SQL database using the R Studio dB Maria package. Once this linkage was made, the prototype deployment tasking DSS was officially formed. Because the database was linked to a deployment matching model in R Studio, it became a decision-support system as defined in Chapter 2.

DSS Validation

The ADES validation methodology by Korkmaz et al. (2008) was used as a guideline for the validation procedure of the DSS developed in this research. Korkmaz et al. (2008) compared the assignment results of their ADES with a manual assignment matching process. The assignment results of their ADES were categorized as the “assisted” process, whereas the manual process was labeled as the “unassisted” process. To compare their assignment matches numerically, Korkmaz et al. (2008) developed a utility scoring metric to determine the assignments’ goodness of fit. Using the validation procedure by Korkmaz et al. (2008) as a guide, the deployment tasking assignments from the DSS simulations were compared to a manual, “unassisted” assignment process, which imitated the current deployment tasking process flow as outlined in Chapter 2. Because the officers were matched according to their Jaccard similarity scores, numerical, comparative metrics already existed for the deployment matches; therefore, a utility score was not needed to compare the results of the DSS’s “assisted” process against the manual, “unassisted” process. Additionally, the DSS results were compared to the taskings themselves to ensure the DSS could meet the deployment tasking's minimum rank requirements. Suppose the DSS was not capable of meeting the minimum rank requirements. In that case, the rank variable could be weighted more heavily than the other variables to ensure the DSS achieves minimum requirements.

Current Process Replication

Given that the current deployment process is described as "more akin to rolling dice than following a deliberate procedure" by Parker (2012), flexibility exists in a replication of the current process for a validation procedure of the DSS (p. 68). However, a simplistic process map, shown in Figure 14, was developed based on the literature review performed in Chapter 2 and a discussion with a former MAJCOM FAM.

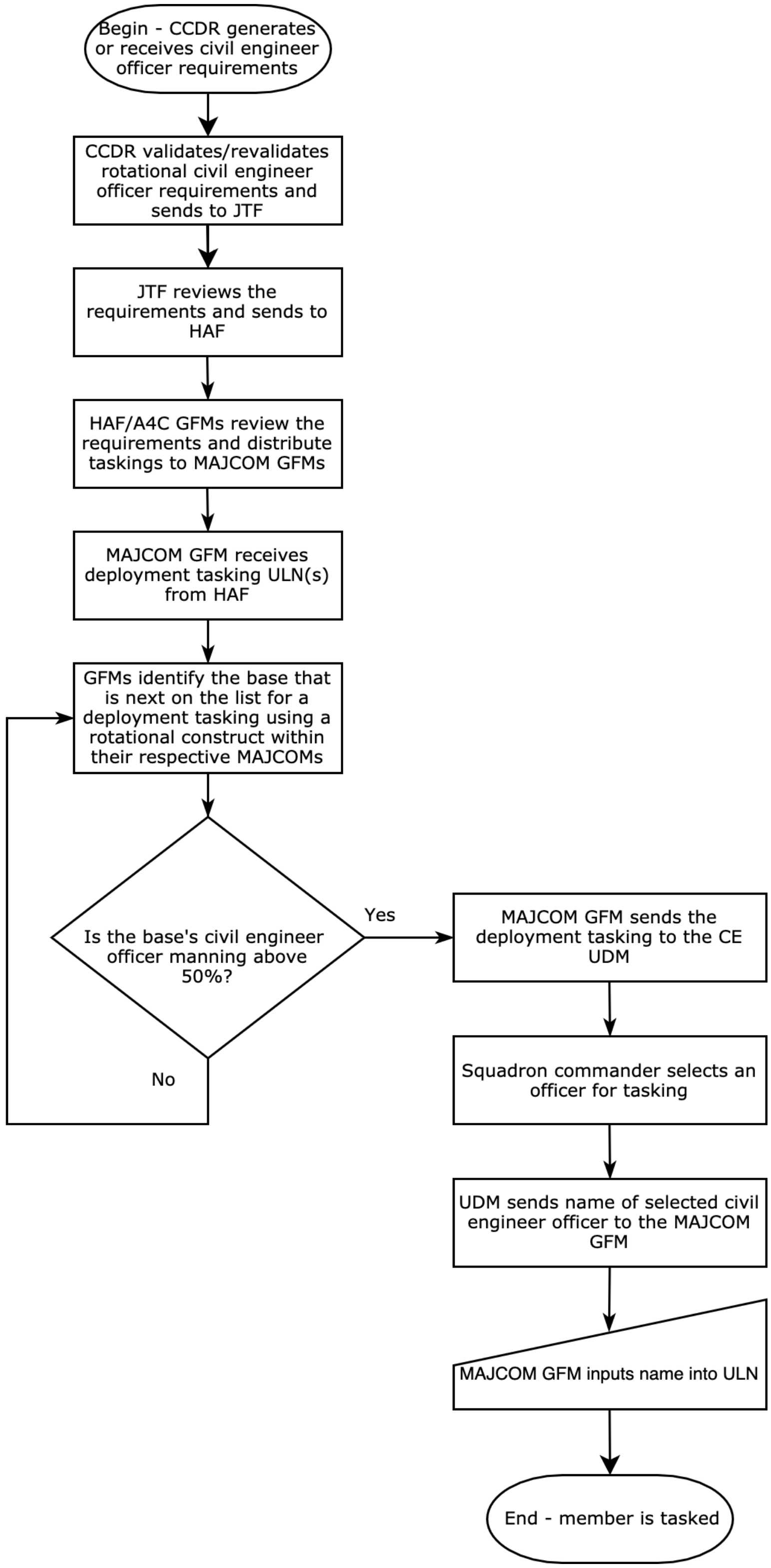

Figure 14. Current Process Flow Diagram

The simplistic process flow diagram of the current deployment tasking process was developed to provide validity to the validation procedure. Although the DSS proposed in this research is agnostic to an individual's home-station location and MAJCOM, home-station locations and respective MAJCOMs were assigned to the simulated officer candidates for a realistic replication of the current deployment tasking process for the DSS validation. Because Air Combat Command (ACC) and Air Mobility Command (AMC) are the Air Force's primary AEF rotational force providers (AFI 10-401), Table 3 shows the "unassisted" deployment tasking allocation that was used in the validation process. Air Force Material Command (AFMC), represented by "Upper Midwest" in the database, was selected to represent the MAJCOMs like PACAF and USAFE that are considered "deployed in place." Not all MAJCOMs provide civil engineer officers to support rotational AEF requirements (AFI 10-401).

Table 3. MAJCOM Deployment Tasking Distribution

MAJCOM	Simulated Representative	Tasking Allocation	Number of Deployments
ACC	Northeast	40%	8
AMC	Central	20%	4
AFGSC	South	15%	3
AFSOC	Southeast	15%	3
AETC	West	10%	2
AFMC	Upper Midwest	0%	0
	Total	**100%**	**20**

Matching Visualizations

The personal assignment matching results by Korkmaz et al. (2008) consisted of a table showing which person matched to which assignment. Moreover, Korkmaz et al. (2008) developed line graphs of the consequences of varying personal preference quantities. However, their assignment matching results did not provide a potential decision-maker with substantial or useful information to make future decisions. Constantopoulos (1989) stated that "accessibility and usefulness to higher levels of management are of great importance in developing systems for supporting manpower allocation in organizations" (p. 355). In response to the lack of visual representation of the ADES results by Korkmaz et al. (2008), it was determined that a heatmap or tile plot would increase the usefulness of personnel assignment matching results for a decision-maker. A heatmap or tile plot quickly displays the entire solution space so that a decision-maker can quickly make inferences on gaps, shortfalls, overages, and overall health of the deployment taskings' objectives. Moreover, if a deployment tasking has a trend of low Jaccard scores, it would indicate that not many civil engineer officers in the solution space have the required training or qualifications for that particular tasking.

Test Subjects

Ten years of unclassified civil engineer officer deployment tasking data was obtained from Dyess Air Force Base in Abilene, Texas, to serve as the real-world test subjects of the prototype deployment tasking DSS. From 2010 to 2020, Dyess Air Force Base deployed 23 civil engineer officers to fill seven different rotational AEF taskings. The rank distribution of the civil engineer officer deployment data is shown in Figure 15. Although the DSS developed in this research applies a new methodology to the current

deployment tasking process, an attempt to use real-world data was explored to demonstrate the DSS's capability and validity. Despite the differing methodologies, three out of the 10 DSS's objective variables and the constraint variable exist in the current deployment tasking process. The other seven objective variables used in the DSS do not formally exist as qualifiers or preferences of the expeditionary positions.

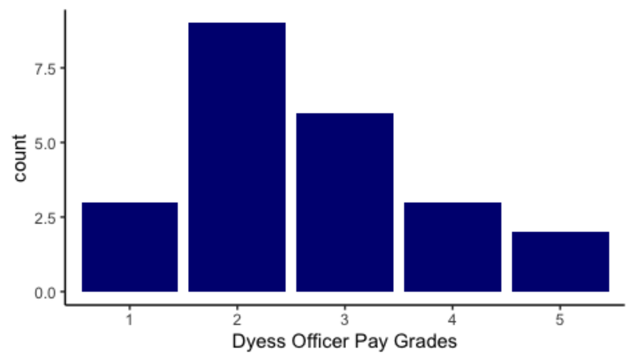

Figure 15. Rank Distribution of Dyess Civil Engineer Officer Deployment Data

Summary

This chapter presented the research methodology for the decision-support system (DSS) construction, the personnel management information system (MIS), data simulation, personnel matching framework, matching criteria, matching algorithm decision-support system formation and validation, the matching visualizations, and the test subjects. The next chapter will present the analysis and results of the simulations used to develop, configure, and validate the DSS presented in this research. Additionally, the next chapter will review the test subjects' results and this research's investigative questions.

IV. Analysis and Results

Chapter Overview

This chapter presents the analysis and results of the simulations used to develop, configure, and validate the previous chapter's decision-support system. Additionally, the results of ten years of civil engineer officer deployment data are presented and analyzed using the DSS to examine the feasibility and challenges associated with implementing this DSS on the current deployment tasking process. Finally, the investigative questions presented in the first chapter will be reviewed.

Results of Matching Simulations

Three progressive deployment tasking simulations were conducted in R Studio using the Jaccard similarity scoring algorithm to match the 20 deployment taskings with the optimal civil engineer officer from the 226 deployment tasking candidates. The output of the results presenting the matches for each simulation is shown in Table 4. The first column contains the expeditionary position number. The second, third, and fourth columns indicate which civil engineer officer candidate optimally matched to the deployment tasking according to the two objectives and matching constraint, respectively.

Table 4. Deployment Tasking Simulation Matches (DSS Assisted)

Exp Position No.	Objective 1 - Qualifications	Objective 2 - Qualifications & Preferences	Constraint 1 - Home-Station Manning
	Officer ID	Officer ID	Officer ID
1	175	57	53
2	2	2	85
3	36	99	66
4	168	66	110
5	27	96	70
6	128	128	135
7	159	30	94
8	29	58	106
9	185	112	218
10	5	110	188
11	16	16	175
12	1	93	26
13	194	11	38
14	34	218	170
15	55	60	51
16	113	55	190
17	12	70	112
18	8	102	219
19	6	65	138
20	60	214	71

Officer candidate 2 matched to expeditionary position number 2 for both the qualifications matching simulation and the qualifications and preferences matching simulation. However, when adding a home-station manning constraint to the matching algorithm, officer candidate 85 matched to expeditionary position number 2. Additionally, officer candidate 128 matched to expeditionary position number 6 for both the qualifications and the qualifications and preferences matching, but officer candidate

135 matched to position 6 when the manning constraint was added. Moreover, officer candidate 16 matched to expeditionary position number 11 for both the qualification matching simulation and the qualifications and preferences matching simulation but was replaced by officer candidate 175 when the home-station manning constraint was added. From these three progressive matching simulation results, it can be inferred that the home-station manning constraint does have an impact on which officer gets matched to the deployment tasking as the matches completely changed when the home-station manning constraint variable was added. Additionally, it can be inferred that when considering the variables for the two primary objectives in this research, an officer may match to the same tasking for both the individual qualifications and personal preferences matching scenarios. Upon reviewing the ADES results of Korkmaz et al. (2008), the assignment matches were the extent of their ADES results. However, it was determined that heat maps could be created from the matching algorithm's results to view the entire solution space's Jaccard similarity scores.

Furthermore, the output of the deployment tasking simulations can also be expanded beyond producing optimal matches as shown in Table 4. The first, second, third, fourth, and fifth optimal candidates were determined for each of the deployment tasking simulations for expeditionary position number one to demonstrate the prototype DSS’s ability to determine backup candidates shown in Table 5.

Table 5. Identification of Backup Candidates for Tasking 1

		Objective 1 - Qualifications	Objective 2 - Qualifications & Preferences	Constraint 1 - Home-station Manning
Exp Position No.	Optimal Match No.	Officer ID	Officer ID	Officer ID
1	1	175	57	53
1	2	6	58	70
1	3	8	70	106
1	4	35	146	112
1	5	57	175	138

Based on the results in Table 5, backup candidates were identified for each of the tasking simulations for expeditionary position number one. Officers 175 and 57 matched to expeditionary position one for both objectives; however, they were not the optimal matches when the constraint variable was added. Moreover, officer 175 was the first optimally qualified candidate for the first objective and the fifth optimally qualified candidate when the first and second objective were combined. Officer 57 was the fifth optimally qualified candidate for the first objective and the first optimally qualified candidate for when the first second objectives were combined.

Visualizations of Matching Simulations

Visualizations of the three matching simulations were developed in R Studio. The visualizations are shown in Figures 16, 17, and 18.

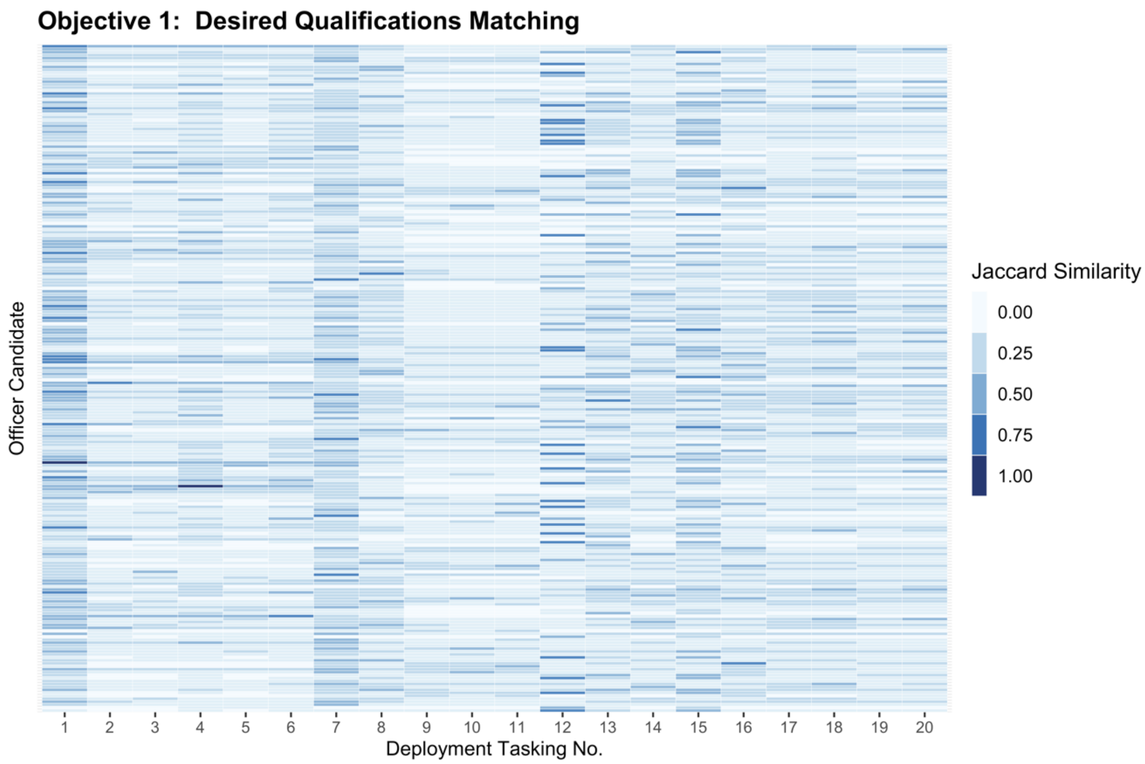

Figure 16. Simulation 1 Visualization

Upon inspection of the Simulation 1 Visualization in Figure 16, it was quickly apparent that expeditionary taskings 1 and 7 had the most qualified individuals in the solution space. Taskings 12 and 15 show a moderate number of qualified individuals. Conversely, taskings 9, 10, 11, and 19 show a relatively low number of qualified individuals as the columns are lighter in color with quite of few white rectangles, which indicate low Jaccard similarity scores.

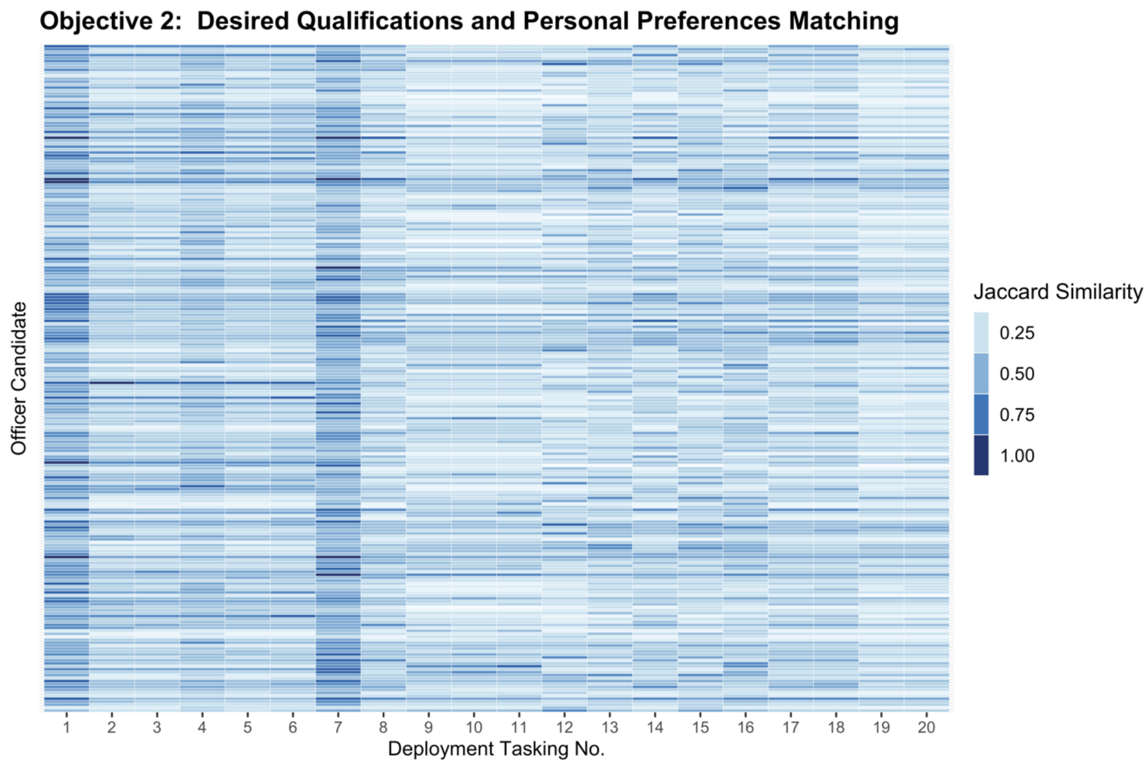

Figure 17. Simulation 2 Visualization

Upon inspection of the Simulation 2 Visualization in Figure 17, it became easier to identify the expeditionary taskings with many qualified individuals than in the Simulation 1 Visualization. The Simulation 2 Visualization in Figure 17 showed more qualified individuals in the solution space to fill Taskings 1 and 7 as more objective variables were added to the matching algorithm. From this visualization, a decision-maker can quickly infer that deployment taskings 1 and 7 are in good health as many individuals in the solution space are optimally qualified to fill them. Moreover, taskings 9, 10, 11, 19, and 20 had a low number of qualified individuals in Simulation 2. Figure 17 quickly tells a decision-maker that these deployment taskings need to be examined in more detail to see which requirements and preferences are associated with the taskings

that had a low number of optimally qualified individuals. Once reviewed, a decision-maker can notify training pipelines to increase throughput or deliberately target specific individuals to attend specific training courses to generate more qualified individuals in the deployment tasking solution space.

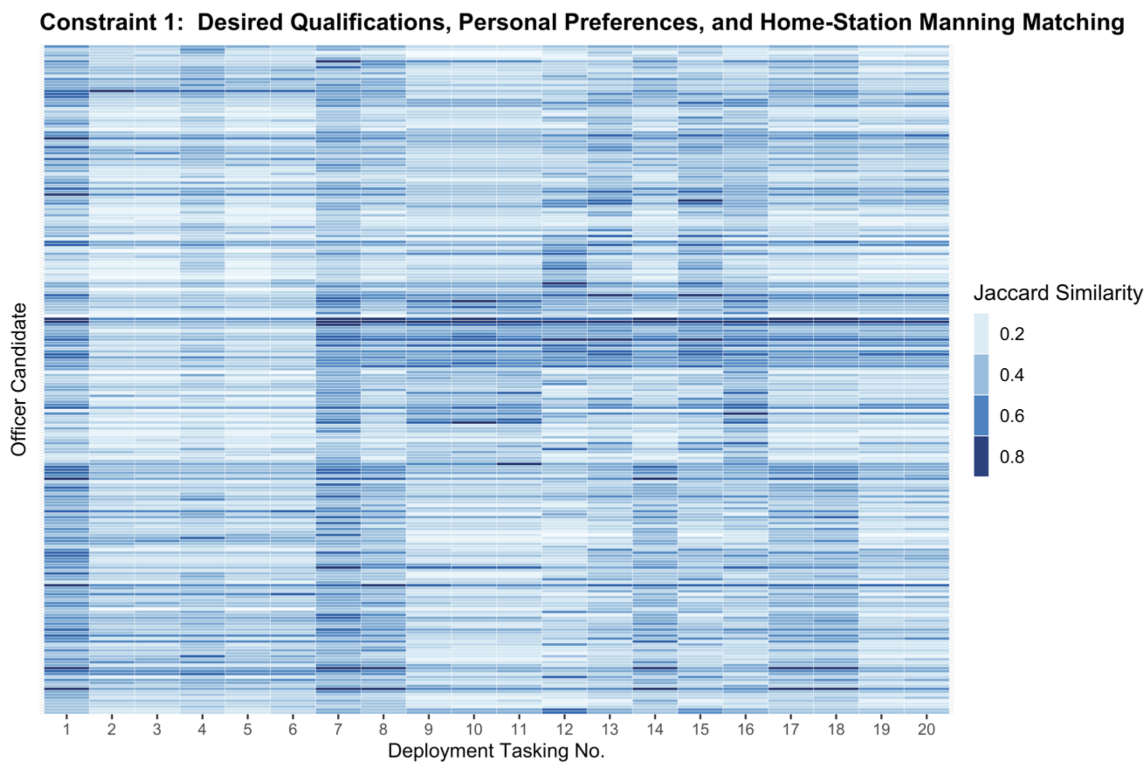

Figure 18. Simulation 3 Visualization

Upon inspection of the Simulation 3 Visualization in Figure 18, lateral trends began to emerge in addition to the vertical trends identified in the first two simulations. A lateral trend identifies individuals who meet the optimal objective and constraint considerations for multiple deployment taskings. Thus, it can be said that the individuals with a lateral trend of high Jaccard similarity scores are “hot” for a deployment tasking. When adding a constraint variable to the matching algorithm, the vertical trends changed;

however, taskings 1 and 7 still contained the most optimally qualified individuals. Positions 8, 14, 17, and 18 did not emerge with higher Jaccard similarity trends when a home-station manning constraint was added. However, officer candidates with home-station officer manning percentages closer to 100 percent became more qualified for a deployment tasking than in the previous simulations.

In response to these observations and trends identified via heat map visualizations, organizational decision-makers have the opportunity to direct training pipelines to promote specific training courses, which could increase the number of optimally qualified civil engineer officers available for deployment taskings. Additionally, with further scrutiny of the taskings with a low number of optimally qualified candidates, individuals can be deliberately tasked to attend particular training courses to increase their qualification optimality further. Furthermore, the heatmap visualizations of the entire deployment tasking solution space, although computationally expensive, gives decision-makers the ability to quickly identify and assess training shortages, gaps, and the force's overall deployment health. Moreover, as the decision-maker sees the solution space get darker in color, they can be confident that they are supplying the most qualified individuals to the combatant commanders who ideally desire to be there.

DSS Validation

Following the validation process, as outlined in Chapter 3, the civil engineer officer candidates were matched to the 20 expeditionary positions mimicking the current deployment tasking process. The results of the manual, unassisted process simulation are shown in Table 5.

Table 6. Deployment Tasking Simulation Matches (Unassisted)

	Current Process
Exp Position No.	**Officer ID**
1	39
2	101
3	104
4	91
5	112
6	93
7	100
8	130
9	199
10	177
11	201
12	2
13	40
14	96
15	41
16	45
17	99
18	103
19	64
20	56

Based on the manual, unassisted matching simulation results in Table 5, the average Jaccard similarity score was computed in R Studio for the officer candidates. Then, the average Jaccard similarity scores of the three progressive matching simulations using the DSS's assisted process were computed. The mean Jaccard similarity scores for the assisted and unassisted matching simulations are shown in Table 6. Additionally, the differences and standard deviations between the unassisted, manual simulation and DSS's

assisted simulations were calculated to compare the “measures of goodness” of the prototype deployment tasking DSS and the manual, unassisted tasking process.

Table 7. Comparison Results of Mean Jaccard Scores

	Qualifications	**Qualifications and Preferences**	**Constraint**
Unassisted	0.13	0.34	0.39
DSS	0.54	0.77	0.77
Difference	0.41	0.43	0.38
Std Dev	0.29	0.30	0.27

Based on the validation procedure, there is evidence to support the prototype deployment tasking DSS developed in this research. The deployment tasking DSS can identify and match officer candidates that are more qualified than the unassisted, manual process, which mimics the current deployment tasking process flow through the MAJCOMs and down to a single base. When matching officers to deployment taskings based on the individual qualifications' objective, the DSS increased the officer matches’ Jaccard similarity scores by an average of 0.41 compared to the unassisted, manual matching process. When matching officers to deployment taskings based on the individual qualifications and personal preferences objective, the DSS increased the officer matches’ Jaccard similarity scores by an average of 0.43 compared to the unassisted, manual matching process. Finally, when matching officers to deployment taskings based on the individual qualifications and personal preferences objective and the home-station manning constraint, the DSS increased the officer matches’ Jaccard similarity scores by an average of 0.38 compared to the unassisted, manual matching process.

In addition to the model validation procedure outlined in Korkmaz et al. (2008), a visual inspection of the officers who matched to the 20 deployment taskings in the final matching simulation was conducted to ensure the DSS could meet the deployment taskings' minimum rank requirements. The results of the visual rank inspection are shown in Table 7.

Table 8. Minimum Requirements Visual Inspection

	Constraint 1 – Home-station Manning	
Exp Position No.	**Officer ID**	**Rank Violations**
1	53	No - exact
2	85	No - exact
3	66	No - one up
4	110	No - exact
5	70	No - one up
6	135	No - exact
7	94	No - exact
8	106	No - exact
9	218	No - one down
10	188	No - exact
11	175	No - exact
12	26	No - exact
13	38	No - exact
14	170	No - exact
15	51	No - exact
16	190	No - exact
17	112	No - exact
18	219	No - exact
19	138	No - one down
20	71	No - exact

From the visual inspection of the deployment tasking matches in Table 7, there were no rank violations, which further validates the matching ability of the DSS. It is permitted for an officer to be one rank above or one rank below the required rank of the deployment tasking. Sixteen of the 20 positions were matched with officers that were the preferred rank of the taskings. Two deployment taskings were matched with officers who were one rank above the desired rank, and two taskings were matched with officers who were one rank below the desired rank, which is acceptable. Upon visual inspection of the final DSS matches, no rank violations were committed, which further demonstrated the DSS capability.

Results of Test Subjects

Despite the challenges of using real-world data in a DSS that operates on a differing methodology, this research's prototype DSS successfully scored ten years of deployment tasking data from Dyess Air Force Base. Using the criteria of required rank and preferred training and the home-station manning constraint, the 23 civil engineer officers were scored against the seven rotational deployment taskings. The results demonstrated the prototype DSS's ability to determine which officers were the most qualified for the deployment taskings based on their Jaccard similarity scores.

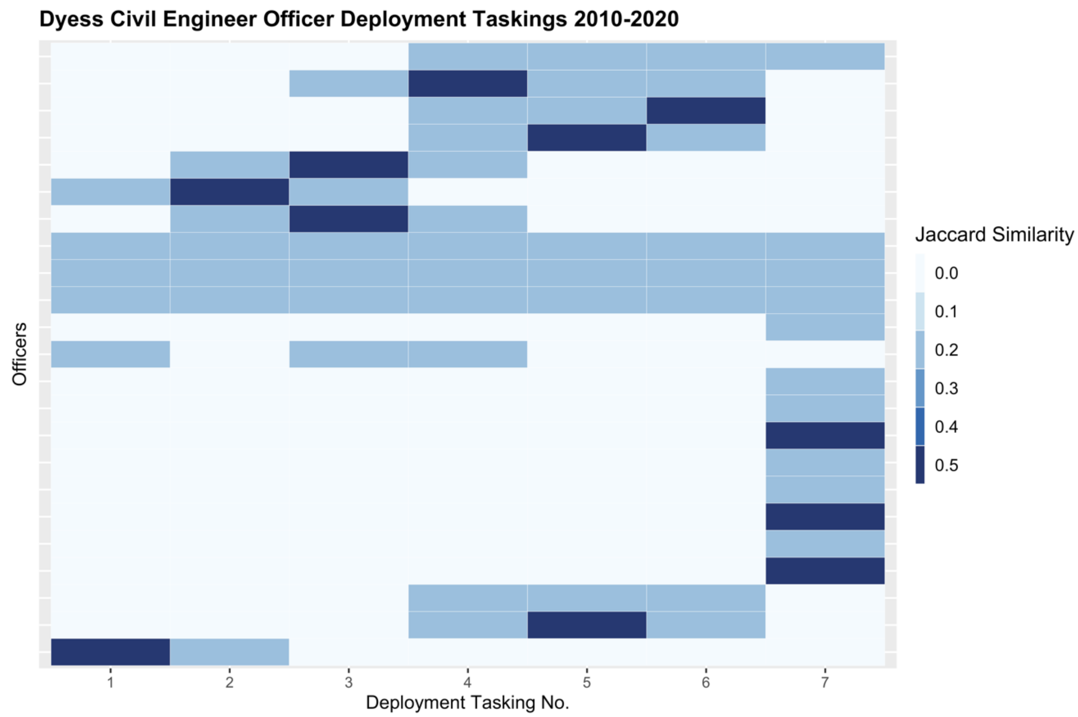

Figure 19. Visualization of Dyess Civil Engineer Officer Deployment Taskings

Based on the test subjects' results in Figure 19, deployment tasking number 7 had the most qualified individuals, and number 1 had the least qualified individuals. When deployment taskings 7 and 1 were examined further, tasking number 7 was a readiness flight commander position, and tasking number 1 was an expeditionary civil engineer squadron commander position. These results are plausible as the required rank for the readiness flight commander was an O-2, and the required rank for the expeditionary squadron commander position was an O-5. In civil engineer squadrons, there is typically only one O-5; thus, there should only be one optimally qualified candidate. Conversely, since there are multiple officers in a civil engineer squadron in the ranks O-1, O-2, and O-3, the number of qualified candidates for a deployment tasking with a required rank of O-2 should be relatively high. Despite having only three variables to compare against, the prototype deployment tasking DSS could score the officers against the taskings to

produce optimality measures via Jaccard similarity scores. Compared to the simulations used in the prototype DSS development, which demonstrated 11 decision variables, the test subjects' Jaccard similarity scores were reduced when the number of available decision variables was reduced. The dark blue color indicated a high score is 0.5 in Figure 19. In the simulations, the dark blue color indicated a Jaccard similarity score of close to 1.

The testing scenario results using civil engineer officer deployment data from Dyess Air Force Bases identified the current deployment tasking process's problems. By sending taskings down to a single squadron, the solution space becomes limited. Furthermore, by giving a squadron commander limited time and information on the deployment tasking and limiting the solution space to a single squadron, their ability to make an optimal selection is limited as taskings are matched in isolation from other taskings. If the entire solution space is examined by comparing a few hundred officers, it is possible to generate many optimized solutions as demonstrated in the simulations.

Investigative Questions Answered

In addition to developing a deliberate, systematic methodology for the current deployment tasking process of U.S. Air Force civil engineer officers through a prototype decision-support system, this research examined the following investigative questions:

1. Why is a decision-support system needed to assist assignment detailers and squadron commanders in matching personnel to deployment taskings?
2. In addition to individual qualifications, what other factors could be considered in a deployment tasking decision-support system?

3. Which personnel assignment models are suitable to optimize individual qualifications while also considering personal preference considerations?

4. What challenges and limitations are associated with implementing a new deployment tasking methodology on the current process?

The comprehensive literature review presented in Chapter 2 answered the first two investigative questions. Robards (2011) found that it is probable that the quality of human decisions will be degraded unless aided by a decision-support system in making assignment decisions where cognitive limits are reached. Additionally, it was learned that when assignment decisions are to be made, and there are multiple criteria to be considered for each assignment, the matching process quickly becomes a complicated process for assignment detailers (Robards, 2011). Because this research's objectives constituted a series of complex personnel assignment decisions, it was determined that a decision-support system was needed to match civil engineer officers to deployment taskings. Moreover, Parker (2012) answered the second investigative question in his paper by identifying other criteria that a prototype deployment tasking model could consider in addition to professional qualifications. Parker (2012) described some criteria that squadron commanders informally use in selecting individuals for deployment taskings such as "dwell time, home-station duties, and timing of significant life events (wedding, childbirth, attendance at professional military education school, etc.)" (p. 69).

Furthermore, by conducting a comprehensive literature review of the potential models equipped to solve personal assignment problems in Chapter 2 and developing a prototype deployment tasking DSS in Chapter 3, the third investigative question was

answered. Additionally, the results of Chapter 4 demonstrated that the Jaccard similarity function proved capable of matching officers to deployment taskings while optimizing objective variables in addition to considering constraints variables. Although network flow models have demonstrated success in military personal assignment models in the past, the age of machine learning has emerged. Finally, to answer investigative question number four, this research used 10 years of deployment tasking data from Dyess Air Force Base to identify the challenges and limitations of implementing the prototype deployment tasking DSS. Although capable of scoring officers in its current state, the prototype DSS performs best when comparing more criteria and personnel and examining the entire solution space.

Summary

This chapter presented the analysis and results of the simulations used to develop, configure, and validate the decision-support system proposed in this research. Additionally, this chapter analyzed the results of ten years of civil engineer officer deployment data using the prototype DSS to discuss the feasibility and challenges of using the DSS on the current deployment tasking process. Finally, this chapter reviewed the investigative questions presented in the first chapter.

V. Conclusions and Recommendations

Research Conclusions

This thesis focused on developing a deliberate, systematic methodology for the current deployment tasking process of U.S. Air Force civil engineer officers by providing a prototype decision-support system (DSS) capable of matching officers to deployment taskings by maximizing an officer's individual qualifications while maximizing an officer's preference considerations; thus, providing the combatant commanders with the most qualified officers who ideally desire to be there. Additionally, this research applied a realistic constraint variable by considering an officer's home-station officer manning. Finally, this research used real-world deployment data to examine the feasibility and challenges of utilizing the prototype DSS on the existing deployment tasking process.

First, Chapter 2 evaluated human decision-making and a thorough analysis of the current deployment tasking process to understand how a DSS could support the current process. Additionally, this chapter presented a brief overview of the personnel assignment problem and personnel management research in the Air Force to understand the problem's historical context. Finally, Chapter 2 provided an in-depth examination of personnel assignment models and decision-support systems to determine an appropriate DSS construct and an assignment matching algorithm.

Chapter 3 presented the research methodology for the prototype DSS construction, personnel management information system (MIS), data simulation, matching framework, matching criteria, matching algorithm, decision-support system formation and validation, matching visualizations, and the test subjects. Chapter 4 presented an analysis and results of the simulations used to develop, configure, and

validate the DSS. Additionally, the results of 10 years of civil engineer officer deployment data were presented and analyzed using the prototype DSS to examine the feasibility and challenges associated with implementing the DSS on the current deployment tasking process. Finally, the investigative questions presented in the first chapter were reviewed.

Research Contributions

The contribution of this research is that it provides U.S. Air Force academia with a prototype deployment tasking DDS capable of matching personnel to deployment taskings while extending beyond minimum requirements selection criteria through a deliberate, systematic process that is scalable and adaptable to the needs of a decision-maker. Consequently, there is a potential for increased stability and transparency in the deployment tasking process, which could improve retention. In addition to matching officers to deployment taskings, this research's novelty provided visualizations of the entire solution space. The visualizations could allow decision-makers to quickly determine which deployment taskings have shortages, gaps, and overages in available, qualified personnel. In response to the observations made through heat map visualizations, a decision-maker could direct training programs to be more deliberate, tailored, and targeted towards supporting the combatant commander with the most qualified officers for their positions.

Recommendations for Action

A recommendation for action as a result of this research is to partner with the Air Force’s Talent Marketplace development team to explore the feasibility of adding a deployment module to the talent management system. Additionally, it is recommended

that partnerships be developed with civil engineer training programs to propose using heat maps as a methodology to identify shortages, gaps, and overages in training courses needed to prepare civil engineer officers for deployment taskings better.

Recommendations for Future Research

Expansion

This research could be expanded and modified to incorporate the tasking of enlisted personnel to expeditionary positions. Enlisted personnel have defined skill levels that could serve as an objective variable in matching personnel to positions based on individual qualifications. Additional objective variables, such as foreign language proficiencies and command evaluations, could also be considered. Moreover, surveys could be conducted to increase the fidelity of the objective variables. However, a disadvantage of surveys is that the strength of the information obtained is limited, as the results are only valid for a singular point in time. Additionally, this research could be expanded and modified to utilize other personnel assignment models to develop a comparative analysis. Furthermore, this research could be expanded by performing a statistical analysis on deployment tasking reclama process. Finally, an expansion incorporating the newly published civil engineer officer core competencies into the expeditionary position criteria could be studied. As civil engineer officers achieve core competencies, they could become more qualified for deployment taskings.

Clustering

Another area for future research is examining clustering algorithms to see if they are capable of matching officers to deployment taskings. Bindi et al. (2007) studied the clustering of optimal solutions using Jaccard similarity for the assignment problem in

warehousing systems (Bindi et al., 2007). This method could be explored using a personnel assignment problem. Combined with the heatmaps, there is potential to superimpose a dendrogram from a clustering algorithm on top of a heatmap to provide further visual information to a decision-maker.

Real-World Experiment or Case Study

Finally, this research could be expanded beyond using simulations and past deployment data. An expeditionary location could be identified for a case study to formulate optimal position requirements, then apply a search process over the entire solution space. It is not recommended that the squadron commander's authority be usurped; however, it is recommended that the search process begins at the Air Force level to identify optimally qualified candidates.

Research Summary

In summary, the argument presented in this research is that a deliberate, systematic methodology is better than a process that is "more akin to rolling dice than following a deliberate procedure" (Parker, 2012). To that end, this research presented a prototype decision-support system in response to the first course of action identified in Parker (2012) to support the combatant commanders with the most qualified individuals. Additionally, this research used U.S. Air Force civil engineer officers as a case study to develop a prototype decision-support system. Upon configuring and validating the prototype DSS with simulated data, the DSS scored past deployment tasking to demonstrate its capability on the current deployment tasking process. However, the DSS was configured to consider more qualification and preference criteria than formally exist in the current process. Unless the Air Force implemented this prototype DSS on the real-

world deployment tasking process, it cannot be said that this research's DSS improves the current process as there would have to be a comparative study to demonstrate evidence for improvement. Nonetheless, this research's prototype deployment tasking DSS provides a potential solution for a more deliberate and systematic methodology that achieves the objectives of Tenant A: Airman in the CSAF's Action Orders *Accelerate Change or Lose*.

Appendix

Simulated Deployment Taskings:

EXP_POSITION MINIMUM REQUIREMENTS AND DESIRED QUALIFICATIONS

Position_ID	Position_Title	Minimum Reqt's (Acceptable Ranks)	Desired Quals (PROF)	Desired Quals (TRNG)	Desired Quals (EDU)	Desired Quals (HOMESTAT_POSITION)
1	Expeditionary Civil Engineer Group (ECEG) Design Cell Chief (Maj)	Capt - Lt Col (3-5)	FE (1)	CONT_FAC_DSN (481)	NULL	Engineer Flt Deputy/CC (3)
2	Expeditionary Civil Engineer Group (ECEG) Design Cell Civil Engineer (Capt)	1Lt - Maj (2-4)	PE_CIVIL_GEO (13)	CONT_FAC_DSN (481)	CIVIL ENG,SOIL&FOUNDATION (1200)	Project Engineer (1)
3	Expeditionary Civil Engineer Group (ECEG) Design Cell Mechanical Engineer (Capt)	1Lt - Maj (2-4)	PE_MECH (6)	CONT_FAC_DSN (481)	MECH ENG,THE/HT T,AIR COND (1384)	Project Engineer (1)
4	Expeditionary Civil Engineer Group (ECEG) Design Cell Electrical Engineer (Capt)	1Lt - Maj (2-4)	PE_ELEC (5)	CONT_FAC_DSN (481)	ELEC ENG,EGY CON/DIS,OTHER (1254)	Project Engineer (1)
5	Expeditionary Civil Engineer Group (ECEG) Design Cell Structural Engineer (Capt)	1Lt - Maj (2-4)	PE_CIVIL_STRUCTURAL (3)	CONT_FAC_DSN (481)	CIVIL ENG,STRUCTURAL,DESIG (1202)	Project Engineer (1)
6	Expeditionary Civil Engineer Group (ECEG) Design Cell Architect (Capt)	1Lt - Maj (2-4)	PE_ARCH_ENGR (8)	CONT_FAC_DSN (481)	ARCH ENG,CY&RGN PLN,CITY PL (1059)	Project Engineer (1)
7	Expeditionary Civil Engineer Group (ECEG) Project Manager (Capt)	1Lt - Maj (2-4)	PMP (2)	PROJECT_MGT (422)	NULL	Project Engineer (1)
8	Expeditionary Pavement Evaluation Team Leader (Capt)	1Lt - Maj (2-4)	PE_CIVIL_TRANSPO (12)	PAVEMENT_INSP (555)	CIV ENG,TRANS&TRAF,AIR SYS (1211)	NULL
9	Expeditionary Pavement Evaluation Team Member (1Lt)	2Lt - Capt (1-3)	NULL	PAVEMENT_INSP (555)	NULL	NULL
10	Expeditionary Civil Engineer Squadron (ECES) Project Programmer (1Lt)	2Lt - Capt (1-3)	NULL	PROJECT_PROGRAMMING (423)	NULL	Project Programmer (2)
11	Expeditionary Civil Engineer Squadron (ECES) Community Planner (1Lt)	2Lt - Capt (1-3)	NULL	COMPREHENSIVE_PLANNING (520)	ECON,LAND,REGION/URBA PLAN (2707)	NULL
12	Expeditionary Civil Engineer Squadron (ECES) Commander (Lt Col)	Maj - Col (4-6)	NULL	CONT_ENGR_CMD (585)	NULL	Squadron Commander (8)
13	Expeditionary Civil Engineer Squadron (ECES) Operations Flight Commander (Maj)	Capt - Lt Col (3-5)	NULL	OPS_FLT_CC (430)	NULL	Director of Operations (5)
14	Expeditionary Civil Engineer Squadron (ECES) Engineering Flight Commander	1Lt - Maj (2-4)	NULL	ENGR_FLT_CC (420)	NULL	Engineer Flt Deputy/CC (3)
15	Expeditionary Civil Engineer Squadron (ECES) Deputy Commander (Maj)	Capt - Lt Col (3-5)	NULL	CONT_ENGR_CMD (585)	NULL	Director of Operations (5)
16	Expeditionary Civil Engineer Squadron (ECES) Chief of Operations Engineering	2Lt - Capt (1-3)	NULL	BUILDER_LV2_ASSESSOR (231)	NULL	Operations Engineering Element Chief (4)
17	Expeditionary Staff Officer (Capt)	1Lt - Maj (2-4)	NULL	NULL	NULL	NULL
18	Expeditionary Joint Staff Officer (Capt)	1Lt - Maj (2-4)	NULL	JOINT_ENGR_OPS (590)	NULL	NULL
19	Expeditionary Staff Officer (Maj)	Capt - Lt Col (3-5)	NULL	NULL	NULL	NULL
20	Expeditionary Joint Staff Officer (Maj)	Capt - Lt Col (3-5)	NULL	JOINT_ENGR_OPS (590)	NULL	NULL

Database Attribute Tables:

RANK DATA

Rank_No	Rank_Title
1	2nd_Lieutenant
2	1st_Lieutenant
3	Captain
4	Major
5	Lieutenant_Colonel
6	Colonel

PROF_QUAL DATA

QUAL_ID	QUAL_NAME
1	FE
2	PMP
3	PE_CIVIL_STRUCTURAL
4	PE_ENVIRO
5	PE_ELEC
6	PE_MECH
7	PE_MATERIALS
8	PE_ARCH_ENGR
9	PE_FIRE
10	PE_INDUSTRIAL
11	PE_CIVIL_CONSTRUCTION
12	PE_CIVIL_TRANSPO
13	PE_CIVIL_GEO
14	PE_CIVIL_WATER
15	PE_CONTROL_SYS
16	CSSGB
17	CSSBB
18	LEED_GREEN_ASSOCIATE
19	LEED_AP
20	FMP

EDU DATA

EDU_ID	EDU_CODE	EDU_ABBREVIATED_TITLE	EDU_LONG_TITLE
444	2CAB	F & A ARTS,ARCH,CTY,REG,IND	CITY, REGIONAL AND INDUSTRIAL PLANNING, ARCHITECTURE
446	2CAD	F & A ARTS,ARCH,LANDSCAPE	LANDSCAPE, ARCHITECTURE
449	2CAY	ARCHITECTURE	ARCHITECTURE
1059	4DAA	ARCH ENG,CY&RGN PLN,CITY PL	CITY PLANNING, ARCHITECTURAL ENGINEERING
1060	4DAB	ARCH ENG,CY&RGN PLN,RGN PLN	REGIONAL PLANNING ARCHITECTURAL ENGINEERING
1061	4DAC	ARCH ENG,CY&RGN PLN,URB DES	URBAN DESIGN ARCHITECTURAL ENGINEERING
1062	4DAX	ARCH ENG,CY&RGN PLN,OTHER	ARCH ENGINEERING, CITY AND REGIONAL PLANNING, OTHER
1063	4DAY	ARCH ENG,CITY&REGIONAL PLAN	CITY AND REGIONAL PLANNING, ENGINEERING
1200	4HFY	CIVIL ENG,SOIL&FOUNDATION	SOIL AND FOUNDATION ENGINEERING
1202	4HGB	CIVIL ENG,STRUCTURAL,DESIG	STRUCTURAL DESIGN CIVIL ENGINEERING
1211	4HIA	CIV ENG,TRANS&TRAF,AIR SYS	AIR SYSTEMS
1219	4HYY	CIVIL ENGINEERING	CIVIL ENGINEERING
1252	4IEE	ELEC ENG,EGY CON/DIS,PWR/SY	POWER SYSTEMS
1254	4IEX	ELEC ENG,EGY CON/DIS,OTHER	ELECTRICAL ENGINEERING,ENGERGY CON,DISTRIBUTION,OTHER
1255	4IEY	ELEC ENG,ENGY CONV & DISTR	ENERGY CONVERSION AND DISTRIBUTION
1318	4LBD	IND ENG,ENG ECON,IND ORGAN	INDUSTRIAL ORGANIZATION, INDUSTRIAL ENGINEERING
1384	4MIA	MECH ENG,THE/HT T,AIR COND	AIR CONDITIONING AND REFRIGERATION
1394	4MYY	MECHANICAL ENGINEERING	MECHANICAL ENGINEERING
2705	9BFB	ECON,LAND,GEOGRAPHY	ECONOMIC GEOGRAPHY, LAND ECONOMICS
2706	9BFC	ECON,LAND,NATURAL RESOURCES	NATURAL RESOURCES
2707	9BFD	ECON,LAND,REGION/URBA PLAN	REGIONAL AND URBAN PLANNING

HOMESTAT_POSITION DATA

Position_ID	Position_Title
1	Project Engineer
2	Project Programmer
3	Engineering Flt Deputy/CC
4	Operations Engineering Element Chief
5	Director of Operations
6	Installation Mgt Flight/CC
7	Readiness Flt/CC
8	Squadron Commander

TRNG_ID	TRNG_CAT	TRNG_NAME
440	WENG	ROOF_DSN
481	WENG	CONT_FAC_DSN
550	WENG	PAVEMENT_DSN
555	WENG	PAVEMENT_INSP
500	WMSS	PE_REVIEW
519	WENG	INSTALLATION_PLANNING
131	WMGT	SMS_LV1_READ_ONLY
141	WMGT	PAVER_LV1
231	WMGT	BUILDER_LV2_ASSESSOR
301	WMGT	ASSET_MGT
331	WMGT	BUILDER_LV3_MGR
412	WMGT	FM_FUNDAMENTALS
417	WMGT	AMPS
424	WMGT	REAL_PROPERTY
436	WMGT	REQTS_AND_OPT
513	WMGT	FM_LEADERS
470	WENG	ELEC_SYS_INTRO
572	WENG	POWER_SYS_DSN
573	WENG	ELEC_PWR_DISTRO_DSN
576	WENG	ELEC_PWR_SYS_DSN_CAP
160	WENV	RECYCLING
222	WENV	HAZMAT_MGT
521	WENV	HAZ_WASTE
531	WENV	AIR_QUAL_MGT
532	WENV	AIR_QUAL_MGT_ADV
541	WENV	WATER_QUAL_MGT
10	WESS	RCRA
31	WESS	STORMWATER
70	WESS	HAZMAT_SEMINAR
542	WESS	ENVIRO_QUAL
102	WENV	ENVIRO_INTRO
175	WENV	CONT_ENVIRO_MGT
220	WENV	UEC
350	WENV	ENVIRO_AUDITING
418	WENV	ENVIRO_CONTRACTING
450	WENV	EAIP_ANALYSIS
150	WESS	EAIP_SEMINAR
21	WENV	ENVIRO_RESTORE_INTRO
419	WENV	ENVIRO_RESTORE_PM
441	WENV	ENVIRO_SAMPL_DSN
409	WMGT	READINESS_EM_PRINCIPLES
410	WMGT	READINESS_FLT_CC
427	WMGT	FIRE_EM_SUPT
433	WMGT	EOD_FLT_CC
585	WMGT	CONT_ENGR_CMD
590	WMGT	JOINT_ENGR_OPS
206	WHSS	HOUSING_REFFFERAL_MGT
207	WHSS	FURNISHINGS_MGT
312	WHSS	PRIVATIZED_HOUSING_MGT
314	WHSS	OCONUS_HOUSING_MGT
324	WHSS	MIL_HOUSING_INSP
404	WHSS	GO_QUARTERS_MGT
402	WMGT	UNACCOMP_HOUSING_LDRSHIP
406	WMGT	HOUSING_MGT
101	WMGT	AF_CE_BASIC_COURSE
400	WMGT	CC_DEPUTY_COURSE
420	WMGT	ENGR_FLT_CC
430	WMGT	OPS_FLT_CC
533	WMGT	INSTALLATION_FLT_CC
570	WMGT	CE_SUPT
571	WMGT	OPS_FLT_CIV_SUPERVISOR
600	WMSS	ADV_BASE_CE_SEMINAR
670	WMSS	CE_SUPT_SEMINAR
700	WMSS	SENIOR_CE_OFFICER_SEMINAR
460	WENG	MECH_INTRO
466	WENG	FAC_MAN
560	WENG	HVAC_FUNDAMENTALS
561	WENG	HVAC_APPLICATIONS
563	WENG	HVAC_CONTROLS
464	WTSS	ENERGY_MGT
200	WENG	SCOPING_ESTIMATION
520	WENG	COMPREHENSIVE_PLANNING
423	WMGT	PROJECT_PROGRAMMING
480	WMGT	HIGH_PERFORMANCE_BLDGS
201	WTSS	PACES
518	WTSS	ENCROACHMENT_MGT
401	WENG	LIFE_CYCLE_COST_ESTIMATION
501	WENG	COST_ENGINEERING
322	WMGT	PROJECT_MGT_INTRO
421	WMGT	CONTRACTING
422	WMGT	PROJECT_MGT
437	WMGT	TROOP_CONSTRUCTION

Preference_1_ID	Desire_to_Deploy
1	No_Desire
3	Little_Desire
5	Moderate_Desire
7	Strong_Desire
9	Extremely_Strong_Desire

Preference_2_ID	Dwell_Time (months)
1	6
2	12
3	18
4	24
5	30
6	36
7	42
8	48
9	54
10	60
11	66
12	72

Preference_3_No_Deployments
0
1
2
3
4
5
6
7
9
8
10

Preference_4_ID	Added_Dependent_<=1yr
0	No
1	Yes

Preference_5_ID	Prof_License_Testing_<=1yr
0	No
1	Yes

Dyess Deployment Data:

Exp_Position_No	Exp_Position_Name	Exp_Position_Rank	Preferred_Training_Quals	Preferred_Homestat_Manning
1	ECES/CC	5	585	1.0
2	ECEG Deputy CC	4	585	1.0
3	ECEG Operations CC	4	430	1.0
4	Operations Engineering Flight/CC	3	331	1.0
5	Engineering Flight/CC	3	420	1.0
6	SOCENT Engineering Liason	3	590	1.0
7	Readiness Flight/CC	2	410	1.0

Officer_ID	Rank_No	Trng_Qual	Homestat_Manning
1	5	585	0.8
2	5	430	0.8
3	4	430	0.8
4	4	585	0.8
5	4	430	0.8
6	3	420	0.8
7	3	590	0.8
8	3	430	0.8
9	3	410	0.8
10	3	420	0.8
11	3	331	0.8
12	2	410	0.8
13	2		0.8
14	2	410	0.8
15	2	331	0.8
16	2		0.8
17	2	410	0.8
18	2		0.8
19	2	331	0.8
20	2		0.8
21	1	331	0.8
22	1		0.8
23	1		0.8

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14. ABSTRACT
The Armed Forces frequently deploy their personnel to expeditionary locations around the world. For example, the Air Force tasks its personnel to deploy based on a six-month rotational cycle. In the current tasking process, the deployment makes its way down from combatant commanders to squadron commanders through the chain of command. The commander then has a few days to select an individual from their unit to fill the tasking. The commander may consider an individual's dwell time, home-station position, and upcoming significant life events; however, because commanders have little time and information, minimum requirements selection criteria often become the driving force. Additionally, the commander must select an individual in isolation from other taskings, and the search space is restricted to one unit, leaving no opportunity to optimize the process. This thesis presents and evaluates a prototype decision-support system for the deployment tasking process of Air Force civil engineer officers. The prototype system extends beyond the minimum requirements selection criteria to optimize an officer's professional qualifications and personal preference considerations across the entire enterprise while considering home-station manning constraints. Finally, this research uses past deployment tasking data to examine the feasibility of utilizing the decision-support system on the current tasking process.

15. SUBJECT TERMS
Decision-support system, personnel assignment problem, military, deployments, U.S. Air Force, civil engineering, Jaccard similarity, optimization

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