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USAF FMS Manpower Analysis: Manpower Ratios and Linear Regression

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THESIS

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Abstract

This research studies the relationships between Air Force Foreign Military Sales (FMS) case factors and manpower authorizations. The Air Force FMS program has seen consistent annual increases in sales since 2017 and average annual growth of 7 percent since 2006. Manpower is a key factor in the continued success of the FMS program. The need to predict future manpower requirements and the lack of prior research in this area motivates this exploratory analysis to determine which FMS case factors are potential candidates to predict manpower needs. An initial comparison analysis of the available FMS case data was conducted, followed by the application of two commonly utilized manpower modeling methods: regression analysis and manpower ratios. A comparison analysis provided a common unit of analysis for case data and manpower data, Program Executive Office (PEO). It also provided a range of potential predictors of manpower with high correlations to manpower authorizations. A linear regression analysis determined total case value, case counts, and case density were useful in modeling the changes in manpower authorizations. An examination of potential manpower ratios for the Air Force FMS program suggests these ratios should be considered for additional research as the sample provided demonstrated a relative level of stability over time. This research provides a modern foundation for Air Force FMS manpower research and a better understanding of which case factors are useful for FMS manpower planning.

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Carlos A. Esguerra

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USAF FMS MANPOWER FACTOR ANALYSIS WITH MANPOWER RATIOS AND REGRESSION

I. Introduction

Background

The United States uses the sale and transfer of defense articles and services to allies and partners as a foreign policy tool to strengthen national and regional security, promote the defense industry, and lower U.S. military procurement costs. The U.S. Air Force's Foreign Military Sales (FMS) program fulfills its role in these transfers via numerous organizations and offices located around the world. To ensure it continues meeting its ever-growing mission, the United States Air Force (USAF) FMS program must plan strategically, especially when it comes to one of its most valuable resources – its personnel.

Long-term manpower planning is as much an art as it is a science. It can require vast amounts of data and be both time consuming and limited by its assumptions. Models which predict manpower requirements can incorporate information from a wide range of sources often requiring the collection of vast amounts of complex data. However, without some form of long-term manpower forecasting strategy, organizations are left reacting to manpower demands rather than preparing for them. Manpower requirements can be driven by factors such as volume of sales or customers which are dependent on the specific organization, its processes, environment, and demands. The first phase in manpower planning involves examining influential factors and gaining a better understanding of them (Morton, 1968). Only with a clear understanding of these factors and their impact on manpower requirements can an organization begin determining the strategy to forecast manpower needs. This research effort focuses on analyzing USAF FMS workload factors and their relationship with manpower requirements. Note for this study, manpower authorizations were used as a measurement of manpower requirements.

After a review of the literature on manpower forecasting, four common methodologies were selected based on their use in government and non-government applications: ratio analysis, regression analysis, Markov chains, and simulations. The various strengths, weaknesses, and applications of each method will be discussed in Chapter II. The selection of a given method is largely dependent on the organization, its manpower strategy, data availability, and its manpower planning capability (Emmerichs et al., 2004). However, the foundation of any methodology begins with identifying factors which contribute to manpower requirements (Morton, 1968). These factors can then provide manpower analysts a framework from which to forecast an organization's manpower needs. Therefore, this research provides an initial understanding of USAF FMS factors, tests the application of manpower ratios, and examines the relationship between selected factors and manpower authorizations using linear regression.

The USAF FMS program has a multibillion-dollar portfolio with impacts across the globe. As this portfolio continues expanding, it becomes more critical for the Secretary of the Air Force for International Affairs (SAF/IA) to plan for future manpower requirements across the enterprise. The last comprehensive manpower study available for the Department of Defense (DoD) FMS enterprise was conducted in 1979. By providing an analysis of FMS factors and applying two of the reviewed methodologies, this study will provide a modern foundation for further research.

Problem Statement

The USAF FMS program continues expanding annually in terms of overall case values and number of cases. As this growth continues, the USAF FMS community faces a personnel resource constraint with potential negative effects to its mission. The USAF FMS enterprise must incorporate strategic manpower planning into its overall mission strategy. This research is the initial effort to provide an analysis of available case factors and a better understanding of their relationship with FMS manpower requirements for future USAF FMS manpower research.

Research Objectives

To establish key FMS manpower factors and provide a framework for further study, these questions are examined:

1. Which manpower forecasting methodologies are best suited to forecast FMS manning using the currently available data?
2. Which FMS factors can be utilized as indicators of manpower requirements?
3. How should these factors be categorized or organized for further study of FMS manpower requirements?
4. What trends can be identified for these factors and manpower requirements?
5. What are the results of applying modern manpower forecasting techniques to FMS manpower data?

Methodology

Statistical analysis was conducted on data collected from the Air Force Security and Cooperation Directorate (AFSAC). Data included FMS case information from 2005 to 2020 and manpower authorizations from 2015 to 2020 for the Air Force Life Cycle Management Center (AFLCMC). A review of relevant literature and FMS data availability was used to answer question 1. The methods of manpower ratios and linear regression were selected to study the additional research questions. Factor analysis was conducted to answer research questions 2-4.

The factor analysis began with calculating descriptive statistics to identify trends and potential sources of variance in the data. Statistical tests for a difference in means were then conducted to confirm a significant difference by PEO, geographical region, and case complexity categories. Additionally, the relationship between selected workload indicators and manpower was examined with a correlation table for the years manpower data was available. The factors analyzed were used in a regression analysis and the results were used to recommend future research on this topic. This was followed by the generation of manpower ratios using the factors analyzed and the number of manpower authorizations. Manpower ratios were then tested for their level of variance. The results of the linear regression and the generation of manpower ratios were used to answer question 5.

Scope and Limitations

Data was collected from Case Management Control System (CMCS) reports collected by AFSAC's metrics team. These reports provide comprehensive detail at for each line item on every active case in the USAF FMS portfolio from 2006 to 2020. The CMCS reports provide line values and categorical information such as the assigned PEO and country receiving the defense articles or services. They were generated monthly and consolidated by calendar year. The data provided most of the desired level of detail for case execution data. However, some factors that were not captured by the data might prove useful for future manpower research. These include an indication of whether congressional notification was required, the source of funding (i.e., host nations funds versus U.S. foreign aid), and number of personnel assigned for each FMS case. It should also be noted, congressional notification (CN) requirements and Anticipated Offer Date (AOD) codes were added to the data by leveraging the DSCA Security Assistance Management Manual's thresholds for CN and AFSAC's AOD guide.

Data was also collected from Unit Manning Documents (UMDs) provided by AFSAC's Human Resources office. It included details for each manpower authorization to all FMS organizations under the Air Force Life Cycle Management Center (AFLCMC) from 2015 to 2020. While the manpower data provided a total number of personnel authorized with categorical identifiers, such as PEO and individual program office, it did not provide information for number of personnel assigned by FMS case or region. Additionally, the actual number of personnel currently assigned was also not available for this study. The UMD files only provide the number of authorized personnel.

Thesis Overview

The USAF FMS program is an important foreign policy tool with political and economic impacts around the world. Without a long-term strategic manpower plan, its effectiveness over time will be challenged. As customer demand continues to grow, the FMS enterprise will be strained without the required number of personnel. An analysis of its factors and the application of manpower ratios and linear regression will provide a data-driven foundation for future FMS manpower research.

The following chapters will provide information on the USAF FMS program, manpower forecasting, and the process used to analyze available manpower factors. Chapter II includes background on the USAF FMS enterprise and a review of previous research on general manpower forecasting. The information provided in Chapter II will assist the reader by providing context for the analysis in the following chapters. Chapter III discusses the specific data and factors selected for study and the process used to analyze those factors. It covers the logical relationships between factors, the grouping of data used for this study, the generation of manpower ratios, and the use of regression analysis to examine the relationship between the selected factors and historical manpower authorizations. Chapter IV details the findings of the factor analysis, summarizes the results of the manpower ratio variance test, and describes the results of the linear regression. Finally, a summary of the analysis and answers to the research questions is provided. Additionally, suggestions for future research are provided. The goal of this study is to provide the USAF FMS enterprise with a better understanding of its case factors and their relationship with future manpower requirements.

II. Literature Review

Chapter Overview

The FMS program's goal is to sell defense articles and services to foreign partners, and in doing so to boost international relationships, foster cooperation, and strengthen U.S. national security. FMS sales have been growing significantly; from 2016 to 2020, FMS Sales increased 33% increase (DSCA, 2020c). The people who carry out this mission are a vital piece of the FMS puzzle. As the overall USAF FMS portfolio value increases, the USAF FMS enterprise will need to formulate a strategy to ensure they have the right number of qualified professionals in the future. Due to the international attention the FMS program garners, and the billions of dollars involved in these agreements, its success is critical to the U.S. and its international partners. This research endeavors to better understand FMS case factors and applying modern manpower forecasting techniques to the available FMS data.

To understand the analysis conducted in this research it is important to understand how the USAF FMS enterprise is structured, its background and processes. It is also critical to have some understanding of manpower forecasting, its background, its potential limitations and issues, and more commonly utilized manpower forecasting methodologies. This chapter will provide the context needed for the following analysis and results.

USAF FMS

FMS is a foreign policy and national security tool utilized by the U.S. Department of State (DoS) to transfer defense articles and services to international partners and organizations. The FMS program is fully funded by foreign purchasers via an administrative charge on FMS cases as well as direct charges on cases for specific services above a standard level of service

(DSCA, 2020b). The FMS program is authorized by Congress under the Arms Export Control Act (AECA). It attempts to provide foreign customers with similar contract benefits and protections as the U.S. military; it also bolsters U.S. national security via improved partner nation relationships and better weapon system interoperability (Congressional Research Service, 2020).

The USAF FMS portfolio includes 110 partner nations and has a total value of over $182 billion (AFSAC, 2020b). Personnel working within these programs interact daily with foreign partners and the U.S. defense industry to facilitate multi-million and billion-dollar sales. To understand the analysis completed in this research and its application to the USAF FMS enterprise, it is essential to be familiar with its organizational structure and processes, economic impacts, and the specific FMS manpower factors selected for study.

Organizational Structure and Roles

While the USAF FMS program is executed by several organizations, it starts with its two implementing agencies: the Air Force Security and Cooperation Directorate (AFSAC) and the Air Force Security Assistance Training Squadron (AFSAT). AFSAC and AFSAT are responsible for the development of partner nation requests into formal FMS cases. Execution of FMS cases is typically the responsibility of program offices which are organized by weapon system or other supporting defense system. It is worth noting that a significant portion of cases are also executed by AFSAC and AFSAT. Oversight for both case development and execution is provided by DSCA and the Department of State (DoS). An additional layer of oversight and direction is provided by SAF/IA.

As AFSAC, AFSAT, and the various program offices are responsible for the day-to-day execution of FMS cases. The analysis in this research is conducted at the PEO level to focus on this tactical level of work. Note AFSAC and AFSAT were treated as PEOs. AFSAC and AFSAT are both unique in their dual roles of case development and execution. Each of these organizations is responsible for accepting partner nation requests and either developing new FMS cases or amending existing cases to support those requests. The difference between these organizations lies in the type of FMS cases they support. AFSAT is responsible for training cases; these are cases that allow international students to attend USAF training programs such as USAF pilot training or USAF professional military education (AFSAT Fact Sheet, 2015). AFSAC supports all other USAF FMS cases which includes both products (e.g., aircraft and armament) and services (e.g., aircraft maintenance). Both AFSAT and AFSAC are organized by country or region. These region/country teams are then assigned personnel based on management's perceived workload for each region/country.

Program offices fall under the Air Force Acquisition community and report to Program Executive Officers (PEOs). PEOs are assigned portfolios with functionally similar weapon and defense systems; for example, the Mobility PEO is responsible for cargo aircraft such the C-17, C-130, and C-5. Typically, each of these individual systems have a program office responsible for its procurement or any major system changes. The personnel structure can vary within FMS program offices where teams are organized by region and/or workload. These offices are typically staffed according to the number and type of cases assigned. The amount of staffing required per FMS case is typically determined prior to case implementation and is based on historical staffing levels and expert opinion (DSCA, 2020a). A simplified organizational chart is provided in Figure 1 for the organizations discussed above. Note that the dotted lines represent working relationships between organizations and not a direct reporting relationship. The green box indicates the organizational level of analysis for this study.

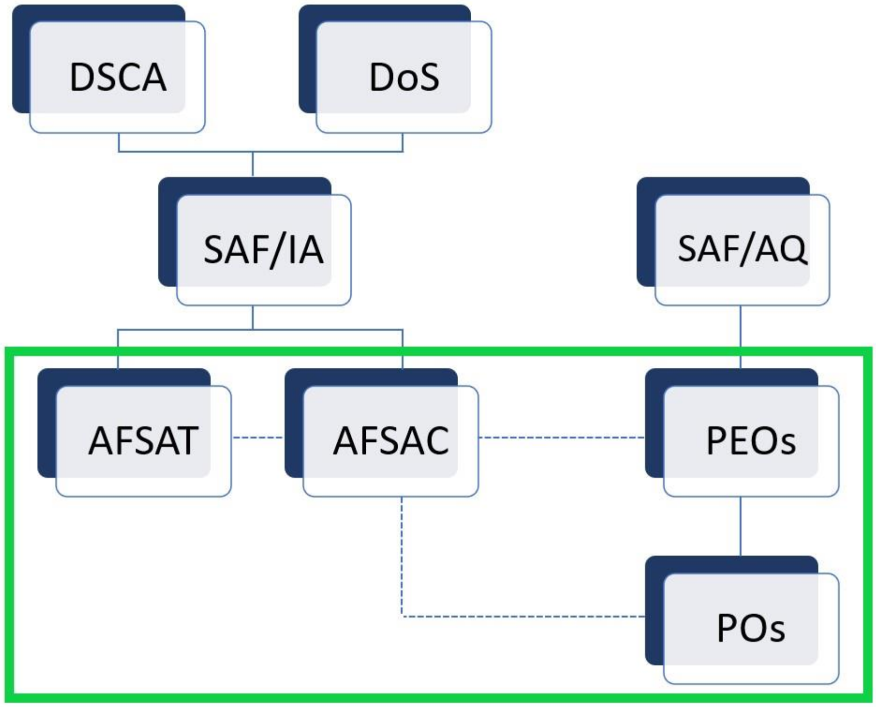


Figure 1. USAF FMS Organization Chart

Process and Cases

The process of supporting partner nation requests occurs via Letters of Request (LOR), which become Letters of Agreement (LOA), also referred to as an FMS case. LORs are similar to a request for proposal commonly used in contracting. They contain a partner nation's request for a specific defense commodity, along with the supporting information used to determine how the USAF will fulfill that request. During development, LORs are routed through a process to confirm exact requirements, obtain cost and manpower estimates, confirm stakeholder agreements, and finally obtain partner nation approval. At the end of the LOR process, an LOA is produced and presented to the partner nation. Note that, the terms LOA and FMS case are used interchangeably within the FMS community. Upon acceptance and signature of the proposed LOA, the FMS case moves into execution. During the execution phase, the program office assigned to the case will conduct the required contracting and procurement activities to provide the defense articles or services.. LOAs allow the U.S. government to act on behalf of other nations to procure defense articles and services. These two major phases of development and execution are depicted in Figure 2. This study focuses on data available for the case execution phase.

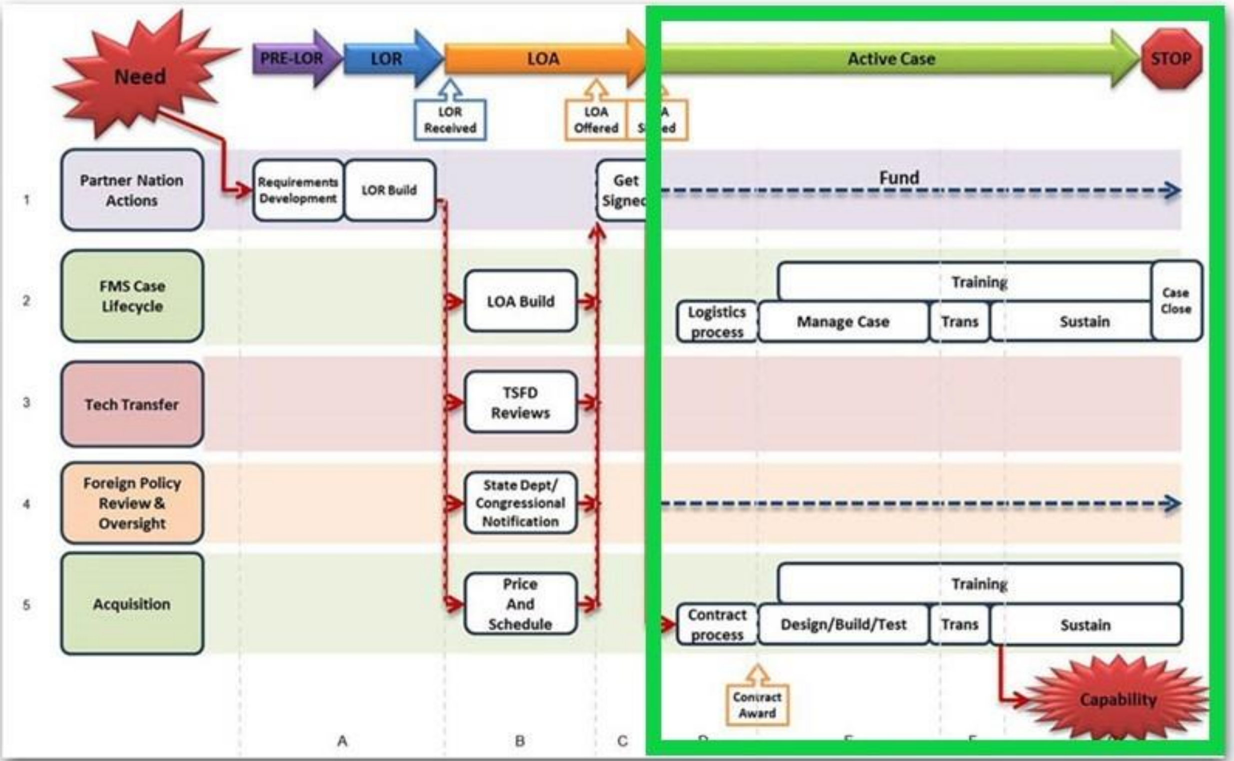


Figure 2. FMS Case Lifecycle (DSCA, 2017)

Each FMS case must go through this multi-staged process. FMS cases are analogous to government contracts. The process of development and execution is similar to contract requirements development and formalization. The LOA is not considered complete until all parties agree, and it is signed by both countries. Each FMS case contains "lines." These lines are analogous to contract line-item numbers (CLINs), in that they break the FMS case down by the specific commodities being provided and each line is funded separately. It should be noted that FMS cases are not considered contracts. This analogy is made only to help the reader better understand the structure of FMS cases, and in turn better understand the data being analyzed. Next, we examine the economic impacts of the FMS program.

Economic Impacts

The most recent figure places annual FMS sales at $55 billion (DoS, 2020). As stated earlier, the AFSAC alone boasts a portfolio valued at $182 billion which includes the cumulative case values of all implemented and active cases. These figures illustrate the significance of the international community as a market for U.S. contractors – a market that has seen steady growth in recent years. In 2011, the Congressional Research Service ranked the U.S. first in global conventional arms transfer agreements with foreign nations (Sherman, 2012). Between 2011 and 2013, the top 20 U.S. defense contractors reported an increase in international revenue from 2% to 11% (Schoulder et al., 2014). In fiscal year 2012 the U.S. exceeded its FMS forecasts by 14% (Sherman, 2012). More recently, Lt Gen Hooper, former Director of DSCA, cited a 33% increase in FMS sales from 2017 to 2018 (Mehta, 2018).

In addition to creating a market for U.S. contractors, the FMS program has also been found to bring about cost savings in particular instances. FMS provides the U.S. government with cost savings in three areas: economies of scale, sustainment, and international cooperative programs (Allen et al., 2015). Studies by the Congressional Budget Office found FMS programs led to a 15% cost reduction on weapon systems procurement and 8% on total research and development costs (Fifer, 1976). While researching the Army's Apache FMS program, savings of $138.7 million were found due to the cost savings benefits mentioned above (Allen et al., 2015). The following section provides a summary of the literature reviewed on manpower forecasting methods.

Manpower Forecasting

Manpower forecasting has been used throughout the 20th and 21st centuries to predict the labor needs of companies and organizations. It has evolved into several approaches and methodologies over time. Manpower forecasters have used both qualitative (e.g., Delphi method, market research, or panel consensus) and quantitative (e.g., learning curves, time-series analysis, or regression analysis, etc.) techniques (Morton, 1968). Additionally, manpower forecasting can occur at the macro or micro economic level (Morton, 1968). Manpower forecasts can be provided for an entire sector at the national level or for individual organizations. The specific methodology used is often determined by the available information, the specific industry or business, and the forecaster's modeling preferences.

This section will provide a summary of the research done on this subject with the goal of providing context and a reference for future research in FMS manpower forecasting. First, a brief background of manpower forecasting will be provided. This will be followed by the common challenges faced by manpower analysts and organizational considerations when developing manpower forecasts. Finally, modern manpower forecasting techniques will be reviewed; examples of the techniques and a discussion their advantages and disadvantages will be provided. These methodologies were selected for their potential application to FMS manpower planning.

Background

Since the 1930s and 1940s, manpower forecasting has become more specialized and specific. Following the dramatic economic effects of the Great Depression and WWII, manpower forecasting became a tool for strategic planning at the national level (Morton, 1968). Initially, forecasts came in the form of macroeconomic reports which provided statistics and predictions of labor demand by industry--e.g., the Bureau of Labor Statistics' projection of the labor force starting in 1966 (BLS, 2016). Over time, targeted or micro level forecasting have become commonplace (Rafiei et al., 2016; Lynn and Duane, 1985). There has also been an increase in the number of methods with some recent surveys and articles listing up to 16 different manpower forecasting methods (Rafiei et al., 2016; Somers et al., 1979).

The extension of manpower forecasting from the macro to the micro level was a natural progression as individual industries and organizations attempted to formulate more specific predictions (van Eijs, 1994). This research is focused on the USAF FMS enterprise and is concerned with methods utilized at the microeconomic level. Therefore, the methods reviewed in this study have all been applied at the microeconomic level. Four commonly utilized manpower forecasting methods were reviewed for study, regression analysis, manpower ratios, Markov chains, and simulations. These were reviewed for their potential application to the USAF FMS enterprise.

Potential Limitations and Organizational Considerations

The following section will examine common limitations faced by manpower analysts. First, model validity is examined relative to organizational strategy and the models' assumptions. Second is data availability and its impact on any analysis and model creation. Finally, some notes are provided on the practical application of manpower forecasting and considerations for selecting the appropriate method.

In terms of validity, two areas of concern exist. One is the alignment of workforce planning with an organization's overall strategy. As manpower forecasting has shifted to the micro level, individual organizations are generating manpower models and predictions. In these cases, a lack of communication between executives, employees, and manpower analysts leads to a disconnected, or invalid, manpower planning model (Emmerichs et al., 2004). Additionally, an overreliance on historical trends without adjusting for changes in factors such as policy or strategic goals has also been found to yield invalid manpower planning models (Emmerichs et al., 2004). For example, during a 2014 study of USAF manpower planning, the process and model for USAF manpower was found to be incongruent with its predicted demand (Mills, 2014). Mills found the USAF’s process of determining manpower requirements by home station demands was mismatched with its overall mission to serve as an expeditionary force (2014).

The second area of concern is the assumed relationships between workload factors and manpower requirements. The methods reviewed in this study rely on understanding the underlying relationships of the chosen factors or activities used to create the model. To understand these relationships, manpower analysts typically rely on expert interviews and some level of statistical analysis (Somers et al., 1979; Zais, 2017; Emmerichs et al., 2004; McGravey, 2013). Additionally, external factors add a layer of complexity as they cannot be easily measured or captured (Morton, 1968). Some examples include future government policies, personnel leaving or entering the workforce, or more recently the impact of a health crisis such as COVID on the workforce. These factors should be considered when building a model and determining its suitability as a long and/or short-term forecasting tool.

Next is a look at the issue of data availability. Historically, manpower data was not actively captured and retained by organizations (Morton, 1968). The lack of readily available manpower data has been noted in several studies as a limiting factor on analysis (Somers et al., 1979; Bigelow et al., 2013; Ghosh, 1981; Aref and Sabah, 2015). Additionally, when manpower data has been available, it typically is incomplete or requires additional manipulation (Somers et al., 1979; Bigelow et al., 2013). To account for this data issue, researchers often use assumptions or analogous data from similar organizations or systems (Bigelow et al., 2013). However, these techniques add degrees of uncertainty to the final model and its forecasts (Morton, 1968).

Organizational considerations for selecting a manpower forecasting method include an organization's environment, both internal and external, and size. A relatively stable environment facilitates consistent metrics gathering and provides more confidence in the underlying assumptions of any models created (Jackson and Schuler, 1990; Aref and Sabah, 2015). Stable environments can afford some organizations the ability to use simpler, more deterministic models. The more volatile an environment, the more difficult predictions will be--especially for any period beyond 2 to 3 years (Morton, 1968). In these cases, any method used will need to account for the dynamic nature of the organization's environment, e.g., using stochastic models to account for the varying probabilities of the different states of each variable. Similarly, the size of an organization should be considered when determining suitability of a manpower forecasting technique. Larger organizations with large and diverse customer bases will utilize more complex methods (Aref and Sabah, 2015).

The next section provides a review of the most common and relevant manpower forecasting methods. A review of manpower planning and forecasting literature provided an extensive list of methods and tools which vary in complexity and comprehensiveness. However, many methods or models found under different names were found to be highly related or almost identical, e.g., system dynamic modeling versus manpower system simulation models and Delphi versus panel consensus. The following section will cover the following methods: ratio analysis, regression analysis, Markov chains, and simulations. These were selected based on their frequency of use in the literature, application to both government and non-government organizations, and because they are quantitative methods. While qualitative methods may be suitable to the FMS manpower issue, the purpose of this study was to use the current available quantitative data and study the relationships between the available factors.

Methodologies

The following manpower forecasting methodologies are presented to provide the reader with an understanding of their use, advantages and disadvantages, and potential application to FMS manpower forecasting. The analysis performed in this research utilized regression analysis and manpower ratios. The methods discussed, but not tested, in this research have potential future application in FMS manpower studies.

Ratio Analysis

The use of ratios to determine manpower requirements is a relatively simple method. It is broadly used in both commercial and non-commercial (i.e., government) applications. It is typically based on previous manpower levels and maintaining a set level of service for a given customer population (Rafiei et al., 2019). Organizations such as the World Health Organization (WHO) have utilized ratios to establish healthcare manpower requirements for their programs (Dussault et al., 2010). There are three primary assumptions needed for this method to work. First, the current manpower structure (in terms of skill levels, staffing numbers, and distribution) are all adequate (Rafiei et al., 2019). Second, the demographics and productivity of available manpower will remain unchanged (Rafiei et al., 2019). Third, any changes in manpower requirements will occur due to observed trends, i.e., there will be no sudden, unexpected changes affecting an organization's manpower system (Rafiei et al., 2019).

Manpower ratios indicate the number of required personnel per some measure of workload or productivity. Typically, a base year or other time period is selected to generate these ratios. For example, USAF maintenance positions are typically determined using a simulation model called the L-COM (Logistics Composite Model) system. Within the L-COM system, maintenance manpower requirements are determined by ratios. Utilizing historical data on aircraft usage, availability rates, downtimes, repair times, and previously assigned personnel, ratios were generated to represent the number of direct maintenance personnel required per aircraft (Fisher et al., 1968). "Direct" indicates personnel whose tasks include hands-on maintenance of aircraft. These ratios are then adjustable based on fleet size to account for the advantages gained when additional aircraft are available (Fisher et al., 1968). Similarly, the number of supervisory and upper-level management positions are determined by ratios. For a given number of direct maintenance personnel, a supervisor is authorized--e.g., for every 50 maintenance personnel one supervisory position is required (Fisher et al., 1968).

The simple nature of this approach makes it easy to comprehend and apply. It also enables quick adoption across regions, industries, or countries (Rafiei et al., 2019). Assuming data exist for manpower factors, manpower ratios can be quickly derived (Rafiei et al., 2019). On the other hand, due to its simple nature and broad assumptions, manpower ratios can be ineffective in forecasting manpower needs. They do not account for changes to the current system or process. As mentioned previously, all three assumptions must be met for manpower ratios to be useful in forecasting future needs.

Regression Analysis

Regression analysis is a statistical method of identifying relationships between variables. Quantifiable factors, such as sales or number of customers, are used as drivers of manpower requirements (Morton, 1968). Typically, these factors are tested as independent variables (IVs) against the dependent variable of manpower using various regression techniques such as linear or logistic. It is worth noting that manpower can be quantified several ways, e.g., number of personnel currently assigned versus authorized versus needed. The key, as with any regression analysis, is identifying the potential independent variables and understanding the underlying relationships (Morton, 1968; van Eijs, 1994).

The application of regression analysis in manpower forecasting is broad and can be seen in healthcare (Rafiei et al.,, 2019), education (Aref & Sabah, 2015), and the DoD (Yasin, 1987). Regression is also utilized as a tool in other methods. For example, regression analysis provides the mathematical relationships needed to build a manpower simulation or to study workload trends needed for manpower ratio development (Zais, 2017; Fisher et al., 1968). Its versatility and simple application make regression analysis a useful tool as a standalone method; this is particularly true when resources are limited or time and expertise are not available for a more complex approach (Rafiei et al., 2019).

Regression also has its limitations. It is typically only suitable for short-term forecasting and is only as accurate as the underlying data (Morton, 1968). Manpower regression normally involves some level of time series analysis. This reliance on historical data typically assumes both internal and external conditions will remain constant for the duration of any predictions (Morton 1968). These limitations aside, regression provides a method for finding and understanding the statistical relationships between manpower requirements and workload factors.

Markov Chains

A Markov chain is a stochastic model which can be used to characterize a sequence of possible events or transitions based on probabilities. These probabilities are determined on the measured unit’s current state (Soni, 2018). Markov chains have been utilized in various applications and have become popular as a tool for manpower forecasting. Markov chains are typically leveraged to better understand employee movement within an organization and the flow of employees into and out of the organization (Soni, 2018). To better understand their application in manpower forecasting, examples are provided below.

In healthcare, Markov modeling was used to predict the supply of Tanzania’s physicians for 10 years (Goodell et al., 2016). Utilizing data from the Tanzanian government and public universities along with expert interviews, researchers created a pathway model. This model captured the path from student to active physician with 92 potential states. The potential states included transitions out of this pathway—e.g., as dropping out of medical school, retirement, death, or unemployment. University data was used for students from 1990 to 2010 who were tracked throughout this pathway model. Assuming doctoral student admission rates were constant, the movement of doctors through this system were then forecast through 2025.

In another instance, Markov chains were used to create a manpower model for teachers within the educational system of Northern Ireland (McClean and Karageorgos, 1979). In this case, researchers created states by dividing teachers into age brackets. Data from 1964 to 1972 were then used to determine the attrition of teachers by age group and gender. The resulting transition matrix helped researchers identify patterns; results included a general decrease in attrition as age increases and significantly higher attrition rates for female teachers under 30 years old. It also provided recruitment goals for a steady state--i.e., the number of recruits required to offset the number teachers leaving the system (McClean and Karageorgos, 1979).

Markov chains focus on the supply of manpower and can be used at the micro level or aggregated to create a macro level view. The stochastic nature of Markov chains helps increase precision of the model and allow for a variety of parameter values (Rafiei et al., 2019). Markov models enable analysts to identify current and potential future issues such as promotion bottlenecks and poor staffing distributions (McClean and Karageorgos, 1979). These models also allow manpower analysts to identify staffing cycles and can highlight attrition and retention patterns (McClean and Karageorgos, 1979). Markov models can also be adjusted for policy changes affecting the transition between states (e.g., new promotion or recruitment policies). The Markov approach is flexible and can provide insight into an organization's manpower flow and supply.

Limitations of Markov models include data availability, complexity, and lack of demand forecasting. The data needed to produce transitions between states is not typically readily available to manpower planners. While hiring and turnover rates might be captured by a human resources Human Resource department, internal state transitions (e.g., promotions, lateral moves, etc.) are not typically captured as data points. The use of Markov chains also requires an understanding of relatively advanced statistical techniques. This can make Markov chains an impractical choice for some organizations (Freyens, 2010). Finally, Markov manpower models focus on the supply of labor. They model and help track labor resources through a system which leaves demand as either a nonfactor or potentially as a predictor of probability (Rafiei et al., 2019).

The focus of this research is on the manpower demand of the USAF FMS program. However, Markov chains are presented as a potential method to examine the supply of FMS manpower which is also an important consideration. The USAF FMS program competes with other USAF acquisition offices for personnel. Its personnel receive highly specialized training relative to foreign arms transfers and the FMS process. Creating a model of the current flow of personnel through its system could aide FMS leadership with its strategic decision making.

Simulation

Simulations are a common tool for modeling the design and architecture of physical systems such as defense weapon systems. In the context of manpower forecasting, an organization's manpower is treated as a comprehensive system. Simulations allow manpower analysts to recreate their organization's manpower system using a model of the various factors and interactions in their workforce. Simulations can offer accurate, holistic models of an organization's manpower and its future needs. There are various methods available to create a manpower simulation. Two simulation models are reviewed below: one for Army warrior transition units (WTUs) and the other for USAF aircraft maintenance personnel.

The process of creating a simulation model begins with a base model to determine the workforce requirement based on future demand for a product or service. This is followed by adding layers of contributing factors--either as deterministic values or stochastic variables. In the case of WTUs, which provide medical care for wounded Soldiers, the number of patients determines demand (Zais and Laguna, 2017). Factors such as personnel availability, skill level, and location were added to the model. Strategic goals and policy, such as requiring a certain skill level for specific patient types, are added to the model as either minimum or maximum limits (Zais and Laguna, 2017). Finally, Monte Carlo simulation is used to find a range of patient levels with corresponding manpower requirements. Additionally, factors such as salary and training costs were added to the model. This allowed the model to minimize cost while maintaining strategic goals (Zais and Laguna, 2017).

The previously discussed L-COM is a computer model utilized to simulate operations and support functions at a USAF base. One of its primary goals is to determine the optimum level of required maintenance personnel per aircraft (Fisher et al., 1968). The foundation of the simulation model is user-developed task networks which include different task types and occurrence probabilities for each task (Fisher et al., 1968). These task networks are extensive and included activities from preflight activities to post flight activities (Fisher et al., 1968). Probabilities are based on historical repair and maintenance data. L-COM continues to be used to generate USAF support and maintenance personnel requirements (Bigelow et al., 2013).

Simulations provide key benefits to manpower analysts and organizational leaders. These models provide analysis flexibility without the need to alter the current real-world situation (Rafiei et al., 2019). As a policy making tool, simulations can be instrumental to an organization. The ability to include stochastic elements in simulations allow organizations to address the uncertainty around manpower forecasting (Zais and Laguna, 2017). Additionally, the availability of commercial, high-performance software and hardware make this approach more accessible (Zais and Laguna, 2017). Data input and management done for Army WTU personnel requirements was completed in Microsoft Excel (Zais and Laguna, 2017). The ability to aggregate data also allows this method to be applied at a micro and macro level. Unlike Markov chains, simulation models can be utilized to analyze both supply and demand of manpower.

Simulations are not without their disadvantages or limitations. First, the cost in terms of required data and initial effort to construct the models is significant (Rafiei et al., 2019). In the WTU example above, the model included 7,800 variables, 1,600 constraints, and 14,000 bounds

(Zais and Laguna, 2017). Thus, depending on the organization size and resource availability, this approach might be overly cumbersome (Rafiei et al., 2019). Simulations typically produce a confidence interval, rather than a single deterministic answer to enable a simple yes/no decision. (Rafiei et al., 2019). However, a point estimate can be obtained from the results, to support decision making. Also, as the model complexity grows, the computational resources to run the model will grow. Modelers will need to be exceedingly familiar with the organization, its processes, and the factors influencing its manpower requirements. Regardless of these potential limitations, simulations can provide a detailed and multifaceted manpower modeling solution.

Chapter Summary

For this study manpower ratios and linear regression were selected to answer the research questions. Linear regression provides a method for understanding the relationships between the current available case data and manpower authorizations. The available case and manpower data allowed for the creation of FMS manpower ratios. The measurement of work volume per authorized employee fit the reviewed use of manpower ratios. There was not enough data or previous research on the FMS manpower system to create an effective simulation at this time. Similarly, Markov chains would require additional data collection and previous research to establish employee transition matrices.

Ensuring organizations have the right personnel is critical for any organization’s success. Creating manpower models and predicting future needs is challenging. It requires knowledge of an organization’s goals, processes, and customer demands. It also calls for an understanding of workload factors and their effects on manpower requirements. Additionally, most organizations do not have the manpower and workload factor data readily available for analysis. This chapter reviewed common manpower methodologies and provided examples of their application.

Additionally, background was provided on the USAF FMS program, its processes, and the manpower factors selected for study. The following chapter discusses the data and statistical methods used for analysis.

III. Methodology

Chapter Overview

This chapter provides a detailed description of the data and the methods used in this analysis. Two types of FMS data were obtained: case data and manpower authorizations. Case data was available from 2006 to 2020 and included details for each active case during these periods. Manpower data was available from 2015 to 2020; specifically, manpower authorizations with descriptive data was provided. The analysis begins by examining the descriptive statistics of the case data and comparing means to determine the proper unit of analysis for this research. This was followed by the creation of new potential independent variables to account for the effect of region and case complexity. Correlations between the potential independent variables were also examined. Linear regression was then used to test the relationships between case factors and manpower authorizations. Manpower ratios were then generated and tested for their stability and consistency over time, in terms of variance and their beta coefficients from simple linear regression.

Data

Case data and manpower data were gathered from AFSAC's Policy and Metrics office and AFSAC's Human Resources office, respectively. Case data included monthly reports from CMCS, which includes a high level of detail for each line of every active case in the USAF FMS portfolio. Note that, the data gathered for this study was provided at the "line level," i.e., data was provided for each line on every active USAF FMS case. It was then consolidated to the case level. This was done to remain consistent with the USAF FMS enterprise's use of case counts and case values to measure volume of customer demand. Data was also aggregated at the annual level using end of year values for each year of available data. Note, data for the current year, 2020, was taken from the most recent available month, March 2020. Consolidation to the calendar year was done to ensure the time periods examined for case data were consistent with the data available for manpower authorizations. Manpower data was only available in annual periods. Out of 31 potential variables provided in the CMCS files, this study focused on the following factors: case ID, country, case type, total case value, total delivered value, Program Executive Office (PEO), and regional code. Regional codes were added to the dataset based on Tables C4.T2B and C4.T2A in the Security Assistance Management Manual (SAMM). Additionally, country and case type were derived from case ID.

USAF FMS Factors

The specific factors analyzed in this study were selected based on data availability, expert opinion, and the limited research available on this topic to date. Note that case values are further broken down into two factors: total case value (TCV) and total delivered value (TDV). Additionally, AOD categories, congressional notification, and ease of doing business scores were added as potential variables. AOD categories were also used to generate an AOD ratio as another potential independent variable. The full list of FMS factors examined is provided in Table 1, which includes factors available in the CMCS files and variables created from the available data and DSCA policy and guidance.

Table 1. USAF FMS Manpower Factors

Factor	Description
total case value (TCV)	total amount of funding in USD available on the case
total delivered value (TDV)	total amount of commodities, in USD, delivered to the partner nation
case count (CC)	number of active cases for a given category (e.g., PEO or region)
PEO	Program Executive Office (PEO) responsible for case execution
region	specific geographical region
case type	single alpha character used to define the type of commodity sold on a given case
congressional notification (CN)	yes/no indicator on whether a case required CN
AOD Category	DSCA provided classification of cases used to group cases by level of complexity
EDB score	World Bank Ease of Doing Business score assigned to each case based on country ID and year
AOD Ratio	Ratio of AOD C cases to AOD A and B cases
TCV:CC	Ratios of total case value to case count, used as measure of case density per PEO

These factors were selected for their logical relationship to manpower requirements; they are either key indicators of FMS workload or logical categories for studying manpower requirements within FMS. Total case value (TCV) is analogous to the total value of a typical government contract, as the amount can be used as a measure of estimated effort on a given agreement or sale. As TCV increases, it is assumed that manpower requirements will also increase, since the estimated level of effort rises. Total delivered value is analogous to the amount billed or work completed on a government contract and is therefore equivalent to the level of effort completed on a given FMS case. Case PEO and region were selected as categorical factors to account for the logical differences in both groupings. PEOs in the USAF acquisition community are divided according to the weapon systems or other defense systems under their control, e.g., Fighter Bomber, ISR/SOF, and Agile Combat Support. The unique nature of each respective weapon system and its corresponding PEO will bring significantly different pricing and levels of complexity. Case data was available for 20 PEOs; however, manpower data was only available for 12 PEOs. Of the PEOs available, only eight had data present across manpower and case data for the time periods provided. Therefore, these eight PEOs were the focus of this study. They are listed in Table 2. Note that, AFSAC is being treated as a PEO as it also manages the execution of certain FMS cases.

Table 2. PEO List

PEO	**Acronym used**
Air Force Security Assistance and Cooperation Directorate	AFSAC
Agile Combat Support	ACS
Armament	ARM
Fighter Bomber	FB
Intelligence, Surveillance, Reconnaissance and Special Operations Forces	ISR/SOF
Tanker	TANK
Command, Control, Communications, and Intelligence Networks	C3I
Propulsion	PROP

Annual manpower authorizations for these eight PEOs were collected and joined with their corresponding case data. Table 3 lists the selected PEOs and their manpower authorizations by year. Each UMD provided the number of authorized positions for a given year; each position was identified by the specific office and rank/grade. PEO was also indicated in the UMD data, which allowed manpower data to be organized at the same level as case data. These figures were used in the regression analysis as the dependent variable. These were also used in the generation of manpower ratios.

Table 3. PEO Manpower Authorizations

PEO	2015	2016	2017	2018	2019	2020
AFSAC	525	527	542	601	611	625
Agile Combat Support	291	299	333	404	413	466
Armament	191	196	213	266	275	296
Fighter Bomber	642	635	684	803	849	938
ISR/SOF	127	166	197	226	231	260
Tanker	33	37	42	57	55	57
C3INetworks	11	14	21	62	60	64
Propulsion	97	91	91	93	100	105

Regions were based on country codes and are categorized geographically as shown in Table 4. Many differences exist at the country level which are assumed to contribute significantly to the level of variance on case values. These include FMS policy, process, requirements, and culture. Additionally, the FMS portfolio is not equally distributed in these regions, with three of the six regions compromising most of the portfolio. For example, the NESA region accounted for 47.03% of the USAF FMS portfolio, while AR and AFR combined account for less than 3.5%.

Table 4. Regional Groups

Regional Groups	Region Symbol	% of total portfolio (2020)
Africa	AFR	2.54
America	AR	0.71
East Asia/Pacific	EAP	26.63
European	EUR	22.09
Near East/South Asia	NESA	47.03
Non-Regional	NR	1.00

PEO and regional groups are assumed to contribute variance in manpower requirements. As mentioned above, PEOs are segmented by weapon systems or defense commodity type. As the pricing and level of complexity vary naturally between these, i.e., F-15 vs C-130 vs JDAM missiles, each PEO will have a different range of case values. Similarly, regions have distinct characteristics which contribute to average case values, such as differences in national budgets, governmental defense policies, and varying levels of bureaucracy. Segmenting the case data by PEO and region allows for modeling the effects of these categorical variables.

The variables of congressional notification (CN) and Anticipated Offer Date (AOD) category were also considered logical categorization tools for cases. Within the dataset, there were 20 different case types spanning a wide range of case values and commodities. Case types are established by DSCA and are service branch specific, i.e., an L case has a different definition for the Army versus the Air Force. For this study, only USAF cases were examined and therefore USAF case type definitions were used. Case types indicate general categories of the goods or services available on an FMS case--e.g., S cases are weapons system sales and T cases are training. Appendix A provides a detailed list of the case types used in this dataset along with their definition. These case types were leveraged along with total case values to create a binary yes/no indicator for CN. Case types were also used to determined AOD categories. A summary of congressional notification requirements and AOD categories is provided here to explain their use as categorical variables.

Congressional notification is mandated under section 36b of the AECA (Congressional Research Service, 2020). CN requires that Congress receive formal notification of sales proposals of major defense equipment (MDE), defense articles, or services to nations beyond set monetary thresholds (Congressional Research Service, 2020). This notification period is intended to give Congress an opportunity to contest a sale. CN occurs during the development of FMS cases, before any formal agreements are made with foreign partners. The official timelines for CN are relatively short--see Table 5. However, the overall CN process can add development time as a CN package must be prepared, and the implementation agency must wait for confirmation of receipt from Congress before beginning the official notification window. The addition of a CN indicator is potentially useful as an indication of political and process complexity per case. Table 5 summarizes the CN requirement thresholds, and the number of days Congress must have to review the sale prior to LOA acceptance. NATO plus includes all NATO members, as well as South Korea, Australia, Japan, Israel, and New Zealand.

Table 5. Congressional Notification Thresholds and Timelines

	MDE sales	**Any sale**	**# of days prior**
NATO Plus	≥ $25M	≥ $100M	15
Non-NATO	≥ $14M	≥ $50M	30

Case types, country codes, and total case values were used to code each case with a Yes/No indicator for congressional notification. The following case types were considered MDE sales: A, C, L, N, O, S, and Y. This decision was based on the definition of MDE within the U.S. Munitions List. The CN thresholds identified in Table 5 were then utilized to identify cases where CN would be required. Each case was then coded with a yes/no indicator for CN required.. Additionally, CN can be used as a continuous variable in the form of the number of cases requiring CN. The assumption going into this analysis is that a higher number of CN cases will result in more manpower being required.

Anticipated Offer Date (AOD) codes are used by DSCA to categorize cases by level of complexity. These codes determine the length of time implementing agencies are allotted to process an LOR into an LOA. They are based on case type and are intended to represent the level of complexity required to develop a customer request into an active FMS case. Note, for this study this complexity is assumed to carry over into case execution. This assumption was made since the activities required for case execution for more complex commodities will require longer contracting processes with more customer interaction, thus adding complexity to execution. Table 6 describes the AOD codes from least complex (code A) to most complex (code C) and lists the case types within each AOD category.

Table 6. AFSAC AOD Guide (AFSAC, 2020a)

Category	Notes	Types of Cases
A Blanket Order	- Follow-on spares and repair parts - Support equipment - Publications and studies - Supplies (fuel, personnel items, etc... - Technical assistance services/surveys) - Formal training and training aids	E – Support equipment K – CLSSA M – Repair/return P – Publications R - Spares
B Defined Order	- Significant Military Equipment (SME) - Major end items/weapons systems - Explosives and munitions - Classified and sensitive articles - Specific services (i.e. transportation, etc...) - Technical data packages	A – Munitions C – CAD/PAD D – COMSEC G – Services (manpower) N – Special support O – INFOSEC T – Training V – Maj/Minor Modifications
C Complex	- Defined LOA's - First time (initial) purchase - At least one CDEF	S – Major Aircraft (System) Q – Specialized sustainment support (catch-all)

AOD categories were added to the dataset as a potential variable to measure the level of complexity within a given portfolio. After the AOD category was coded into the case data, it was used to generate two potential regression variables:1) a ratio of complex to non-complex cases AOD C: AOD A and B; and 2) the number of AOD C cases. Both are assumed to drive higher levels of manpower as portfolio complexity increases.

The effects of region were also considered for this analysis. To quantify this aspect of FMS sales and its effect on manpower requirements, various economic markers by region and country were considered as potential measures of regional complexity. Factors such as Gross Domestic Product, Gross National Product, and Consumer Price Index are commonly used to measure economic development by country. However, the World Bank ranking of "ease of doing business" (EDB) provided a more relevant measure for this study as it measures various aspects of a given country's ability to conduct business both within its borders and with other nations. It leverages 41 component indicators, normalized across countries, to provide a score which measures how conducive a given economy and regulatory environment are to business (World Bank Group, 2020). Thirteen of the 41 component indicators measure the ease of trading across borders, enforcing contracts or agreements, and resolving insolvency, all of which are relative to FMS agreements and cases. The EDB score indicates the regulatory performance of a given country or region, where 0 represents the lowest performance and 100 the best performance. To generate an average score per region, the individual annual scores for each country were recorded and added to each case as a separate data point. The average score per region, by PEO and year, were then calculated and added to the data. Considering the increased performance as average EDB scores increase, it is assumed a higher EDB score will drive lower manpower requirements as the structure and level of governmental regulation facilitates more efficient execution of FMS cases.

Factor Comparison Analysis

Next, descriptive statistics for TCV, TDV, and case count were calculated for the entire USAF FMS enterprise, then by PEO, Region, and AOD category. The statistics for the FMS enterprise are listed in Table 7. Appendix B provides a full list of the statistics calculated. Additionally, Table 8, 9, and 10 below provides a summary of the means of each variable by PEO, region, and AOD code.

Table 7. FMS Enterprise Descriptive Statistics (n = 15)

Variable	Mean	Standard Deviation	Min	1st Quarter	Median	3rd Quarter	Max
TCV (B)	171.0	50.1	98.5	124.0	178.0	206.0	252.0
TDV (B)	104.0	22.0	71.7	86.4	103.0	118.0	140.0
CC	3,413.00	282.00	2,997.00	3,253.50	3,348.00	3,637.50	3,866.00

TCV = total case value

TDV = total delivered value

CC = Case count

Table 8. PEO Means (n = 15)

Variable	AFSAC	ACS	ARM	C3I	FB	ISRSOF	Prop	Tank
TCV (B)	33.5	0.9	7.7	0.1	44.0	4.9	258.0	845.0
TDV (B)	26.1	0.5	3.6	0.1	25.4	2.1	0.05	0.5
CC	1,839	38	228	1,839	137	63	44	12

Table 9. Region Means (n = 15)

Variable	AFR	AR	EAP	EUR	NESA	NR
TCV (B)	2.9	1.4	39.4	37.8	85.5	3.9
TDV (B)	1.4	1.0	22.9	25.7	50.4	3.1
CC	113	232	904	1,190	812	162

Table 10. AOD Means

Variable	AOD A	AOD B	AOD C
TCV (B)	11.2	28.7	131.0
TDV (B)	8.4	18.5	77.5
CC	828	1,701	884

These statistics were used to gain a better sense of the differences in means and ranges of case values and case counts. The large differences in means and quartile ranges suggests there is a significant difference between groups. Note that, an alpha level of .05 was selected for all statistical tests in this study. This alpha level was selected as its common use to suggest sufficient evidence exists to reject a null hypothesis (Miller and Ulrich, 2019). The .05 alpha threshold ensures the tested hypothesis are supported by sufficient evidence, but not so limiting that relationships between factors cannot be detected. Since the data was found to be non-parametric, the Kruskal-Wallis test was used to confirm a statistically significant difference exists in the medians of these groups. A Bonferroni test was then used to obtain a pairwise comparison and determine which specific groups are statistically different. The results of these test support the need to segment case and manpower data by PEO, region, or AOD categories, or account for their effects in a regression model. This comparison analysis was used to support the organizational unit of analysis used for this study. Current manpower authorization data does not contain any indicators for region or AOD. For this reason, the manpower ratio and regression analysis conducted in this study segmented data by PEO and could not be further segmented by AOD. However, to account for the effect of AOD on manpower authorizations, an AOD ratio of AOD C to AOD A and B cases was created. Similarly, to account for the effects of region on manpower authorizations, EBD scores were used as a quantitative measure of regional effects. Additionally, these categories were used to make recommendations on how to group similar PEOs and regions for future research with the option to further segment data by AOD category—see Figure 3.

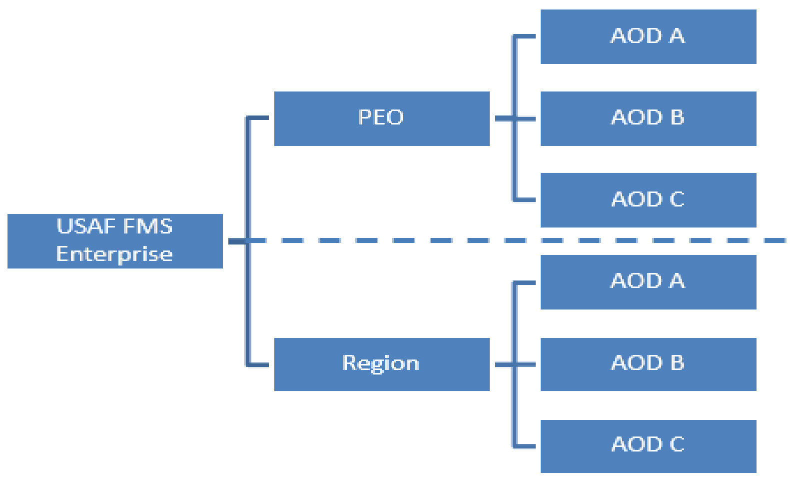


Figure 3. FMS Case Data Groups

Next, the relationship between each potential independent variable and manpower authorization was studied using a correlation table. The results of the correlation table were also used to examine the level of correlation between the independent variables. The results of this comparison and correlation analysis were used to select the variables used in conducting the linear regression analysis.

Regression Analysis

Regression is used to evaluate the statistical relationships between a dependent variable and one or more independent variables. As discussed in Chapter II, manpower regressions typically treat the number of personnel required or authorized as the dependent variable and the workload factors, presumed to drive manpower requirements, as the independent variables. For this study, the number of manpower authorizations gathered from the UMDs are being treated as the dependent variable in the regression model. The use of manpower authorizations, instead of manpower assigned, was primarily due to data availability. UMDs provide a list of authorized positions within an organization. They do not provide data on currently assigned personnel. Additionally, UMDs are used by the Air Force as a management tool to track the manning requirements of a given organization and are the used to determine current and future staffing levels (USAF AF/A1MR, 2019).

A range of linear regression models were used to estimate the effects of the independent variables on manpower authorizations. The results of the correlation table, along with the assumed relationships between manpower and the available data, were used to create four regression models. The use of linear regression provided both a measure how well these models fit in terms of an r-squared value as well as the level of significance each variable contributes to the model. Shapiro-Wilk was used to review the normality assumption, and the Breusch-Pagan test was used to check for constant variance. Additionally, multicollinearity was evaluated using variation inflation factors (VIFs). Due to a lack of normality, bootstrapping was used to provide a 95% confidence interval for the tested models.

FMS Manpower Ratios

Manpower ratios were generated for the variables of TCV, TDV, and CC. These ratios were calculated for each PEO by year. Each ratio represents the number or amount of the given variable for each manpower authorization. For example, the ratio of TCV to manpower provides a figure for the amount of case value for each manpower authorization. As discussed in Chapter II, manpower ratios establish a set relationship between a selected workload factor, such as sales, and the number of staff required. These ratios are typically established during a predetermined baseline period, when management considers productivity to be adequate in meeting customer demand. For this study, this assumption could not be verified. However, the stability of these ratios was examined. For manpower ratios to be useful as a predictor of future manpower requirements, the ratios must be consistent over time, e.g., the number of students per teacher should remain constant for the ratio of students to teacher to be useful as a manpower planning tool.

To gauge the level of stability of the FMS manpower ratios generated two statistical tools were applied. First the consistency over time of the ratios was examined via simple linear regression. Note that, normality for each ratio was tested using the Shapiro-Wilk test. Each ratio was regressed against time in calendar years. The resulting beta coefficient, model significance, and r-squared were used to assess the stability of the ratios for each PEO. Second, the level of variance for each ratio was examined using a chi-squared test. The target standard deviation for each ratio was established using a margin of 3 percent from the mean. This was done for each PEO, for the available 6 years of data, thus resulting in $n = 6$. The small sample size is a limitation of this study. However, this initial analysis does provide some reference for the utility of manpower ratios as high levels of variance or change from year to year would indicate whether these ratios should be further investigated.

Chapter Summary

The case data provided was extensive, both in terms of periods captured and level of detail per case. Additional factors were used for case complexity and degree of congressional oversight, i.e., AOD categories and CN requirements. These complexity factors were constructed using FMS thresholds and guidance. Additionally, EDB scores were added to the dataset to account for the effects of regions on manpower authorizations. The relationship between these factors and FMS manpower authorizations was examined through the use of linear regression. Manpower ratios were also generated using the available case and manpower data. The stability of these ratios in terms of variance and consistency over time were both examined. The lack of regional or case data in the manpower dataset does not allow for an examination of manpower requirements by region. However, EDB scores were used to address this limitation. The data did allow for a 6-year, multi-PEO regression analysis on manpower authorizations. The next chapter discusses the results of the regression analysis and the stability of the generated manpower ratios.

IV. Analysis and Results

Chapter Overview

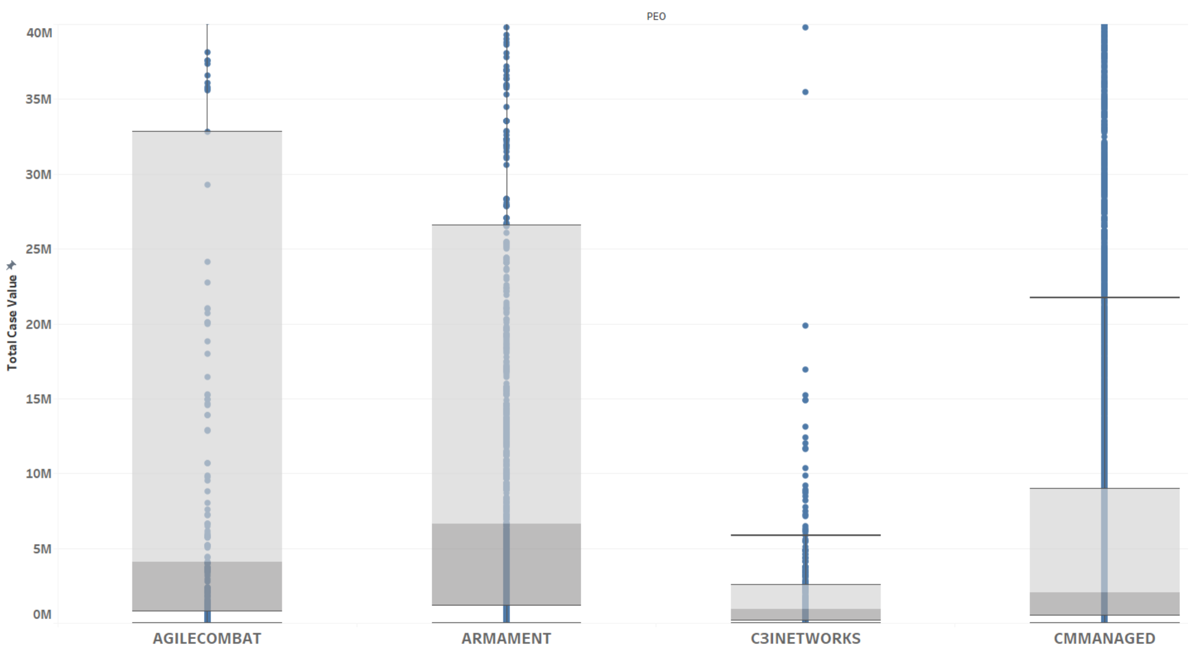
This chapter details the results and analysis of the methods discussed in Chapter III. The results of the factor comparison analysis are provided which were used to support the variables used during the regression analysis. Results are reported for the four linear regression models and the tests for stability in manpower ratios. Linear regression analysis provided insight into the relationship between manpower authorizations and the selected FMS factors. Using regression confirmed the hypothesized relationships between FMS case factors and manpower authorizations. Manpower ratio analysis provided a potential method for estimating FMS manpower authorizations with the current available case data.

Factor Comparison Analysis

Data was grouped by PEO, region, and AOD. The descriptive statistics from these groups demonstrated a wide range of means and inner quartile ranges; Table 11 lists the high and low values for these statistics. Differences in means, standard deviation, and inner quartile ranges for each grouping indicated a high level of heterogeneity between groups suggesting at least some of the members of each group are representative of different populations. For example, AFSAC and C3I appear to be different enough that they should either be analyzed separately or any model containing both should account for their differences. Figure 4 provides histograms of TCV PEO. These histograms show the wide spread of data both between and within groups. However, they also indicate a potential to group similar members together. For example, the mean for Fighter Bomber, ISRSOF, and Tanker PEOs seem to be statistically similar and may allow for these three to be grouped together. Appendix C provides all histograms of the data organized by PEO, region, and AOD. The results for total delivered value and case counts yielded similar results.

Table 11. TCV, TVD, and CC High/Low Statistics

	Avg High	Avg Low	St Dev High	St Dev Low
TCV PEO	44.02E+9	1.4 E+8	17.31 E+9	1.2 E+8
TCV Region	85.53 E+9	1.43 E+9	28.06 E+9	3.0 E+8
TCV AOD	130.99 E+9	11.25 E+9	45.65 E+9	1.69 E+9
TDV PEO	26.09 E+9	5.0 E+7	10.28 E+9	4.0 E+7
TDV Region	50.36 E+9	1.03 E+9	12.70 E+9	2.6 E+8
TDV AOD	77.54 E+9	8.42 E+9	19.54 E+9	1.45 E+9
CC PEO	1838.87	12	109.50	5
CC Region	1190	113	115	12
CC AOD	1700.73	828.47	161	28



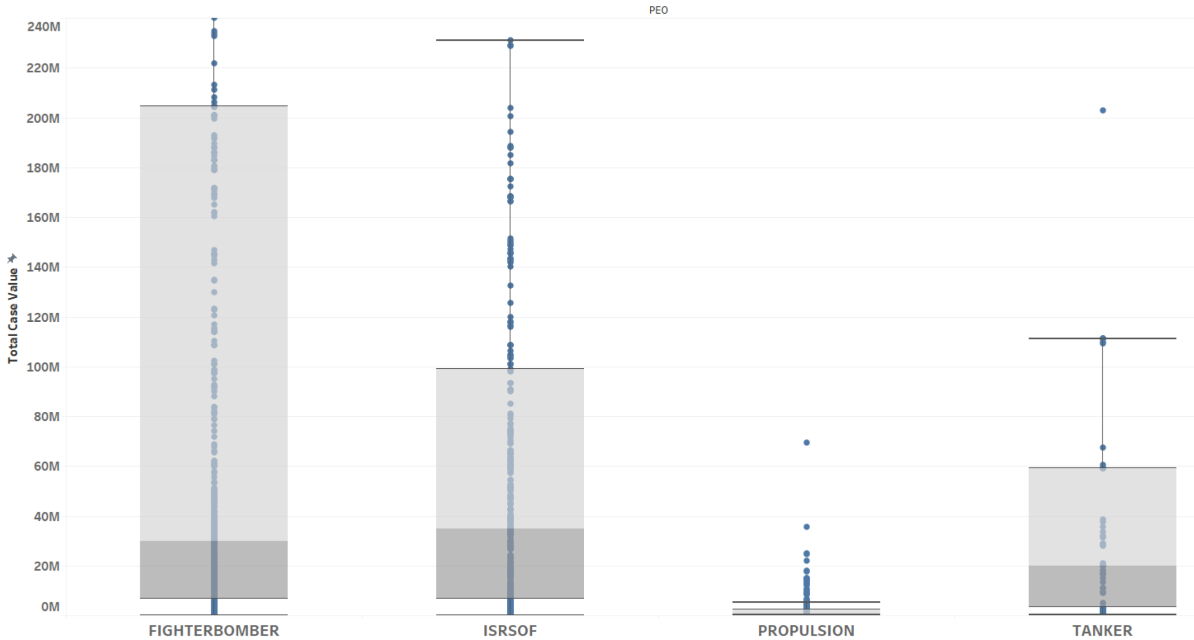


Figure 4. PEO TCV Histograms

ANOVA followed by Kruskal-Wallis tests were used to determine if a statistical difference in means existed for these groups. A one-way ANOVA was conducted to test for a difference in means across each grouping (PEO, region, and AOD), i.e., if there is statistically significant difference in the means of the eight PEOs. The results of each ANOVA indicated a difference in means between PEOs, regions, and AOD categories, with p-values less than .05. However, each dataset did not pass further tests to validate the required ANOVA assumptions. The PEO and region datasets resulted in p-values of less than .05 for the Shapiro-Wilk test and the Levene test, indicating a lack of normality and a lack of constant variance, respectively. The Levene test of the AOD dataset yielded a p-value of less .05, again indicating a lack of constant variance.

The data was next treated as non-parametric and Kruskal-Wallis was used to test for a difference in means. Unlike ANOVA, Kruskal-Wallis does not require the data to conform to a normal distribution and so was selected to test all three group datasets. The results for each Kruskal-Wallis test yielded p-values less than .05. The null hypothesis, when using the Kruskal-Wallis test, states the mean of the populations are statistically equal. Therefore, p-values less than .05 fail to reject the null and indicate that a difference in means exists. Effectively, this supports the theory of using PEO, region, or AOD as the unit of analysis when conducting manpower regression analysis. Next, a Bonferroni pairwise analysis was completed. The results of this analysis show multiple, statistically significant differences in means across all categorical factors. A summary of the specific PEOs and regions found to be statistically different is provided in Table 12 for the variable TCV. Results for TDV and CC produced similar results. The full results of these pairwise comparison can be found in Appendix E.

Table 12. TCV Pairwise Comparisons

Group	Sample	Sample
PEO	C3I	ISRSOF**
		ARM**
		AFSAC**
		FB**
	PROP	ISRSOF**
		ARM**
		AFSAC**
		FB**
	TANK	AFSAC**
		FB**
	ACS	AFSAC**
		FB**
	ISRSOF	FB*
Region	AR	EUR**
		EAP**
		NESA**
	AFR	EUR**
		EAP**
		NESA**
	NR	NESA**

** Significant at the .01 level
* Significant at the .05 level

Table 12 lists the pairwise comparisons found to be significant at least a .05 level. The remaining pairwise comparisons can be found in Appendix E. The results of the pairwise comparison provides two conclusions. One, the specific pairs of PEOs and regions found to be statistically different should be analyzed independently of each other. Two, the results provide some possible combinations of PEOs and regions where future research may elect to aggregate the unit of analysis above the regional or PEO level. For example, the pairing of C3I and Propulsion reported a significance value of .71, suggesting these two PEOs are statistically similar. The regional groups of AR and AFR were also found to have similar means, and EUR, EAP and NESA had similar means. For the regression performed in this study PEOs were not grouped together or aggregated above the PEO level. The differences in means and wide range of descriptive statistics was used to support this decision. The limited sample size for the regression (n = 48) would be further diminished by aggregating to a higher unit of analysis. For example, combining PEOs would decrease the sample size and potentially limit the analysis conclusions. Differences across these categorical factors suggest analyzing manpower requirements at the PEO or regional levels will allow future models or methods to account for the differences between these groups. Additionally, analysis performed at these levels can be easily aggregated into an enterprise-level model or forecast. Modeling or analysis conducted at the enterprise level cannot easily be separated into these component pieces. The next step in the analysis used a Pearson correlation table to examine the relationships between the potential independent variables and manpower authorizations. The results are listed in Table 13. Note that MP is the number of manpower authorizations.

Table 13. Pearson Correlations

	MP	TCV	TDV	CC	AOD Ratio	EDB	AOD C	TCVCC	CN no	CN yes
MP	1	.912**	.915**	.479**	0.122	-0.499**	.668**	.660*	.459**	.633**
TCV		1	.979**	.424**	.045	-.460**	.611**	.806**	.400**	.644**
TDV			1	.577**	-.024	-.464**	.736**	.700**	.558**	.677**
CC				1	-.368*	-.257	.954**	-.152	.999**	.679**
AOD Ratio					1	-.571**	-.155	.394**	-.376**	-.124
EDB						1	-.469**	-.402**	-.235	-.504**
AOD_C							1	.092	.946**	.754**
TCVCC								1	.232	.068
CN_no									1	.643**

** Significant at the .01 level
* Significant at the .05 level

First, the Pearson coefficients were used to assess the level of correlation between the examined variables. For this study, coefficients above .5 were considered highly correlated based on the general guidance found in most statistics textbooks, and commonly applied in research (Schober et al., 2018). Correlation results were used to establish which independent variables have a high correlation to manpower. Second, they were used to assess any high levels of correlation between the independent variables. Third the correlation results were used to form the hypothesized relationships between the IVs and DVs. As Table 13 indicates, manpower authorizations were found to be highly correlated with TCV, TDV, the number of AOD C cases, the case density ratio of TCV:CC, and the number CN_yes cases within a PEO. The table also suggests the following variables are positively related to manpower: TCV, TDV, CC, AOD_C, TCV/CC, and CN_Yes. That is as case values, case counts, the number of AOD C cases, case density, and the number cases requiring CN increase, so do manpower authorizations. Conversely, EDB scores (which are near the threshold for high correlation at .499) are negatively correlated with manpower. This supports the assumed relationship between EDB and manpower as regions with higher EDB scores are assumed to be more effective at managing FMS cases and therefore require less personnel to do so. These relationships follow the assumed trends and were further tested using linear regression.

Regression Analysis

Based on the correlation results and the initial hypothesized relationships between manpower and the IV, the following variables were utilized to generate potential manpower models for a regression analysis: TCV, TCV:CC, EDB, AOD_C, and CC. Other variables considered but not utilized were TDV, AOD Ratio, and CN_Yes. TDV, while highly correlated to manpower, was also very highly correlated to TCV. This would cause issues of intercorrelation between the IVs. Additionally, from a logical perspective, TCV was assumed to provide a better indication of manpower requirements. TCV is known prior to case implementation and is commonly used as an estimate of effort as mentioned previously. TDV on the other hand is accrued during case execution at varying rates, thus making its use as a potential predictor or variable to model manpower requirements limited. AOD ratio was simply not found to be highly correlated to manpower authorizations. For this study, it was not used in the tested models. It may have some use in future models, where manpower is measured either by currently assigned personnel. CN_yes was found to be highly correlated with the number of AOD C cases. CN and AOD both use case types to determine categorization, which may cause issues of intercorrelation of the IVs. The initial regression models in Table 14 were created and tested, following the general linear regression formula: $y = \beta0 + \beta_1 x1 + \beta_2 x2 + \beta_3 x3 + e$. Note, there were a total of 48 samples available, 8 PEOs with 6 years of data for each.

Table 14. Regression Models 1

y	=	Pred.	x1	Pred.	x2	Pred.	x3
MP	=	+	TCV	-	EDB	+	AOD_C
MP	=	+	TCV	-	EDB	+	CC
MP	=	+	TCV/CC	-	EDB	+	AOD_C
MP	=	+	TCV/CC	-	EDB	+	CC

Table 15. Regression Results 1

		Dependent Variable			
Independent Variables	**Pred.**	**MP (n = 48) Coef. (t-stat)**	**MP (n = 48) Coef. (t-stat)**	**MP (n = 48) Coef. (t-stat)**	**MP (n = 48) Coef. (t-stat)**
Constant		473.113	646.931	-210.947	415.925
TCV	+	.933** (10.479)	.978** (11.668)	NA	NA
TCV/CC	+	NA	NA	1.647E-6** (8.561)	1.917E-6** (8.992)
EDB	-	-4.783 (-.973)	-7.015 (-1.404)	3.568 (.579)	-4.631 (-.747)
AOD_C	+	.361* (2.107)	NA	1.438** (8.428)	NA
CC	+	NA	.048 (1.628)	NA	.259** (7.530)
Adjusted R^2		0.844	0.838	0.796	0.767
F-Value		86.035**	82.315**	62.123**	52.552**

** Significant at the 0.01 level

* Significant at the 0.05 level

The results of the initial models are found in Table 15. Following these initial results, a new set of models was developed based on a lack of significance for EDB and case count. The initial models' results indicate EDB is not significant. Therefore, it was removed from any further models. The next models tested are listed in Table 16; the results follow in Table 17.

Table 16. Regression Models 2

y	=	Pred.	x1	Pred.	x2
MP	=	+	TCV	+	AOD_C
MP	=	+	TCV/CC	+	CC
MP	=	+	TCV/CC	+	AOD_C

Table 17. Regression Results 2

		Dependent Variable		
Independent Variables	**Pred.**	**MP (n = 48) Coef. (t-stat)**	**MP (n = 48) Coef. (t-stat)**	**MP (n = 48) Coef. (t-stat)**
Constant		111.847**	64.777*	60.537*
TCV	+	.953** (11.072)	NA	NA
TCV/CC	+	NA	1.991E-6** (10.579)	1.602e-6** (9.186)
AOD_C	+	.404* (2.451)	NA	1.391** (9.327)
CC	+	NA	.268** (8.364)	NA
Adjusted R^2		0.845	0.769	0.799
F-Value		128.926**	79.327**	94.412**
SW p-value		<.001	0.001	0.021
BP p-value		0.219	0.162	0.601

** Significant at the 0.01 level
* Significant at the 0.05 level

The results of the second set of regression models indicate all variables used were significant and the coefficients confirmed the predicted relationship with manpower. However, before any conclusions can be drawn, an assumptions check is needed on the final regression models. The results of the Shapiro-Wilk (SW) and the Breusch-Pagan (BP) tests on the residuals of each model are noted in Table 17. The low p-values for the SW test indicate a lack of normality for each model. All models did pass the BP test for constant variance. To address the lack of normality, bootstrapping was used to create a 95% confidence interval of the coefficient values.. The results are shown in Table 18.

Table 18. Bootstrap Regression Results

Independent Variables	Pred.	MP (n = 48) Coef. (t-stat) β 95% CI	MP (n = 48) Coef. (t-stat) β 95% CI	MP (n = 48) Coef. (t-stat) β 95% CI
Constant		111.847**	64.777*	60.537*
TCV	+	.953** (11.072) .819 - 1.047	NA	NA
TCV/CC	+	NA	1.991E-6** (10.579) 1.6E-6 - 2.202E-6	1.602E-6** (9.186) 1.130E-6 - 1.789E-6
AOD_C	+	.404* (2.451) .263 - .709	NA	1.391** (9.327) 1.196 - 1.769
CC	+	NA	.268** (8.364) .226 - .313	NA
Adjusted R^2		0.845	0.769	0.799
F-Value		128.926**	79.327**	94.412**

Bootstrapping is commonly used to address non-normality as it does not require the data or the residuals to have a normal distribution (Pek et al., 2018). Bootstrapping does require non-small sample sizes (Pek et al., 2018), for this study n = 48 is more than the commonly required sample size of n = 30 and thus is considered a non-small sample. Bootstrapping creates a sampling distribution by sampling from the original data with replacement for a given target number of iterations (Pek et al., 2018). In this study, 1000 was the target number of iterations.

The results of the bootstrap regression also support the original hypothesized relationships between the IV s and manpower authorizations. The 95 percent confidence intervals provided maintain the positive relationship between manpower and case value, case density and number of AOD C cases, as well as total case count. Each of these factors increase as manpower authorizations increase. Additionally, the relatively high r-squared values in all of the models tested indicate that these variables have potential as predictors of manpower authorizations.

Regression Summary

The extensive data provided in the CMCS reports allowed for a comparison analysis of the USAF FMS case factors. A comparison of means across categorical variables confirmed the need to use either PEO or region as the unit of analysis when modeling FMS manpower. In this study PEO was selected as manpower data do not contain an indicator of region. A Pearson correlation table was used to help form potential regression models to better understand the relationship between manpower and FMS case factors. The resulting models confirmed most of the expected relationships. As case values increase and the number of cases increase so do manpower authorizations. The relationship between EDB scores and manpower could not be validated in this study as they were not significant in the tested models. However, other regional economic indicators may be useful for future research when attempting to account for the effects of region on manpower. The next section details the analysis of the generated manpower ratios.

Manpower Ratios

The manpower ratios were examined for their stability both in terms of variance and change over time. The ratios were tested for normality prior to conducting linear regression. Table 19 provides as list of the created ratios and a description of each.

Table 19. Manpower Ratios

Ratio	Description	Example (Agile Combat Support, 2020)		
TCV:MP	ratio indicating the amount of total case value per manpower authorization (per PEO)	TCV = $1,532,694,700	MP_Auth = 466	TCV/MP = $3,289,044.5
TDV:MP	ratio indicating the amount of total delivered value per manpower authorization (per PEO)	TDV = $627,095,936	MP_Auth = 466	TDV/MP = $1,345,699.43
CC:MP	ratio indicating the number of cases per manpower authorization (per PEO)	CC = 94	MP_Auth = 466	CC/MP = .201

As noted in Chapter II, the calculation of manpower ratios is a relatively simple process. The key to their utility lies in their assumptions (Rafiei et al., 2019). That is the assumption of a baseline period during which ratios are established and the continued stability of those ratios over time. While establishing manpower ratios, organizations can select a specific time where the productivity is considered adequate for meeting customer demand. The manpower ratios established in this study were generated from the data available without input on productivity levels or customer satisfaction. These factors are not currently readily available, though this may be an item of interest for future research. Absent any productivity or customer satisfaction data, this study focused on the stability of the generated ratios. The first test was a simple linear regression to test the null hypothesis of $\beta_1 = 0$, using β_1 as a measure of the effect of time on each ratio. Table 20 provides the results.

Table 20. Manpower Ratios β Test Results

	Ratios		
	TCV:MP	**TDV:MP**	**CC:MP**
PEO	**β (R2) Sig SW p-value**	**β (R2) Sig SW p-value**	**β (R2) Sig SW p-value**
AFSAC	-0.067 (0.89) 0.01 0.09	-0.05 (0.83) 0.01 0.27	-5.3E-09 (0.92) 0.00 0.18
ACS	-0.011 (0.76) 0.02 0.30	-0.01 (0.94) 0.00 0.51	null
Prop	0.01 (0.83) 0.01 0.58	0.01 (0.95) 0.00 0.59	1.4E-9 (0.72) 0.03 0.37
ISRSOF	null	null	-8.1E-10 (0.81) 0.01 0.53
Tank	null	null	-.6E-10 (0.72) 0.03 0.07
C3I	NA	-0.02 (0.75) 0.03 0.30	NA

ARM, FB failed to reject the null for all ratios

null = fail to reject the null hypothesis

Note that most ratios across PEOs returned SW p-values greater than 0.05, passing the check for normality. The only exceptions were the ratios of TCV:MP and CC:MP for C3I. Due to this lack of normality the results for C3I were excluded. For the ratios where the null hypothesis was rejected, the calculated β were relatively close to zero, which indicates a small effect size of time on the ratios. These ratios seem to remain stable over time and could be applied to manpower planning within those specific PEOs. However, considering the small sample size, further analysis is recommended. In cases where the null was not rejected, drawing the conclusion that $\beta = 0$ is limited by the small sample size. However, this initial analysis indicates these manpower ratios remain relatively stable over time.

In addition to the use of simple linear regression, a left tailed chi-squared test for variance was used to study the level of variance within these ratios. A review of the literature on manpower ratios did not yield a standard acceptable level of variance for manpower ratios. In lieu of this, a margin of 3 percent from the mean was used to assess a relative level of standard deviation. Chi-squared tests were used to determine whether each ratio had a standard deviation less than 3 percent from the mean. The hypothesis tested is shown in Figure 5.

$$H_0:\ \sigma^2 \geq (.03\bar{x})^2$$
$$H_a:\ \sigma^2 < (.03\bar{x})^2$$

Figure 5. Chi-squared Test Hypothesis

The results of the chi-squared tests failed to reject the null hypothesis across all ratios and PEOs. This indicates that the standard deviation is larger than the proposed 3 percent margin from the mean. However, tests of variance are limited when using small sample sizes (n = 6).

The power of these tests was 0.04 indicating a high probability of type II errors, largely due to the small sample size. Future research should attempt to expand sample sizes by obtaining monthly or quarterly manpower data and generating manpower ratios across those time periods.

Manpower Ratios Summary

The manpower ratios generated from the FMS case and UMD data seem to be relatively stable over time. The low beta coefficients indicate little statistically significant change in these ratios. However, it is important to consider the small sample sizes used in this study. The small sample size can affect both the normality assumption and the r-squared values. The margin of 3% from the mean for standard deviation provides a sense of the level of deviation for these ratios as well. Again, the small sample sizes and lack of a standardized acceptable level of deviation for manpower ratios limits the conclusions drawn from this analysis.

Chapter Summary

The specific statistical analyses and their subsequent results, for both the regression analysis and manpower ratio analysis, were reviewed in this chapter. The comparison analysis explained the case data available and the relevant factors selected for analysis. Descriptive statistics and correlation tables were then generated for those factors to examine the difference in means and the relationships between manpower and the selected case factors. Kruskal-Wallis and Bonferroni tests were used to confirm a significant difference between the proposed categorical variables, thus supporting the use of PEO as the level of analysis for this study. A Pearson correlation table was calculated to support the formation of a range of regression models. Four initial regression models were created with a mix of five variables found to have a high correlation to manpower authorizations. After removing insignificant variables and using bootstrapping to deal with the non-normality of the data, the variables of total case value, case density, case count, and number of AOD C cases were all found to be positively related to manpower authorizations. Future research may consider adding new variables to the model to account for the effects of region and if possible obtaining more historical manpower data.

Manpower ratios were then generated and tested for their stability over time and level of variance relative to the mean of the ratios. Both results indicated a relatively small amount of change or instability in the generated manpower ratios. This initial analysis may be leveraged by adding additional years of data or establishing a baseline period via expert opinion to establish similar manpower ratios. Additionally, variance of the manpower ratios was examined. However, the limitations of the small sample size limited conclusions drawn from the chi-squared tests.

V. Conclusions and Recommendations

Chapter Overview

This chapter summarizes the results of the analysis relative to the specific research questions from Chapter I. The limitations of this study are detailed, including the small sample sizes used for manpower ratios, and the lack of additional manpower data. Finally, recommendations for action and future research topics are discussed. These include adding personnel assigned numbers to cases, investigating the flow of personnel through the FMS system, and expanding on the research in this study or conducting a case study within a PEO or implementing agency

Investigative Questions Answered

1.With the current available data, which manpower forecasting methodology can be applied?

A review of the available case and manpower data was completed. The case data is extensive and includes line level detail on all FMS cases active during the last 15 years, with data broken down in monthly increments. However, the manpower data available is limited. For this study only 6 years of manpower authorization data were available. These authorizations identified the number of positions available within the FMS organizations of AFLCMC per year. Of the reviewed manpower modeling methods, manpower ratios and regression analysis were selected to analyze the available data. Regression analysis provided a method for conducting an initial analysis of the available case factors and their relationships with manpower authorizations. Manpower ratios were found to be relatively simple to generate and could be calculated with the available data. Simulation could not be implemented as the current FMS manpower data is limited with no clear policy or process which could be modeled and holistically captured in a system simulation. Markov chains could not be implemented without the gathering of extensive amounts of manpower transition data.

2. Which FMS factors can be utilized as indicators of manpower requirements?

Nine potential variables from the case data were examined for their potential as indicators of manpower requirements. Of these, four were found to be statistically significant in their relationship with manpower authorizations. The results of the correlation tables and the subsequent regression analysis indicated that total case values, case counts, the number of AOD C cases, and case density can be used as potential indicators of manpower authorizations.

3. How should these factors be categorized or organized for further study of FMS manpower requirements?

FMS teams are typically segmented by the country or region they support. This occurs for both phases of the FMS LOA lifecycle: development and execution. Additionally, each FMS program office supports specific weapon systems or defense commodities. These program offices are aligned under PEOs, which are structured to support similar weapon systems and their related defense commodities. This organizational structure provides a logical breakdown for the categorization of FMS case data.. These potential categories for FMS data were examined during the comparison analysis. Data was organized by PEO and region. These data sets were then examined for differences in means. This was followed by tests for correlation with manpower authorizations. The results of these tests support the need to use PEO or region as the unit of analysis for manpower research. This study selected PEO as the unit of analysis, as manpower data could not be separated by region.

4. What are the results of applying modern manpower forecasting techniques to FMS manpower data?

The results of regression analysis provided a set of variables with high correlations to manpower authorizations, and regression models with high r-square values. These models provide a better understanding of the specific case data directly related to manpower authorizations. These models have the potential to be used to develop predictions of future manpower requirements. At a minimum, the regression models developed provide statistical evidence that as case counts, case values, and the number of AOD C cases continue increase so will manpower authorizations.

The application of manpower ratios provides an initial assessment of their utility to FMS manpower planning. The relative stability of the generated ratios suggests their potential as a method for quickly estimating future manpower requirements. The manpower ratio analysis conducted here was limited by sample sizes, additional research may further support their use for the FMS community.

Limitations

Manpower data and information for the USAF FMS program was the primary limiting factor in this analysis. Manpower forecasting, regardless of specific methodology, requires an understanding of the organization’s current and historical manpower system. This includes its policies, staffing levels and structure, and current manpower decision making process. The only manpower metric readily available was manpower authorizations for a 6-year period. This provided an opportunity to study general trends in authorizations and test regression on these numbers. Without information on the system or policies used to generate these authorization levels, the current manpower system is left undefined and the number of assumptions needed to model it increase. Manpower authorizations also do not indicate the actual current staffing levels, which may be of interest in a more supply-focused manpower study. Additionally, UMDs are not FMS specific. They do not provide any indication of staffing levels by case or region, which limits the ability to view historical trends within these groups. Also, the nature of manpower authorizations on a UMD does not give a meaningful indication of the current capability of the workforce to meet its mission.

Another unique factor within FMS manpower are the sources of funding used to cover personnel costs. FMS personnel positions are either funded through the administrative charge placed across all FMS cases or via direct charges on a specific case. The availability of either source of funding has a direct impact on staffing level. This metric is not readily available and would require a significant level of effort to generate as a case level factor. However, the ability to account for these different funding sources would allow for a more comprehensive manpower system model.

Future Research

FMS manpower is a relatively unexplored area of research, so opportunities to expand on this study or examine other areas of FMS manpower are considerable. Future researchers may focus on one of the two major phases of the FMS case lifecycle. For example, case development is conducted and managed by two primary organizations, AFSAC and AFSAT. AFSAC manages all case types, apart from T cases. AFSAC also collects large amounts of business activity data to generate case development metrics. These data points include the ones used for this study, but they also include the specific timelines for case development, with milestones, on a per case basis. AFSAC's role in the USAF FMS program is significant and affects billions of dollars in defense commodity sales. Research into AFSAC's manpower system, specific to the case development phase, may provide insight useful to its strategic planning. There are also opportunities to investigate the effectiveness of current staffing levels via a combination of customer feedback surveys and gathering more comprehensive manpower data. Future research may also investigate the supply side of FMS manpower. The Markov chain method provides a technique to gain a deeper understanding of how personnel flow through the FMS manpower system. Future researchers may consider generating manpower transition matrices or similar models to help the movement of personnel through the FMS system.

Summary

The goal of this study was to provide a modern foundation for FMS manpower research and to analyze the current data with applicable manpower modeling methods. The comparison analysis conducted provided a recommended unit of analysis for FMS case and manpower data. The selection of region and PEO as categorical variables will allow manpower research to account for the differences in portfolios by both groups. Several potential case factors were considered from the currently available data. The results of correlation and regression analysis provided three regression models with high significance and r-squared values – supporting their potential use as planning tools or for continued research. An examination of FMS manpower ratios suggests their relative stability over time, thus supporting their potential as a method for predicting manpower requirements for the USAF FMS enterprise.

Appendix A – Case Type List

Case Type	Case Type Description
A	Munitions (AFLC)
C	CAD/PAD
D	Communication/Electronic System Sale
E	Equipment (Blanket)
G	Services
K	FMSO
L	Equipment (Defined)
M	MX - repair/return
N	Special Support
O	Communication Security (COMSEC)
P	Publications
Q	System Sustainment Support
R	Spares
S	Aircraft System Sale
T	Training
V	Class IV/V Modifications
Y	Missile System Sale

Appendix B –: Descriptive Statistics

PEO	TCV Descriptive Stats		PEO	TCV Descriptive Stats	
AFSAC	**Count:**	15	Fighter Bomber	**Count:**	15
	Average:	33,457,245,882		Average:	44,017,474,198
	Median:	34,040,228,741.00		Median:	41,661,463,931.00
	Standard deviation:	2,495,820,410		Standard deviation:	17,309,136,208
	First quartile:	33,474,717,560		First quartile:	29,856,702,898
	Third quartile:	35,132,467,287.00		Third quartile:	54,034,178,814.50
Agile Combat Support	**Count:**	15	ISR/SOF	**Count:**	15
	Average:	913,545,884		Average:	4,845,828,170
	Median:	1,030,470,111.00		Median:	4,080,127,454.00
	Standard deviation:	455,520,582		Standard deviation:	3,661,551,976
	First quartile:	667,000,168		First quartile:	1,827,679,858
	Third quartile:	1,239,184,127.00		Third quartile:	7,333,843,188.00
Armament	**Count:**	15	Propulsion	**Count:**	15
	Average:	7,706,965,735		Average:	257,723,187
	Median:	7,203,382,876.00		Median:	324,395,793.00
	Standard deviation:	3,787,910,399		Standard deviation:	233,726,215
	First quartile:	4,690,430,886		First quartile:	28,846,995
	Third quartile:	10,980,375,616.00		Third quartile:	457,270,758.00
C3INetwork	**Count:**	15	Tanker	**Count:**	15
	Average:	143,161,273		Average:	845,429,457
	Median:	119,444,186.00		Median:	756,708,673.00
	Standard deviation:	120,289,730		Standard deviation:	467,026,954
	First quartile:	39,747,257		First quartile:	489,210,977
	Third quartile:	211,072,039.00		Third quartile:	1,064,433,991.50

Total Case Value by PEO

Region	TCV Descriptive Stats		Region	TCV Descriptive Stats	
AFR	**Count:**	15	EUR	**Count:**	15
	Average:	2,901,015,665.67		Average:	37,831,743,685.00
	Median:	2,944,003,061.00		Median:	36,182,563,988.00
	Standard deviation:	1,385,539,823		Standard deviation:	7,237,920,456
	First quartile:	2,853,027,275.50		First quartile:	34,358,604,981.50
	Third quartile:	3,097,804,129.50		Third quartile:	38,291,380,118.50
AR	**Count:**	15	NESA	**Count:**	15
	Average:	1,432,830,625.20		Average:	85,525,381,652.47
	Median:	1,396,044,666.00		Median:	95,798,668,546.00
	Standard deviation:	298,580,791		Standard deviation:	28,057,114,882
	First quartile:	1,204,389,000.50		First quartile:	56,287,915,499.50
	Third quartile:	1,696,644,492.50		Third quartile:	109,439,259,603.00
EAP	**Count:**	15	NR	**Count:**	15
	Average:	39,378,644,434.13		Average:	3,872,584,780.93
	Median:	35,126,863,036.00		Median:	4,081,772,725.00
	Standard deviation:	15,351,631,218		Standard deviation:	1,045,603,940
	First quartile:	25,429,402,383.00		First quartile:	3,147,268,582.00
	Third quartile:	51,612,509,823.50		Third quartile:	4,347,873,817.00

Total Case Value by Region

AOD	TCV Descriptive Stats	
A	**Count:**	15
	Average:	11,248,613,551.07
	Median:	11,112,894,420.00
	Standard deviation:	1,693,064,735
	First quartile:	10,439,624,448.00
	Third quartile:	12,610,084,077.50
B	**Count:**	15
	Average:	28,700,921,082.67
	Median:	27,540,820,611.00
	Standard deviation:	3,606,538,813
	First quartile:	26,381,055,656.50
	Third quartile:	31,066,692,779.00
C	**Count:**	15
	Average:	130,992,666,209.67
	Median:	139,100,181,506.00
	Standard deviation:	45,649,252,390
	First quartile:	87,439,932,416.50
	Third quartile:	163,187,961,947.00

Total Case Value by AOD

PEO	TDV Descriptive Stats		PEO	TDV Descriptive Stats	
AFSAC	**Count:**	15	Fighter Bomber	**Count:**	15
	Average:	26,090,304,772.73		Average:	25,414,992,448.87
	Median:	26,571,381,249.00		Median:	26,834,301,651.00
	Standard deviation:	2,636,018,851		Standard deviation:	10,277,515,121
	First quartile:	24,724,694,208.00		First quartile:	16,474,195,282.00
	Third quartile:	28,189,253,788.00		Third quartile:	32,725,956,889.50
Agile Combat Support	**Count:**	15	ISR/SOF	**Count:**	15
	Average:	464,260,075.67		Average:	2,098,338,432.80
	Median:	627,095,936.00		Median:	1,591,922,886.00
	Standard deviation:	312,628,462		Standard deviation:	1,855,693,283
	First quartile:	95,938,049.00		First quartile:	519,838,235.00
	Third quartile:	708,646,563.50		Third quartile:	3,663,164,109.50
Armament	**Count:**	15	Propulsion	**Count:**	15
	Average:	3,570,437,357.80		Average:	46,503,541.27
	Median:	3,498,449,618.00		Median:	23,716,331.00
	Standard deviation:	1,994,233,824		Standard deviation:	51,286,877
	First quartile:	1,637,975,646.50		First quartile:	9,347,485.50
	Third quartile:	5,155,077,039.50		Third quartile:	72,219,752.00
C3INetwork	**Count:**	15	Tanker	**Count:**	15
	Average:	55,732,902.87		Average:	495,389,167.13
	Median:	36,840,601.00		Median:	425,733,067.00
	Standard deviation:	42,883,932		Standard deviation:	175,658,504
	First quartile:	23,117,017.50		First quartile:	355,288,059.50
	Third quartile:	75,763,181.00		Third quartile:	616,173,946.00

Total Delivered Value by PEO

Region	TDV Descriptive Stats		Region	TDV Descriptive Stats	
AFR	**Count:**	15	EUR	**Count:**	15
	Average:	1,376,932,023.33		Average:	25,665,589,450.80
	Median:	1,957,523,056.00		Median:	27,204,756,608.00
	Standard deviation:	911,813,421		Standard deviation:	4,441,664,965
	First quartile:	261,683,639.00		First quartile:	22,502,651,083.50
	Third quartile:	2,122,420,728.50		Third quartile:	28,930,541,751.00
AR	**Count:**	15	NESA	**Count:**	15
	Average:	1,034,873,818.73		Average:	50,355,389,337.93
	Median:	999,458,720.00		Median:	44,442,222,091.00
	Standard deviation:	259,448,954		Standard deviation:	12,698,805,658
	First quartile:	789,623,205.50		First quartile:	41,059,006,237.00
	Third quartile:	1,281,161,683.50		Third quartile:	58,297,537,473.00
EAP	**Count:**	15	NR	**Count:**	15
	Average:	22,920,608,704.47		Average:	3,128,342,689.13
	Median:	22,399,949,447.00		Median:	2,949,085,161.00
	Standard deviation:	4,749,710,676		Standard deviation:	1,015,363,835
	First quartile:	19,465,956,358.00		First quartile:	2,562,972,004.00
	Third quartile:	25,915,251,571.00		Third quartile:	3,571,338,401.50

Total Delivered Value by Region

AOD	TDV Descriptive Stats	
A	**Count:**	15
	Average:	8,415,664,245.13
	Median:	8,260,464,203.00
	Standard deviation:	1,448,682,693
	First quartile:	7,681,777,239.50
	Third quartile:	9,671,552,774.00
B	**Count:**	15
	Average:	18,529,298,253.13
	Median:	19,190,524,329.00
	Standard deviation:	1,808,866,337
	First quartile:	18,053,873,906.00
	Third quartile:	19,493,228,085.00
C	**Count:**	15
	Average:	77,536,773,526.13
	Median:	75,406,810,885.00
	Standard deviation:	19,541,199,220
	First quartile:	62,549,725,455.50
	Third quartile:	89,328,743,102.50

Total Delivered Value by AOD

PEO	CC Descriptive Stats		PEO	CC Descriptive Stats	
AFSAC	**Count:**	15	Fighter Bomber	**Count:**	15
	Average:	1,838.87		Average:	136.93
	Median:	1,829.00		Median:	134.00
	Standard deviation:	79		Standard deviation:	61
	First quartile:	1,783.50		First quartile:	86.00
	Third quartile:	1,889.50		Third quartile:	191.00
Agile Combat Support	**Count:**	15	ISR/SOF	**Count:**	15
	Average:	38.13		Average:	63.20
	Median:	25.00		Median:	55.00
	Standard deviation:	32		Standard deviation:	40
	First quartile:	11.50		First quartile:	30.00
	Third quartile:	62.00		Third quartile:	101.00
Armament	**Count:**	15	Propulsion	**Count:**	15
	Average:	228		Average:	43.73
	Median:	197.00		Median:	43.00
	Standard deviation:	109.50		Standard deviation:	24
	First quartile:	143.5		First quartile:	22.50
	Third quartile:	328.00		Third quartile:	62.50
C3INetwork	**Count:**	15	Tanker	**Count:**	15
	Average:	1,838.87		Average:	12.00
	Median:	1,829.00		Median:	12.00
	Standard deviation:	79		Standard deviation:	5
	First quartile:	1,783.50		First quartile:	7.50
	Third quartile:	1,889.50		Third quartile:	16.50

Case Count by PEO

Region	CC Descriptive Stats		Region	CC Descriptive Stats	
AFR	**Count:**	15	EUR	**Count:**	15
	Average:	112.67		Average:	1,190.13
	Median:	107.00		Median:	1,167.00
	Standard deviation:	12		Standard deviation:	54
	First quartile:	104.50		First quartile:	1,153.50
	Third quartile:	119.50		Third quartile:	1,230.50
AR	**Count:**	15	NESA	**Count:**	15
	Average:	231.93		Average:	812.40
	Median:	229.00		Median:	836.00
	Standard deviation:	12		Standard deviation:	115
	First quartile:	222.50		First quartile:	769.00
	Third quartile:	242.00		Third quartile:	906.50

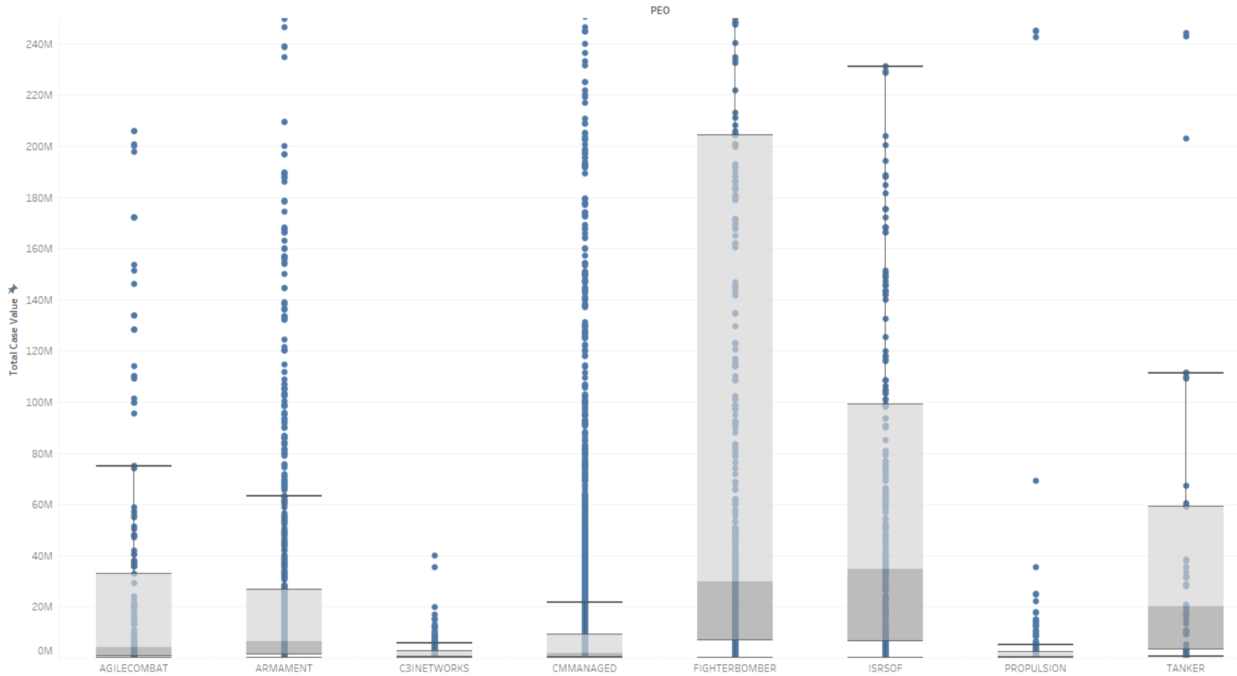
EAP	**Count:** 15 Average: 903.73 Median: 866.00 Standard deviation: 95 First quartile: 836.00 Third quartile: 973.50	NR	**Count:** 15 Average: 162.13 Median: 150.00 Standard deviation: 33 First quartile: 135.50 Third quartile: 179.50

Case Count by Region

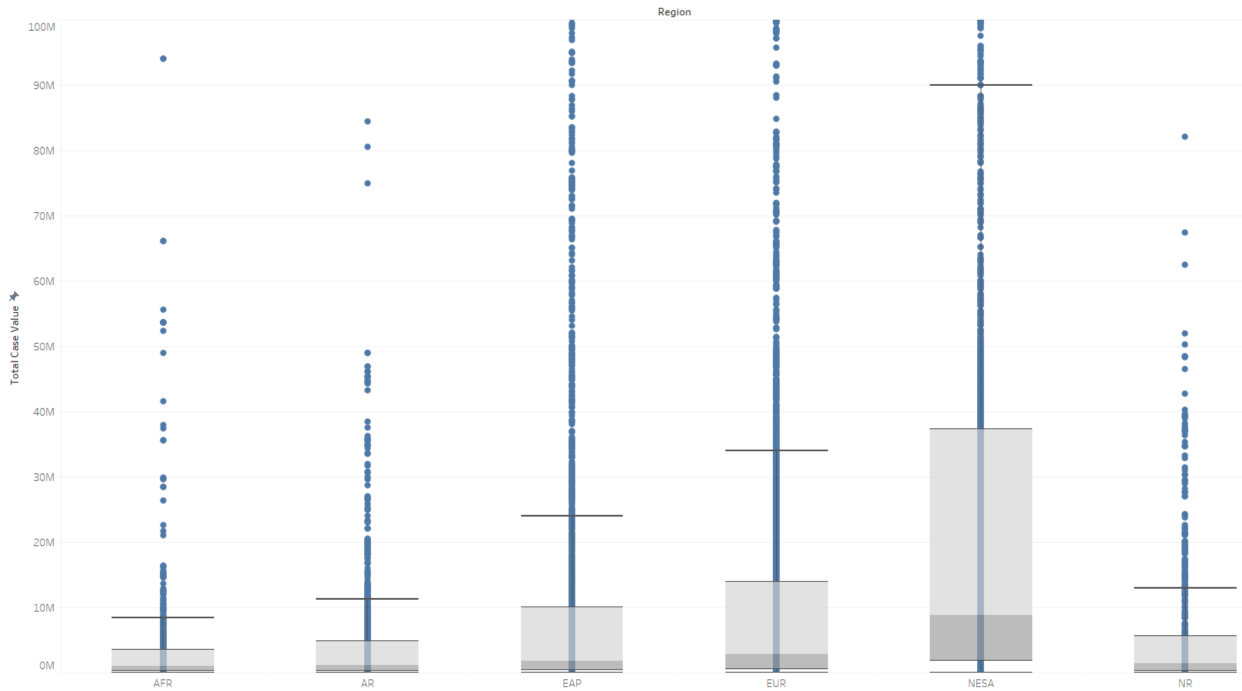
AOD	CC Descriptive Stats	
A	**Count:**	15
	Average:	828.47
	Median:	839.00
	Standard deviation:	28
	First quartile:	804.00
	Third quartile:	851.00
B	**Count:**	15
	Average:	1,700.73
	Median:	1,643.00
	Standard deviation:	161
	First quartile:	1,572.00
	Third quartile:	1,804.00
C	**Count:**	15
	Average:	883.80
	Median:	922.00
	Standard deviation:	123
	First quartile:	835.00
	Third quartile:	978.00

Case Count by AOD

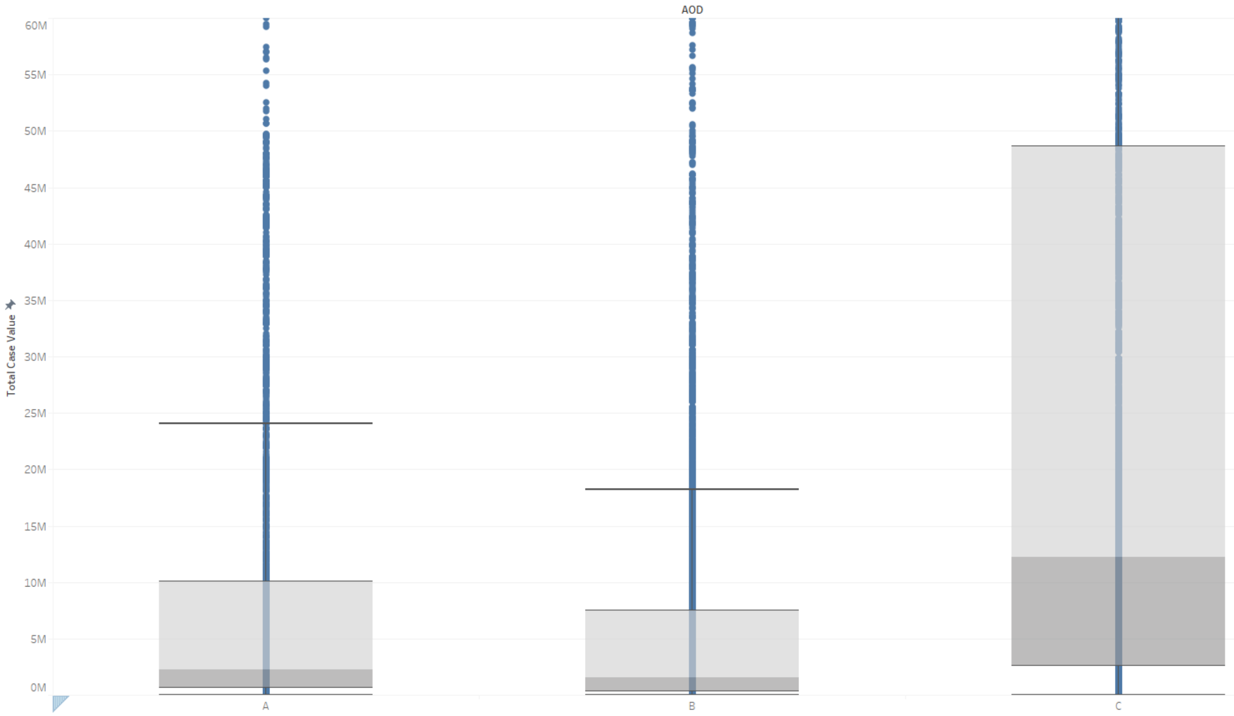
Appendix C –: Histograms



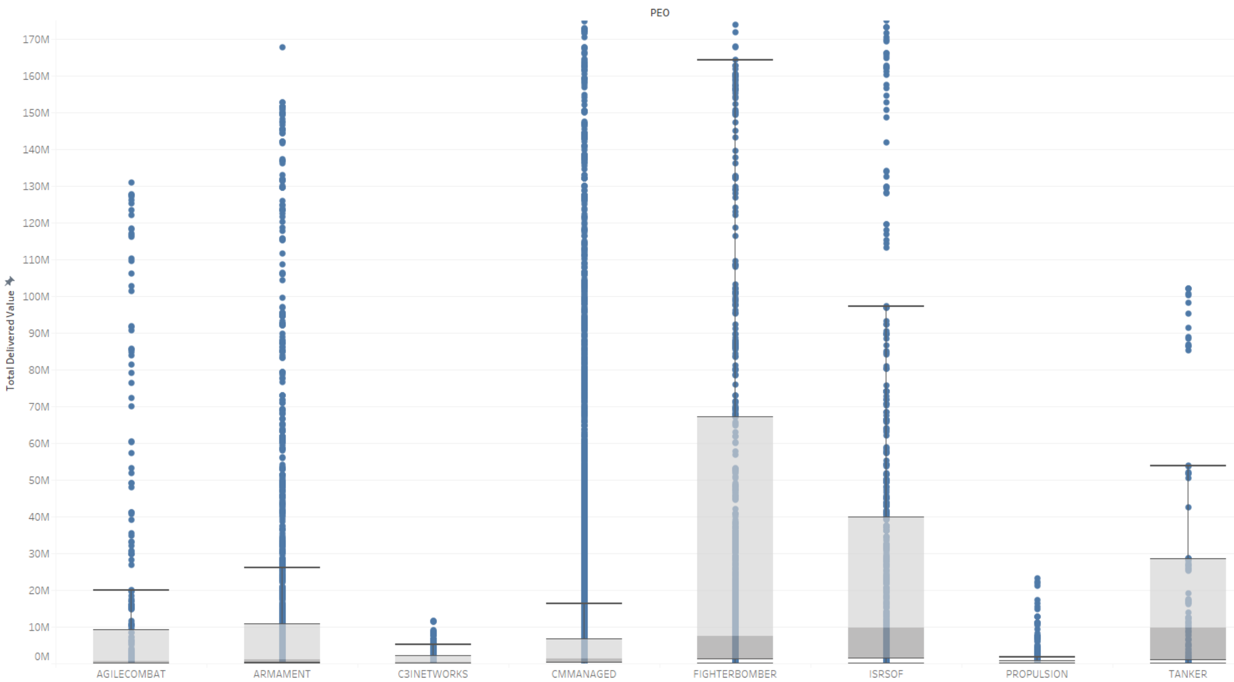
PEO TCV Histogram



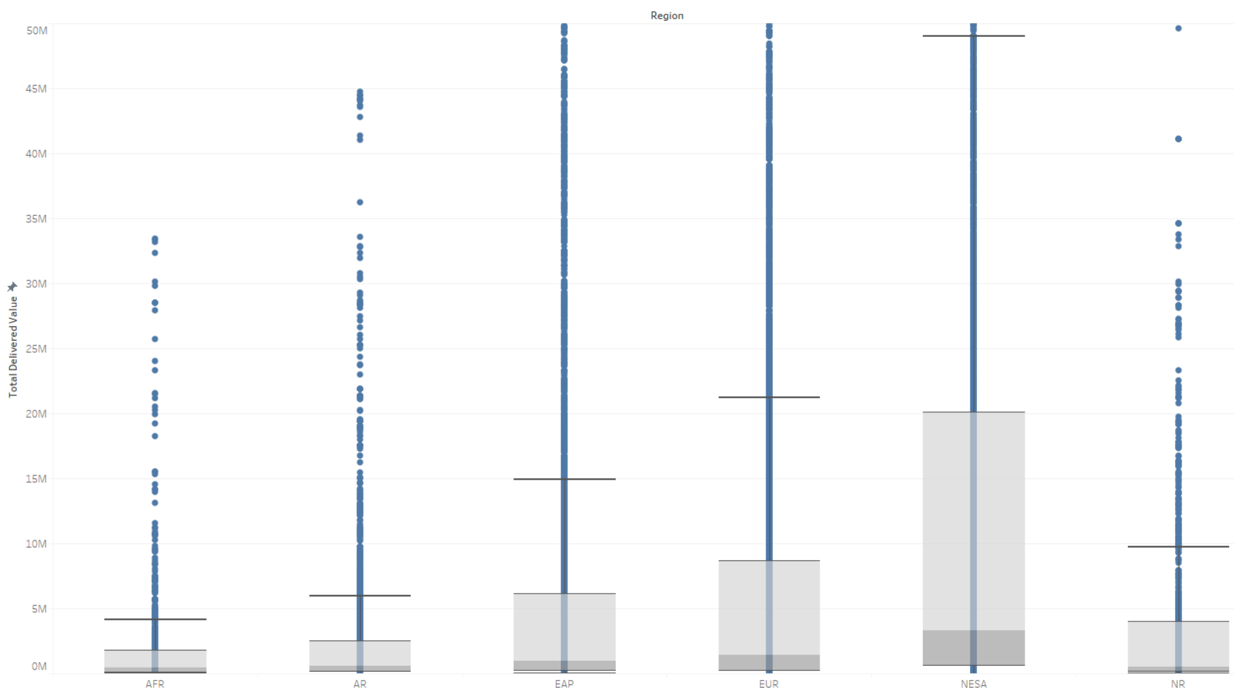
Region TCV Histogram



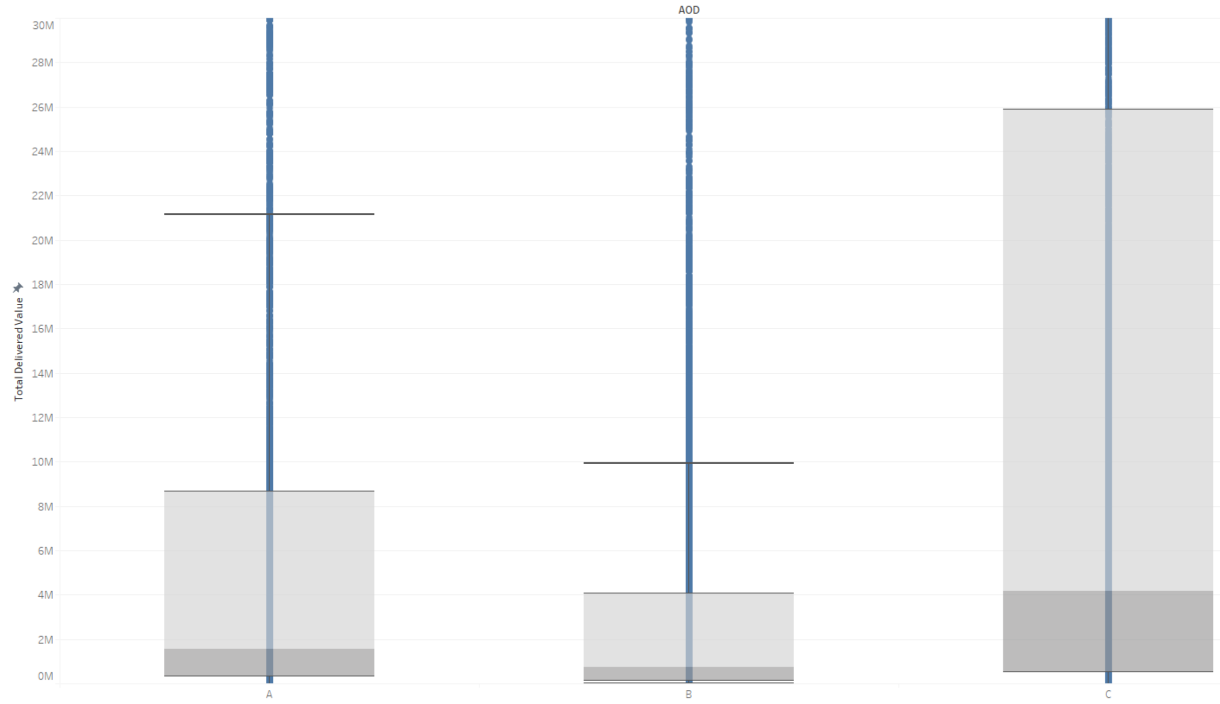
AOD TCV Histogram



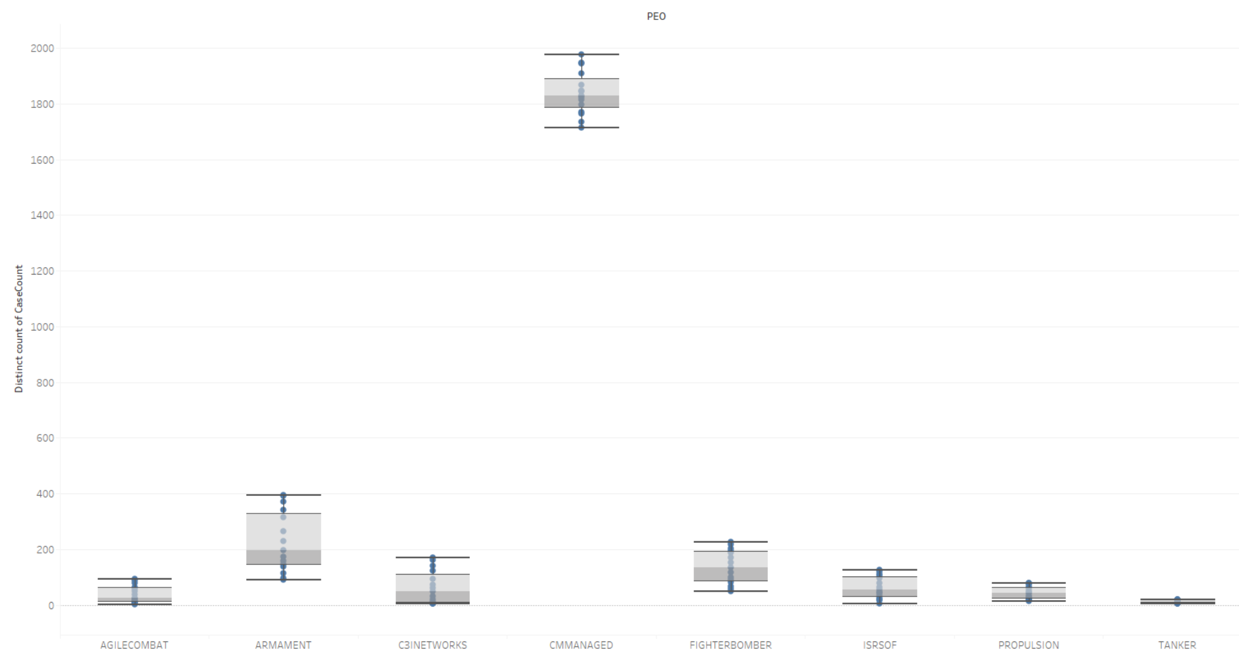
PEO TDV Histogram



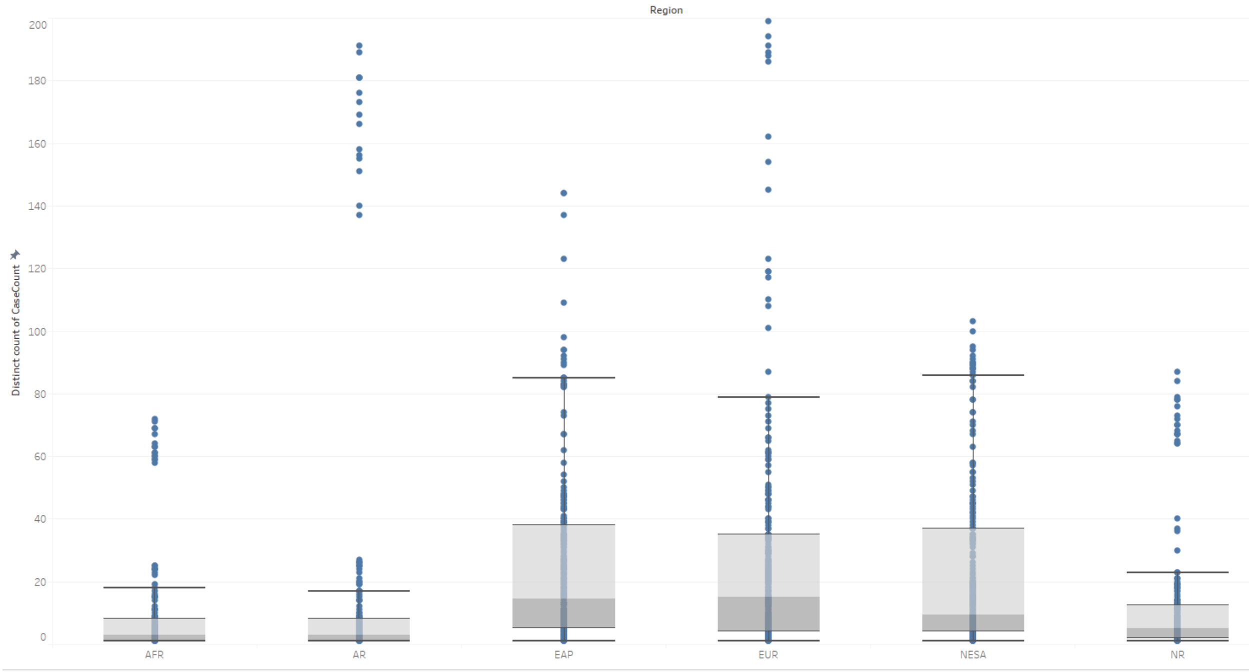
Region TDV Histogram



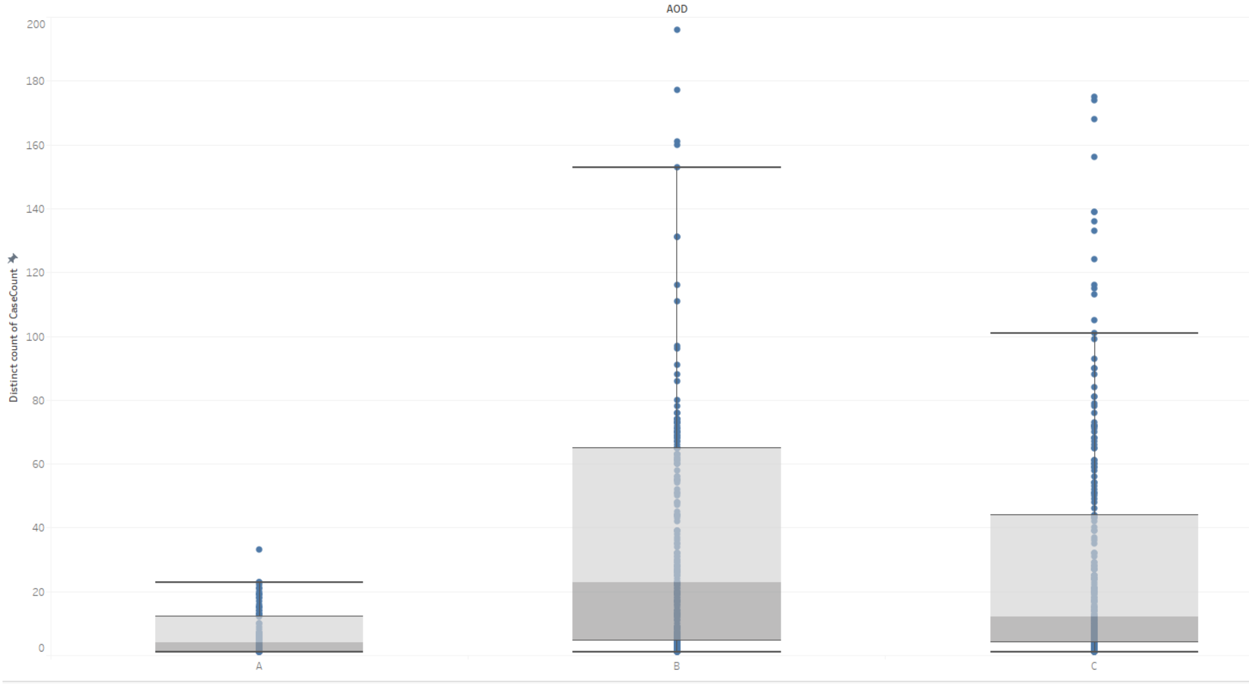
AOD TDV Histogram



PEO CC Histogram



Region CC Histogram



AOD CC Histogram

Appendix D –ANOVA Assumption Test Results

Tests of Normality

	PEO	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
TCV	1	.182	15	.193	.915	15	.162
	2	.301	15	.001	.771	15	.002
	3	.132	15	.200*	.921	15	.203
	4	.167	15	.200*	.852	15	.018
	5	.146	15	.200*	.922	15	.207
	6	.285	15	.002	.812	15	.005
	7	.116	15	.200*	.920	15	.196
	8	.204	15	.094	.815	15	.006

Tests of Normality

	Region	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
TCV	AFR	.307	15	.000	.771	15	.002
	AR	.148	15	.200*	.918	15	.178
	EAP	.192	15	.144	.910	15	.136
	EUR	.242	15	.018	.854	15	.020
	NESA	.238	15	.022	.859	15	.023
	NR	.171	15	.200*	.909	15	.129

Tests of Normality

	AOD	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
TCV	A	.105	15	.200*	.958	15	.654
	B	.190	15	.151	.901	15	.099
	C	.164	15	.200*	.925	15	.228

Shapiro-Wilk Results

AOD

Test of Homogeneity of Variances

TCV

Levene Statistic	df1	df2	Sig.
50.989	2	42	.000

PEO

Test of Homogeneity of Variances

TCV

Levene Statistic	df1	df2	Sig.
23.111	7	112	.000

Region

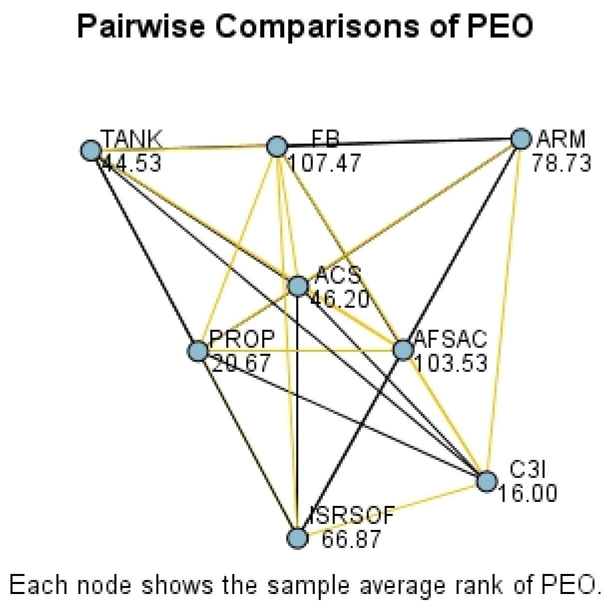
Test of Homogeneity of Variances

TCV

Levene Statistic	df1	df2	Sig.
49.285	5	84	.000

Leven-Statistic Results

Appendix E –Pairwise Comparison Results



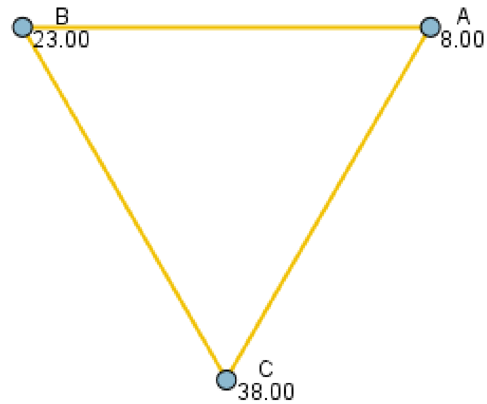
Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
C3I-PROP	-4.667	12.702	-.367	.713	1.000
C3I-TANK	-28.533	12.702	-2.246	.025	.691
C3I-ACS	30.200	12.702	2.378	.017	.488
C3I-ISRSOF	-50.867	12.702	-4.005	.000	.002
C3I-ARM	62.733	12.702	4.939	.000	.000
C3I-AFSAC	87.533	12.702	6.891	.000	.000
C3I-FB	-91.467	12.702	-7.201	.000	.000
PROP-TANK	-23.867	12.702	-1.879	.060	1.000

PROP-ACS	25.533	12.702	2.010	.044	1.000
PROP-ISRSOF	46.200	12.702	3.637	.000	.008
PROP-ARM	58.067	12.702	4.572	.000	.000
PROP-AFSAC	82.867	12.702	6.524	.000	.000
PROP-FB	86.800	12.702	6.834	.000	.000
TANK-ACS	1.667	12.702	.131	.896	1.000
TANK-ISRSOF	22.333	12.702	1.758	.079	1.000
TANK-ARM	34.200	12.702	2.693	.007	.199
TANK-AFSAC	59.000	12.702	4.645	.000	.000
TANK-FB	62.933	12.702	4.955	.000	.000
ACS-ISRSOF	-20.667	12.702	-1.627	.104	1.000
ACS-ARM	-32.533	12.702	-2.561	.010	.292
ACS-AFSAC	-57.333	12.702	-4.514	.000	.000
ACS-FB	-61.267	12.702	-4.824	.000	.000
ISRSOF-ARM	11.867	12.702	.934	.350	1.000
ISRSOF-AFSAC	36.667	12.702	2.887	.004	.109

ISRSOF-FB	40.600	12.702	3.196	.001	.039
ARM-AFSAC	24.800	12.702	1.952	.051	1.000
ARM-FB	-28.733	12.702	-2.262	.024	.663
AFSAC-FB	-3.933	12.702	-.310	.757	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .05.

Pairwise Comparisons of AOD

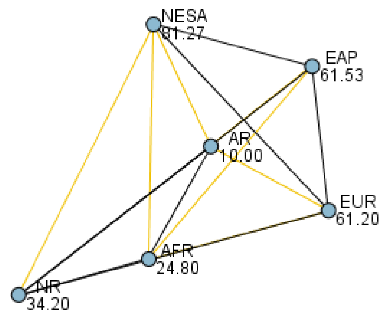


Each node shows the sample average rank of AOD.

Sample 1-Sam...	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
A-B	-15.000	4.796	-3.128	.002	.005
A-C	-30.000	4.796	-6.255	.000	.000
B-C	-15.000	4.796	-3.128	.002	.005

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .05.

Pairwise Comparisons of Region



Each node shows the sample average rank of Region.

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
AR-AFR	14.800	9.539	1.551	.121	1.000
AR-NR	-24.200	9.539	-2.537	.011	.168
AR-EUR	-51.200	9.539	-5.367	.000	.000
AR-EAP	-51.533	9.539	-5.402	.000	.000
AR-NESA	-71.267	9.539	-7.471	.000	.000
AFR-NR	-9.400	9.539	-.985	.324	1.000
AFR-EUR	-36.400	9.539	-3.816	.000	.002
AFR-EAP	-36.733	9.539	-3.851	.000	.002
AFR-NESA	-56.467	9.539	-5.919	.000	.000
NR-EUR	27.000	9.539	2.830	.005	.070
NR-EAP	27.333	9.539	2.865	.004	.062
NR-NESA	47.067	9.539	4.934	.000	.000
EUR-EAP	.333	9.539	.035	.972	1.000
EUR-NESA	-20.067	9.539	-2.104	.035	.531
EAP-NESA	-19.733	9.539	-2.069	.039	.579

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .05.

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14. ABSTRACT

This research studies the relationships between Air Force Foreign Military Sales (FMS) case factors and manpower authorizations. The Air Force FMS program has seen consistent annual increases in sales since 2017 and average annual growth of 7 percent since 2006. Manpower is a key factor in the continued success of the FMS program. The need to predict future manpower requirements and the lack of prior research in this area motivates this exploratory analysis to determine which FMS case factors are potential candidates to predict manpower needs. An initial comparison analysis of the available FMS case data was conducted, followed by the application of two commonly utilized manpower modeling methods: regression analysis and manpower ratios. A comparison analysis provided a common unit of analysis for case data and manpower data, Program Executive Office (PEO). It also provided a range of potential predictors of manpower with high correlations to manpower authorizations. A linear regression analysis determined total case value, case counts, and case density were useful in modeling the changes in manpower authorizations. An examination of potential manpower ratios for the Air Force FMS program suggests these ratios should be considered for additional research as the sample provided demonstrated a relative level of stability over time. This research provides a modern foundation for Air Force FMS manpower research and a better understanding of which case factors are useful for FMS manpower planning.

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