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DEVELOPING STANDARD ENGINEERING AND MANUFACTURING DEVELOPMENT COST FACTORS FOR MAJOR DEFENSE ACQUISITION PROGRAM PLATFORMS

Technical Report prepared for the Naval Postgraduate School Acquisition Research Program (F19-017)

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Abstract

Major defense acquisition program (MDAP) cost estimators use factors as one of their common estimating techniques. However, previous studies developing factors for the Engineering and Manufacturing Development (EMD) phase of the life cycle are limited. Our research significantly expands the currently available toolkit for cost analysts through the development of cost factors in previously unexplored areas. More specifically, we created 443 new standard cost factors that are delineated by five categories: commodity type, contract type, contractor type, development type, and service. The factors are developed for those elements that are common in a wide array of projects such as program management, systems engineering, data, or training. This new factor data set provides cost analysts with the information necessary to appropriately identify and quickly select the most relevant factors to utilize when developing future cost estimates. Through statistical analysis, the research also helps determine those elements to which more analysts' time and energy should be allocated when developing their estimates.

We analyzed data from 102 MDAPs to create the cost factors and conduct non-parametric statistical tests to identify differences in the aforementioned categories (i.e., commodity type, contract type, etc.). We found that the systems engineering/program management (SE/PM) and systems test and evaluation (ST&E) cost elements were unique in most categories analyzed. These cost elements also typically comprised the highest dollar value of the elements analyzed. This suggests that cost analysts should allocate more of their time and effort towards these elements when developing estimates. Due to these findings, utilizing highly aggregated cost factors in the SE/PM and ST&E areas is not advised. Other elements such as training and data, however, rarely demonstrated statistically significant differences in the categories analyzed. Aggregated factors are therefore likely to be sufficient in these areas, enabling estimates to be created quickly. In summary, the cost factor tables and statistical analysis in this research provide cost analysts with suggested guidance and an improved toolkit for applying cost factors within EMD cost estimates.

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Introduction

Cost growth in public projects is a perennial concern. While domestic and international public works—to include rail, bridges, and roads—receive significant attention for cost growth (Flyvbjerg et al., 2002), U.S. major defense acquisition programs (MDAPs) have also experienced substantial cost growth (Younossi et al., 2007; Ritschel et al., 2019). This growth results in a crowding-out of additional programs and an inability to satisfy demands. As shown by Bolten et al. (2008), the reasons behind defense program cost growth are numerous. While decisions by managers (e.g., changes in requirements post project implementation) bear much of the blame, the role of *inaccurate cost estimates* is also evident (Bolten et al., 2008). We focus on the latter transgressions in an effort to improve public procurement cost estimation.

Defense cost analysts utilize a range of models and techniques to estimate program resources. One of these tools is the application of standard cost factors. Factors are traditionally utilized as both a primary and as cross-check methodologies when estimating MDAP "common" cost elements such as program management, systems engineering, training, site activation, and spare costs.

Currently, the research division of the Air Force Life Cycle Management Center (AFLCMC) periodically publishes standard cost factor tables for aircraft engineering and manufacturing development (EMD) that capture prime contractor data for a selection of clean-sheet design aircraft programs. Despite the utility of the AFLCMC published tables, additional data exists that can assist in refining these factors, as well as developing new factors to include Army, Navy, and joint programs. Other identified gaps in currently published EMD factors include neglected commodity categories (e.g., electronic/automated software, missiles, ordnance, space, and unmanned aerial vehicles [UAVs]), development types (e.g., modification programs) and subcontractor data. Each additional category of data provides estimators the ability to accomplish more in-depth analysis based on the type of program in question. Thus, the expansion and refining of factors for EMD programs will provide estimators with a more robust tool set upon which to draw, ultimately leading to more precise estimates going forward.

Research Objectives

The purpose of this paper is to investigate the current state of EMD cost factors, refine existing standards where available, and develop and publish new cost factors for operational use by defense cost analysts in an array of project types. Furthermore, the conclusions from this paper help determine where future efforts should be focused towards gathering new data and/or refining existing factors. The specific questions this research aims to address are as follows:

1. What new standard cost factors can be produced through analysis of a diverse set of projects types?
2. Does the development of new factors significantly reduce the amount of error compared to current estimation models?
3. What statistically significant differences are found in cost factors by commodity type, contract structure, or program characteristic?

Background

Cost-Estimating Methodologies

The tool kit of a cost analyst consists of four primary estimating methods, as well as secondary techniques, but the use of standard cost factors represents a commonly utilized practice that is both defined in the Air Force cost analysis handbook (Air Force Cost Analysis Agency [AFCAA], 2007) and applied to a large extent in many current program offices (Government Accountability Office [GAO], 2009). With billions in taxpayer dollars at stake each year within the Department of Defense's (DOD) acquisition budget, it is imperative that program offices, and specifically cost analysts, understand their program, draw conclusions from past programs, and leverage technology to arrive at estimates in which the American public can place their confidence and trust (GAO, 2009). Because of this responsibility, this research aims to expand the breadth of analytical tools available, specifically with respect to the utilization of standard factors in major defense acquisition programs (MDAP).

To fully grasp the concept and application of standard factors in cost estimating, a basic foundation of knowledge must exist regarding the different cost estimating methodologies. Several key documents designate and define the cost estimating methodologies utilized within the DOD, including the Air Force cost analysis handbook (AFCAA, 2007) and the GAO (2009) *Cost Estimating and Assessment Guide*. These publications assist in setting a baseline for program offices and cost analysts to craft credible and consistent cost estimates, as well as an overarching legal requirement for the DOD to have policies in place to safeguard the billions of taxpayer dollars afforded to MDAPs each year (GAO, 2009). While the documents define the acceptable estimating methodologies, they do not represent an all-encompassing guidebook, as every MDAP presents its own unique challenges. The four primary techniques outlined in the Air Force cost analysis handbook include: analogy and factor, parametric, build-up (engineering), and expert opinion (subject matter expert) (AFCAA, 2007). While each technique represents a different approach to cost estimating and has benefits and drawbacks, the merit of utilizing multiple strategies to achieve greater confidence in an estimate cannot be understated. The introduction of more than one estimating technique provides cost analysts with the ability to triangulate a point estimate that considers levels of detail not fully captured by individual techniques or estimates. Furthermore, this approach serves as a cross-check to ensure estimates do not fall too far outside the bounds of reasonableness for the given program.

Figure 1 from the Air Force cost analysis handbook (AFCAA, 2007) details the four cost estimating methods and shows the progression over the program life cycle.

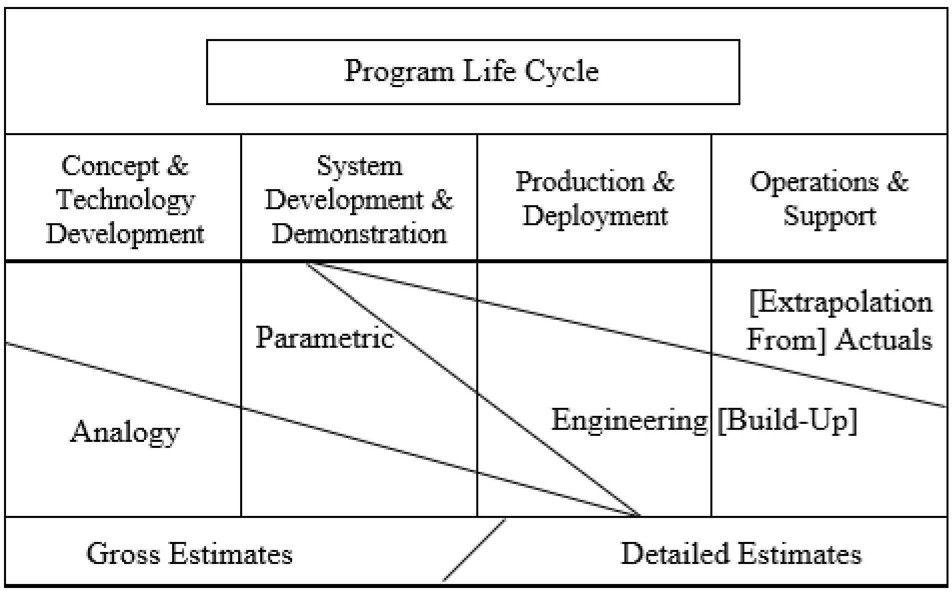

Figure 1. Selection of Methods (AFCAA, 2007)

The analogy method of cost estimating takes historical data from existing similar programs or systems and applies a scaling factor (or range of factors) to account for differences in the new system and arrive at a feasible estimate (Mislick & Nussbaum, 2015). The scaling factor(s) represent disparities between the old and new programs in the context of size, performance, technology, complexity, and many others, and set an initial estimate given the early stage of the program's life cycle (GAO, 2009).

The parametric estimating technique represents an approach based upon a statistical relationship drawn between historical costs and certain characteristics (program, physical, and performance), also referred to as cost drivers (GAO, 2009). A cost estimating relationship (CER), where cost is directly proportional to a single independent variable, is known as a cost factor.

The build-up method of cost estimating consists of an exhaustive collection of lower-level program element estimates followed by a roll-up of each estimate to arrive at the total program cost (AFCAA, 2007). Often referred to as the engineering approach, this technique is based largely on in-depth engineering data and requires a great deal of labor and material cost information to produce a reliable estimate.

Elements of the Work Breakdown Structure

The Work Breakdown Structure (WBS) as a concept is one of the few aspects of MDAPs that has remained constant over the course of the past several decades (Department of Defense [DoD], 2005). It represents a decomposition of a project into smaller, more manageable components and is sometimes referred to as the management blueprint for the project (Mislick & Nussbaum, 2015). The WBS is mandated and governed by MIL-STD-881D (DoD, 2018), ultimately fulfilling broader requirements set forth in Department of Defense (DoD) Instruction 5000.2 (Under Secretary of Defense, 2013); this DoD publication aims to maintain uniformity in definition and consistency of approach for programs developing a WBS (DoD, 2018). For the sake of consistency, the DoD has revised and updated guidance regarding the WBS only when major technological advances or changes in the acquisition process warranted such action (DoD, 2005).

The WBS can be broken down further at a variety of levels; the first sub-categorization of the WBS lies in two interrelated substructures: the contract WBS and the program WBS. The contract WBS exists primarily as a reporting mechanism for the contractor to the government and relates directly back to the contract statement of work (SOW). Whereas the contract WBS focuses on contractor requirements, the program WBS serves as an extension of the contract WBS by encompassing the entire program at a summary level (Mislick & Nussbaum, 2015). Within the program WBS, three distinct levels display and define the actual program outputs and relate the elements of work to one another, as well as to the end product (Mislick &

Nussbaum, 2015). Each represents a medium by which work progress is recorded and communicated from every level to position program leadership and the contractor to identify, coordinate, and implement changes as needed (DoD, 2011).

The WBS consists of three primary hierarchical levels, with a fourth and fifth sometimes included in expanded forms; for this research only the top three levels are addressed. Level 1 represents the entire system or material item such as an aircraft, ship, space, or surface vehicle system (Mislick & Nussbaum, 2015). The second level captures major elements subordinate to the system identified by Level 1 and consists of prime mission products, including all hardware and software elements. Level 2 also includes combinations of system-level services applicable to the program including the following elements common to most programs: integration and assembly, system test and evaluation (ST&E), systems engineering/program management (SE/PM), common support equipment (CSE), peculiar support equipment (PSE), training, data, operational/site activation, and initial spares and repair parts (DoD, 2018). These system-level combinations are then further deconstructed into the Level 3 elements, which consist of more detailed components of the Level 2 major elements of the program, including hardware, software, and services (DoD, 2005). Figure 2 displays a generic version of the WBS with varying amounts of detail as viewed from left to right, as published in MIL-STD-881D (DoD, 2018).

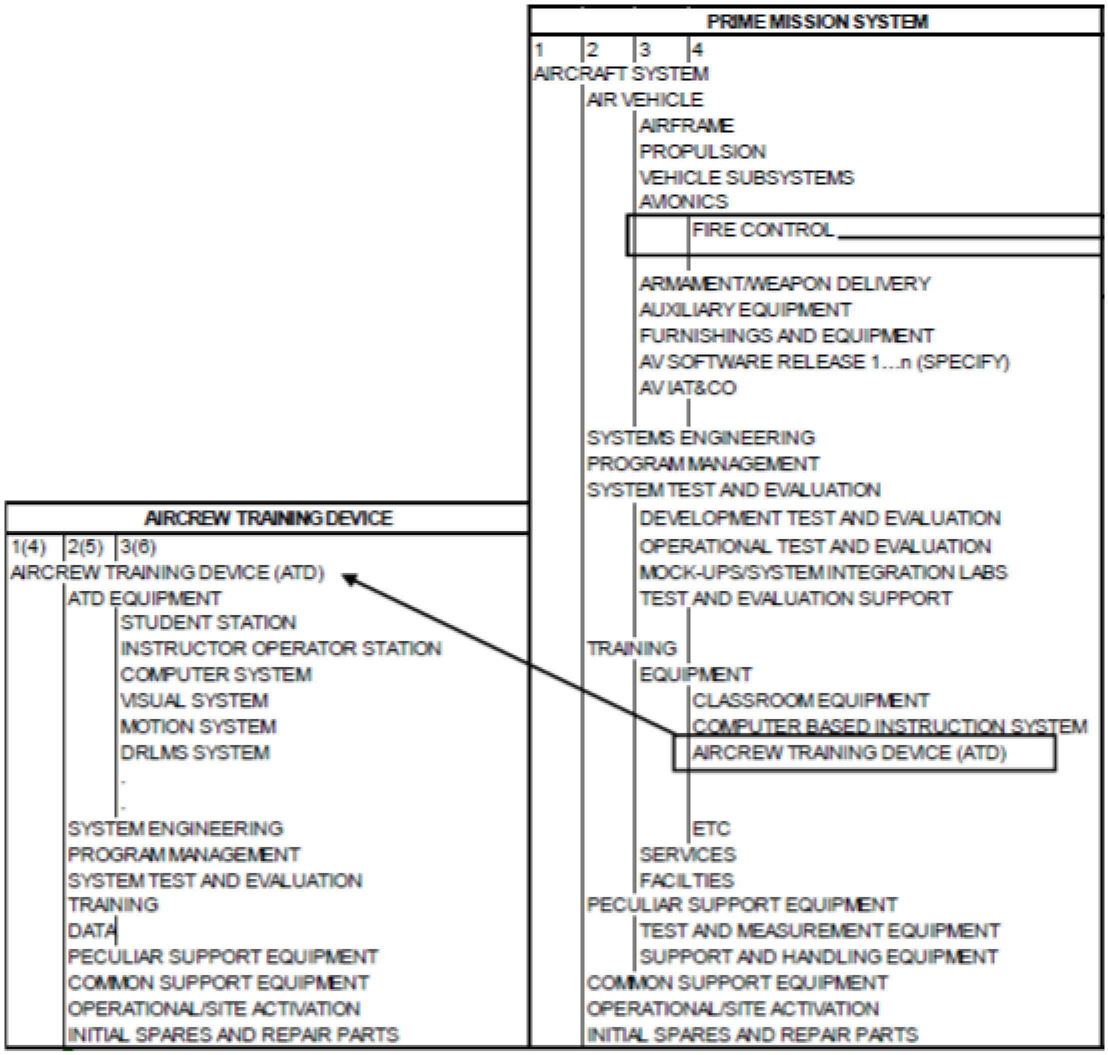

Figure 2. Work Breakdown Structure Matrix (Contract WBS) (DoD, 2018)

The aforementioned "common" elements at Level 2 of the WBS are the focus for developing factors in this research. The mandated MIL-STD-881D structure enables the normalization of data and information across a variety of commodity types and DoD agencies (DoD, 2018). This allows not only for factor development, but also statistical testing of differences between characteristics such as commodity type to answer the proposed research questions.

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Literature Review

Previous Cost Factor Research

Extensive research on major defense acquisition program (MDAP) factors in cost estimating does not exist to the extent necessary to fully and efficiently utilize the technique. Limited scope studies within the Air Force began in the 1980s and were followed up sporadically with similarly limited updates and publication, creating a gap in cost analysts' ability to employ the technique effectively. The first major USAF aircraft factor study, often referred to as the "Blair Study," was conducted by Joan Blair in 1988 and established cost element factors for programs in the Engineering and Manufacturing Development (EMD) phase of the acquisition life cycle (Wren, 1998). The Blair Study consisted of 24 programs and encompassed data for aircraft avionics support systems only, which proved useful for specific purposes at the Aeronautical Systems Center (ASC) at Wright-Patterson Air Force Base (WPAFB) for a period of approximately 10 years but ultimately became outdated and questionable for use in current programs (Wren, 1998).

A study performed by Wren (1998) utilized the Blair Study as a starting point and included an additional 20 programs, but again only in the realm of aircraft avionics and for the primary purpose of utilization by the ASC at WPAFB (Wren, 1998). The efforts of Blair and Wren represent a sizable stepping-stone towards an exhaustive reference table of factors for DoD analysts but lack the breadth required to make the studies applicable to more than a specific set of programs based at WPAFB. Wren (1998) acknowledged in the findings of his 1998 study that he was unable to update the factors from the Blair Study due to unavailability of data and substantial program adjustments over the course of a decade. This acknowledgement reinforced the need for a more exhaustive study, as well as periodic updates to maintain the credibility of the factors. Almost 20 years after Wren's study, Otte (2015) conducted a factor study aimed at updating and expanding the outdated factors utilized by many Air Force Life Cycle Management Center (AFLCMC) personnel. His work reflects another step towards a more substantial set of EMD cost factors for analysts across the DoD and even includes previously unacknowledged WBS elements (Otte, 2015). Despite the substantial increase in utility of Otte's findings versus Blair's and Wren's, a multitude of shortfalls remains, including the lack of additional commodity types besides aircraft, modification programs, subcontractor data, and even contract type.

The utility of factors in cost estimating extends beyond just acquisition programs, reaching across various government agencies and functions to support more efficient budgeting and execution of taxpayer dollars (Mislick & Nussbaum, 2015). With such widespread utilization of the factor method, a variety of different research exists, especially within the DoD. The Naval Center for Cost Analysis (NCCA) engages in continuous research on cost estimation and publishes periodic findings to guide and strengthen cost analysis within the Navy (NCCA, 2018). In addition to this research, the NCCA conducts economic and business case analyses for a variety of issues within the Department of the Navy, creating benchmarks from which factors can be created for cost estimates (NCCA, 2018). While all military branches are governed by general DoD guidance, service-specific directives illustrate some differences in the application of certain requirements, such as cost estimation. The Air Force's use and research of the factor method extends beyond the acquisition world and is detailed in lower-level directives like functional area Air Force Instructions (AFI) to better predict costs in logistics, personnel, programming, and flying hour operations (Secretary of the Air Force, 2018). Additionally, the Air Force publishes dozens of factor tables for personnel to utilize for estimates specific to their respective functions; these tables are updated regularly and serve as a benchmark for cost estimation within the Air Force. Another illustration of cost factors' place in the DoD comes from the publishing of area cost factors each year to assist in preparation and review of military construction, Army and Army family housing projects, and a variety of other facility related projects (PAX, 2018). These factors reflect a selection of characteristics to accomplish broad levels of analysis and estimation and serve as benchmarks for estimators to then add their own individual details to modify the factors and arrive at a credible estimate (PAX, 2018).

Utility of Factors in Cost Estimating

The analogy and factor method of cost estimating is used by DoD analysts constructing estimates for MDAPs, but this approach also serves the private and public sectors in formulating cost estimates for large projects. In the case of public works projects, specifically transportation infrastructure, there is sometimes a lack of credible estimates available due to the financial interests of potential contractors and the agenda that accompanies large contract awards (Flyvbjerg et al., 2002). There are claims of this type of problem existing even within government contract awards; however, the issue can be at least partially relieved by the establishment of standard factors for analogous projects to protect entities (state and local governments in many cases) in need of these major services from being misled with regard to cost estimates. One issue with this remedy, however, lies in the lack of exhaustive analogy and factor studies in existence and/or available to those in need of the data (Flyvbjerg et al., 2002). While it can be argued that MDAPs pose entirely different challenges compared to large infrastructure projects, the common theme lies in the vast complexity and likelihood of changes that each type of project contains. Infrastructure projects do not represent the sole area in need of improved estimation; numerous international studies have found construction projects in general exhibit cost overruns and inefficiencies that can be traced to poor estimating practices (Baloi & Price, 2003; Elfaki et al., 2014). Such widespread occurrence of inaccurate estimating necessitates a focus on the establishment of improvements in the resources available to estimators, with historical standard factors being one of those resources.

While the practice of cost estimating exists in different capacities around the world, the common intent is to arrive at an estimate that aids in the decision-making process of the project (Greves & Joumier, 2003). The shortcomings of the use and structure of historical data and information are illustrated by large projects' consistent cost overruns (Riquelme & Serpell, 2013). The myriad issues identified in projects around the world reinforces the need for additional data that will provide analysts the ability to effectively leverage historical information to arrive at a credible cost estimate. The data required to perform the necessary analysis for cost estimating requires scrutiny to ensure accuracy and applicability, but the time invested in this pursuit yields more effective estimates (Ali Abbas et al., 2012). The analogy and factor technique represents just one of many cost-estimating methodologies, but when properly utilized in any field or environment, it aids in achieving an estimate that embodies completeness, reasonableness, and analytic defensibility (Mislick & Nussbaum, 2015).

The creation and utilization of standard factors makes it possible to conduct more effective and extensive analysis at a variety of levels to construct credible cost estimates, especially in programs early in their life cycle or with limited information regarding the central task (Mislick & Nussbaum, 2015). Several of the primary areas in which additional analysis is beneficial for program offices include commodity type, contractor designation (prime or sub), and contract type. These program characteristics serve as a starting point for data normalization, as well as more in-depth scrutiny within the structure of the WBS. The use of qualitative context factors, like those dictated by the WBS format, assists in the effective interpretation and use of historical information, which further strengthens the legitimacy of cost estimates that employ the standard factor approach (Riquelme & Serpell, 2013). Using the Level 2 WBS elements as a guide, analysts have virtually every historical MDAP with relevant data at their fingertips to create factors to then extrapolate upon for their specific program. The value of a central database that encompasses all commodity types, contractor designations, and contract types lies in the ability to conduct analysis at each of these respective levels and manipulate the data to create factors for each Level 2 element of the WBS. Through the creation of factors, cost analysts throughout the DOD can target specific analytical levels and more effectively formulate credible, defensible estimates for MDAPs.

Methods/Design

Data

The data gathered in this research comes from the Defense Automated Cost Information Management System (DACIMS), which exists within the Cost Assessment Data Enterprise (CADE) system. DACIMS contains cost data summary reports, often referred to as 1921s, which contain the necessary cost data to establish factors for the major defense acquisition programs (MDAP) targeted for this research. Engineering and manufacturing development (EMD) data was chosen as the only life-cycle phase to be analyzed based on a gap in this area identified by the literature review. The data set consists of 102 programs spanning from 1961 to 2017, representing a broad range of programs across numerous commodity types and services.

While 189 programs are available within CADE, only 102 of those programs fit the criteria for inclusion in the final data set. Table 1 depicts the exclusion criteria and accompanying number of programs not utilized for this research.

Table 1. Data Set Exclusions

Category	Number Removed	Remaining Programs
Available Programs in CADE		189
Excluded Commodity Types	35	154
No EMD Data	25	129
1921 File Format Not .XLS	27	102
Final Data Set for Analysis		102

Programs containing initial 1921 data only were excluded. A small portion of the data came from interim 1921s. In these instances, the data contained on the interim 1921s was equal to or greater than the final contract price. There were 27 programs that contained data but lacked accessible files within CADE, resulting in the entire program's exclusion from the data set. These were primarily older programs with manually transcribed data from the 1980s or earlier and in many instances contained illegible data.

Differentiation between contractor type, as well as unique aspects of programs (blocks, phases, etc.) resulted in multiple factors for most programs, each with their own Level 2 WBS elements. Table 2 provides an overview of the major characteristics of the final data set for this research, which consisted of 443 unique factors.

Table 2. Data Set Characteristics

Category	Total
Unique Factors Created	443
Commodity Type	
Aircraft	245
Electronic/Automated Software	118
Missile	22
Ordnance	12
Space	36
UAV	10
Contractor Type	
Prime	308
Subcontractor	135

Category	Total
Development Type	
Commercial Derivative	4
Modification	135
New Design	150
Prototype	9
Subsystem	105
New MDS Designator	40
Service	
Air Force	196
Army	94
Multiple	24
Navy (includes Marine Corps)	129

Category	Total
Contract Type	
CPAF	74
CPFF	39
CPIF	66
Cost-Other	135
FFP	27
FPI	20
FPIF	19
Fixed-Other	6
Unknown	57

Each category and accompanying subcategory represented in Table 2 corresponds to information from the CADE database utilized for data collection except the development type subcategories: new design, modification, prototype, new mission design series (MDS) designator, commercial derivative, and subsystem. This category contained a level of subjectivity due to a lack of explicit definitions within current governing DoD acquisition publications. Defining each subcategory of development type was accomplished through consultation with active cost estimators and alignment with generally accepted descriptions utilized in the field. New design programs were those whose capabilities were new to the DoD, while modifications were defined as programs undergoing a major change to core capabilities or performance. Prototypes were MDAPs whose intent was to test an emerging capability for future utilization within the DoD. New MDS designator captured primarily aircraft MDAPs with minor changes, such as the F-16B, which accommodates two pilots instead of one for training purposes. Commercial derivatives were defined as programs whose capability hinged upon a capability present in the commercial market that was adapted for military use. The subsystem designation was also primarily for aircraft MDAPs and was assigned to those programs whose efforts were accomplished independent of the airframe, such as an engine upgrade.

Factor Calculation

The methodological approach has two phases. The first stage is creation of individual factors. The cost element factors contained in this research are the ratio (percentage) of the individual Level 2 Work Breakdown Structure (WBS) elements to a base cost. The base cost is represented by a program's prime mission equipment (PME) value, which does not include the contractor's fee or miscellaneous expenses (general and administrative, undistributed budget, management reserve, facilities capital cost of money). The general form of the calculation is shown below:

$$\frac{WBS\ Level\ 2\ Element_{ij}}{PME_j}$$

where *i* = SE/PM, ST&E, Training, Data, PSE, CSE, Spares, and Site Activation; *j* = individual programs

After establishing cost factors for the Level 2 WBS elements, it is possible to develop composite factors for myriad unique categories. Specific Level 2 WBS elements can be examined in groupings to establish aggregate values that represent an average or percentage that can be used in formulating estimates. These groupings allow for analysis at innumerable levels, such as fixed-wing aircraft, rotary-wing aircraft, a specified contractor for radar modifications, a specified contractor's role in a program (prime versus sub), a specified period for a certain commodity type, and many more. Table 3 illustrates how this averaged cost factor represents a more accurate factor as it guards against the skewness that can result from calculations based on single data points.

Table 3. Example Composite Cost Factor Calculation

		PME	SE/PM	Percentage
Program 1		250K	60K	0.24
Program 2		370K	41K	0.11
Program 3		450K	80K	0.18
Program 4		155K	30K	0.19
	TOTAL	1,225K	211K	0.72

Cost Factor = 0.72 ÷ 4 = 0.18 or 18%

Once the factors were established for each program, the mean, median, and standard deviation values for the various program groupings were calculated. In addition, interquartile ranges were calculated to examine variability among factors. This allowed for descriptive analysis and provided a basis from which the programs were grouped and analyzed to compare differences in total cost.

The second stage of analysis subdivided the cost factors into categories for statistical testing to aid the cost analyst in determining appropriate levels of aggregation for practical use. This research highlights five major comparisons: service, commodity type, contractor designation, contract type, and development type, with associated subcategories shown in Table 4.

Table 4. Categories for Comparison Analysis

Categories				
Service	**Commodity Type**	**Contractor Designation**	**Contract Type**	**Development Type**
Army	Aircraft	Prime	CPAF (Cost Plus Award Fee)	Modification
Navy (includes Marine Corps)	Electronic/Automated Software	Sub	CPFF (Cost Plus Fixed Fee)	New Design
Air Force	Missile		CPIF (Cost Plus Incentive Fee)	Prototype
Multiple	Ordnance		Cost-Other (Other than CPAF, CPFF, CPIF)	Subsystem
	Space		FFP (Firm-Fixed Price)	New MDS Designator
	UAV		FPI (Fixed-Price Incentive)	Commercial Derivative
			FPIF (Fixed-Price Incentive Firm Target)	
			Unknown	

Statistical Tests

For each of the categorical comparisons, the hypothesis test in Equation 1 is utilized, where *x* and *y* represent subcategories from Table 4:

$$H_o: \Delta_x = \Delta_y$$

Equation 1

$$H_a: \Delta_x \neq \Delta_y$$

Initial statistical testing utilized the Shapiro–Wilk test for normality. Rejection of the Shapiro–Wilk null hypothesis necessitated the application of non-parametric tests in the analysis. Specific tests used include the Kruskal–Wallis and Steel–Dwass tests. The Kruskal–Wallis test is a rank-based nonparametric test to determine whether statistically significant differences exist between two or more groups of an independent variable on a continuous dependent variable. Because the Kruskal–Wallis test does not identify where within the subcategory comparison differences occur, the Steel–Dwass test was employed. The Steel–Dwass multiple comparison test identifies which rank orders of the tested groups are statistically different for each instance of subcategory comparison.

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Results and Analysis

Stage 1: Descriptive Statistics

Factor development in stage one of the analysis resulted in 443 new, unique cost factors across the eight common Level 2 WBS elements: Systems Engineering/Program Management (SE/PM), System Test and Evaluation (ST&E), Training, Data, Common Support Equipment (CSE), Peculiar Support Equipment (PSE), Site Activation, and Spares. Individual results for each WBS element follow.

Systems Engineering/Program Management (SE/PM)

The SE/PM element of the WBS represents one of the more prominent factors in this analysis in several ways. First, SE/PM had the fewest number of blank values of any WBS element, with only 19 blanks, or 4.29%. SE/PM values ranged from 0.43% to 4,768% of Prime Mission Equipment (PME), indicating potential reporting anomalies and/or additional issues in the extreme upper values. To establish meaningful exclusion criteria, the distribution of all SE/PM values was computed using JMP software. Analysis of the distribution resulted in values above 150% of PME being removed from the data set for all remaining SE/PM analysis. These excluded values represented only 4.06% of the data set, were more than three standard deviations from the mean, and in most cases were part of an MDAP with a total PME of less than $10 million. Figure 3 shows the distribution of SE/PM values after exclusions were made and provides descriptive statistics utilized in further analysis.

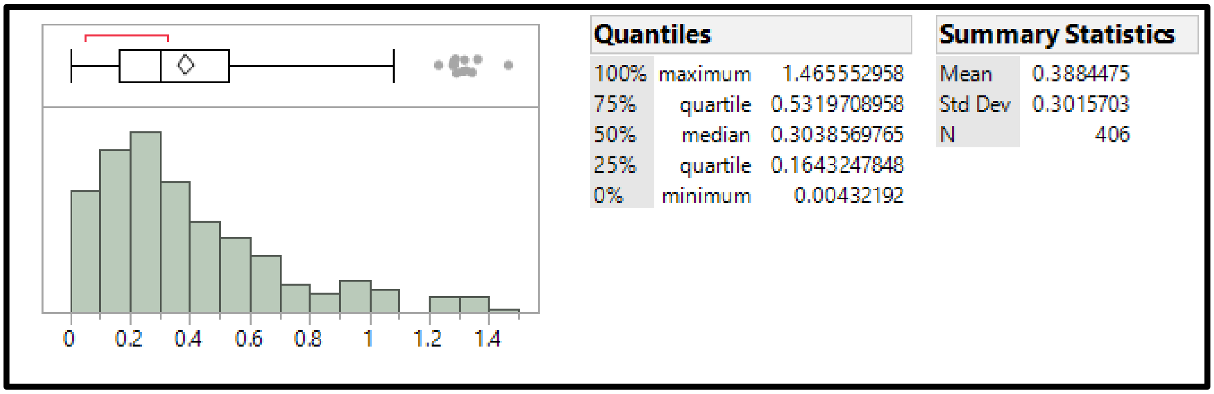


Figure 3. SE/PM Descriptive Statistics

The resulting distribution for the SE/PM WBS element is characterized by many data points, as well as a high standard deviation value. The distribution's central points lie between 0.25 and 0.40, which is reinforced by the mean and median values of 0.38 and 0.30, respectively. The graph suggests a lognormal distribution may be an appropriate distributional shape for modeling the fully aggregated SE/PM cost factor. However, due to the large coefficient of variation, knowledge of unique program characteristics is desirable for selecting the most relevant information.

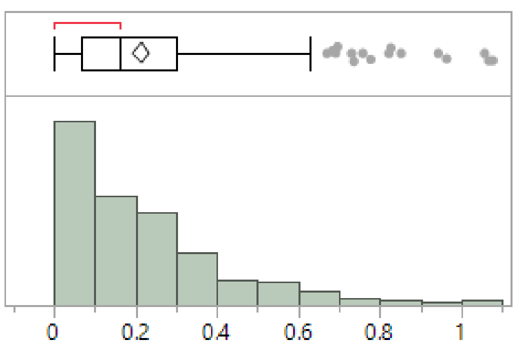
Table 5 displays an example of the individual distributions and descriptive statistics broken out by category for the SE/PM WBS element. Cost analysts can use these descriptive statistics to establish distributional forms and bounds for their SE/PM factor cost model. The detailed analysis displayed in Table 5 for subsequent WBS elements (ST&E, Training, Data, PSE, CSE, Site Activation, and Spares) can be found in Appendix A.

Table 5. SE/PM Summary Table

	Mean	Std Dev	*N*	Max	75%	Median	25%	Min
Service								
Air Force	0.3685	0.2755	177	1.324	0.4894	0.2972	0.159	0.0043
Army	0.508	0.3372	91	1.3453	0.6989	0.4426	0.2514	0.0098
Navy	0.3393	0.3039	115	1.4655	0.465	0.2551	0.1421	0.0105
Multiple	0.3142	0.2053	23	1.0007	0.4047	0.2699	0.1626	0.0903
Development Type								
Modification	0.3484	0.2555	124	1.3191	0.4954	0.2845	0.1539	0.0043
New Design	0.4738	0.3472	131	1.4655	0.6582	0.3759	0.219	0.0053
Prototype	0.1906	0.1472	8	0.39	0.3417	0.1783	0.0627	0.0126
Subsystem	0.373	0.2816	101	1.324	0.5343	0.2793	0.161	0.0105
New MDS Designator	0.3249	0.2924	39	1.3619	0.3887	0.2517	0.1154	0.0445
Commercial Derivative	0.184	0.1011	3	0.2676	0.2676	0.2128	0.0716	0.0716
Contractor Type								
Prime	0.3849	0.3068	284	1.3619	0.4896	0.2947	0.1609	0.012
Subcontractor	0.3966	0.2898	122	1.4655	0.5613	0.3336	0.1724	0.0043
Commodity Type								
Aircraft	0.3025	0.2385	227	1.3619	0.4115	0.2292	0.1421	0.0105
Electronic/Automated Software	0.5463	0.3511	107	1.4655	0.7816	0.4875	0.2568	0.0098
Missile	0.5014	0.3297	20	1.2822	0.7695	0.3897	0.2682	0.0576
Ordnance	0.3426	0.1737	11	0.6117	0.5007	0.285	0.2439	0.0811
Space	0.3825	0.3093	31	1.3191	0.4972	0.3109	0.1488	0.0043
UAV	0.4913	0.3217	10	1.324	0.5435	0.3655	0.303	0.2617
Contract Type								
CPAF	0.4128	0.2641	66	1.2792	0.5792	0.3649	0.2206	0.0337
CPFF	0.5189	0.3896	37	1.3453	0.7022	0.4233	0.2387	0.0053
CPIF	0.3905	0.2987	61	1.2924	0.522	0.2729	0.18	0.0276
Cost-Other	0.4082	0.3103	126	1.4655	0.5874	0.3175	0.1767	0.0043
FFP	0.2457	0.2531	25	1.0786	0.3494	0.156	0.0871	0.0105
FPI	0.2118	0.2232	17	1.0081	0.2349	0.1694	0.0729	0.0484
FPIF	0.4203	0.2811	19	1.2822	0.5578	0.3931	0.2218	0.0675
Fixed-Other	0.572	0.2327	4	0.8384	0.8026	0.5427	0.3707	0.3643
Unknown	0.3131	0.2573	51	1.3144	0.4426	0.243	0.1275	0.0385

System Test and Evaluation (ST&E)

ST&E contained the second largest number of data points for analysis. Only 57 rows, or 12.87%, of the total factors were blank values for ST&E. Values for ST&E ranged from below 0.1% to as high as 1,485% of PME, indicating potential reporting anomalies in the upper extreme values. ST&E values below 0.1% of PME were excluded, as they represented trivial dollar amounts (less than $16,000 in most cases). On the high end of the distribution, ST&E values above 150% of PME were excluded, and in all five instances the PME dollar amount for the MDAP was less than $10 million. The upper and lower exclusions of ST&E values make up only 2.71% of the data set. Figure 4 depicts the ST&E distribution as well as its accompanying descriptive statistics. The individual descriptive statistics for ST&E—broken out by commodity type, contract type, development type, contractor designation, and service—are found in Appendix A.



Quantiles

100%	maximum	1.077668426
75%	quartile	0.2999260488
50%	median	0.1611484545
25%	quartile	0.0658709168
0%	minimum	0.001281157

Summary Statistics

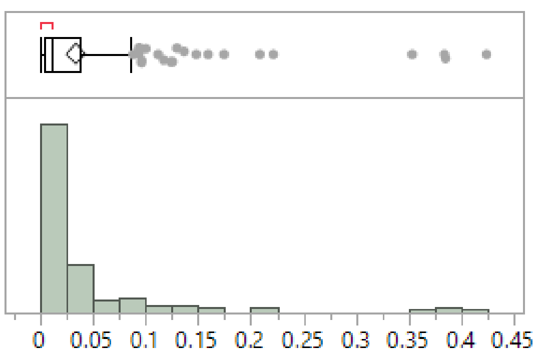
Mean	0.21441
Std Dev	0.2027471
N	374

Figure 4. ST&E Descriptive Statistics

Despite the high value for standard deviation displayed by the ST&E WBS element, the resulting mean and median values lie within close proximity to one another in the distribution. The graph suggests a lognormal distribution may be an appropriate distributional shape for modeling the fully aggregated ST&E cost factor. ST&E also exhibited a large number of available data points, with only 15.5% of the entire data set excluded for analysis.

Training

The Training WBS element showed a sharp decline in reported data, with more than half of the data set containing no value for training. Despite 235 (53.05%) of the rows being blank, this element still contains ample data for analysis. The vast majority (85.4%) of the Training data comes from the aircraft and electronic/automated software commodity types. Distributional analysis resulted in the threshold for inclusion in the analysis of this element being set at values above 0.05% of PME. This resulted in the exclusion of 14 (3.16%) data points, the majority of which were less than $100,000 amounts in multimillion-dollar MDAPs. Also, two Training values above 80% were excluded, which amounted to less than 0.5% of the total data set. These extreme upper values of 82% and 2,275% represented a commercial derivative program and a likely reporting anomaly, respectively. Figure 5 shows the distribution and descriptive statistics for the 192 values analyzed for the Training WBS element. The individual descriptive statistics for Training—broken out by commodity type, contract type, development type, contractor designation, and service—are found in Appendix A.



Quantiles

100%	maximum	0.423777764
75%	quartile	0.0370268538
50%	median	0.0101459635
25%	quartile	0.0031587488
0%	minimum	0.000621284

Summary Statistics

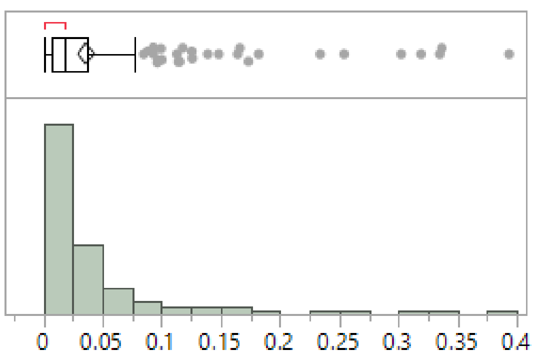
Mean	0.0342243
Std Dev	0.0648891
N	192

Figure 5. Training Descriptive Statistics

The Training WBS element contained data for less than half of the entire data set. Its standard deviation value was high in relation to the calculated mean value, due in part to several data points in one tail of the distribution. The Training data resided largely between the values of 0.01 and 0.04. The lack of distribution shape suggests that the cost analyst must employ discretion when modeling the training factor.

Data

The Data WBS element lacked 176 values, or 39.73% of the total data set. Data is similar to Training with respect to its concentration of information within the aircraft and electronic/automated software commodity groups. It surpasses the characteristics of Training, with 87.3% of the data set for the Data WBS element coming from these two commodities. Data represented the lone element with no additional exclusions beyond blank values, as the distribution was much more concentrated than other elements. Figure 6 provides the descriptive statistics for the Data WBS element. The individual descriptive statistics for Data—broken out by commodity type, contract type, development type, contractor designation, and service—are found in Appendix A.



Quantiles		
100%	maximum	0.39350792
75%	quartile	0.036726503
50%	median	0.01867793
25%	quartile	0.007443493
0%	minimum	5.75642e-6

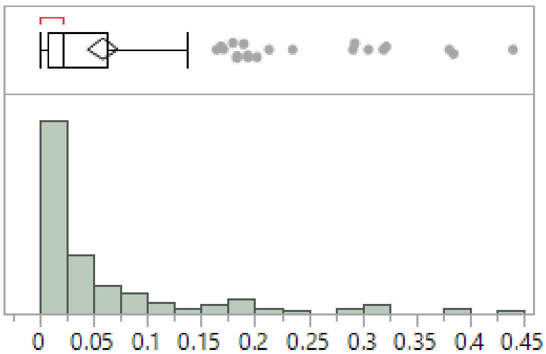
Summary Statistics	
Mean	0.0364283
Std Dev	0.0568872
N	267

Figure 6. Data Descriptive Statistics

While the Data WBS element offered values for over 60% of the entire data set, its distribution is characterized by a high standard deviation value and numerous values well beyond three standard deviations from the mean of 0.03.

Peculiar Support Equipment (PSE)

PSE contained only 149 values of Data. Blank PSE values make up 64.56% of the entire data set. Upper and lower exclusions add another 1.8% to the amount excluded. The upper exclusions made were only two values, one of which was nearly 300% of PME, indicating likely reporting anomalies, and the other was well above three standard deviations and part of a multinational development effort. The concentration by commodity type is similar to the Training and Data WBS elements, with 65.8% of the data set coming solely from the aircraft commodity type. Figure 7 shows the descriptive statistics for PSE. The individual descriptive statistics for PSE—broken out by commodity type, contract type, development type, contractor designation, and service—are found in Appendix A.



Quantiles

100%	maximum	0.440001636
75%	quartile	0.062978593
50%	median	0.021701256
25%	quartile	0.0074884715
0%	minimum	0.000117023

Summary Statistics

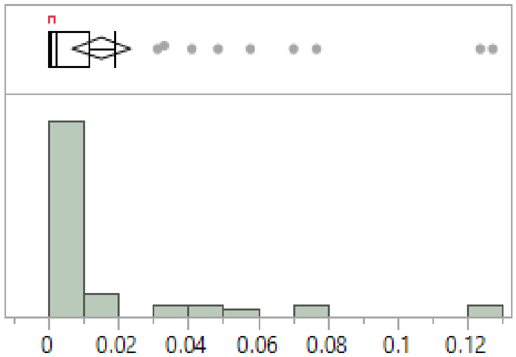
Mean	0.0584986
Std Dev	0.0867449
N	149

Figure 7. PSE Descriptive Statistics

The PSE WBS element displays a concentration of data points between the values of 0.01 and 0.05. Beyond that concentration, the data is spread as far as five standard deviations from the mean. The 149 data points for PSE account for only 33.6% of the entire data set.

Common Support Equipment (CSE)

CSE represented a sharp decline of available data, resulting in only 50 values for analysis. The CSE WBS element is also made up primarily by the aircraft commodity type (62%) and is then evenly distributed between each of the remaining types. Only two values (0.45%) were excluded from the CSE analysis, both of which were beyond three standard deviations and indicative of reporting anomalies based on their extremely high values. The descriptive statistics for the CSE WBS element are shown in Figure 8. The individual descriptive statistics for CSE—broken out by commodity type, contract type, development type, contractor designation, and service—are found in Appendix A.



Quantiles

100%	maximum	0.127285037
75%	quartile	0.011501404
50%	median	0.0019863765
25%	quartile	0.0006335303
0%	minimum	2.5209e-7

Summary Statistics

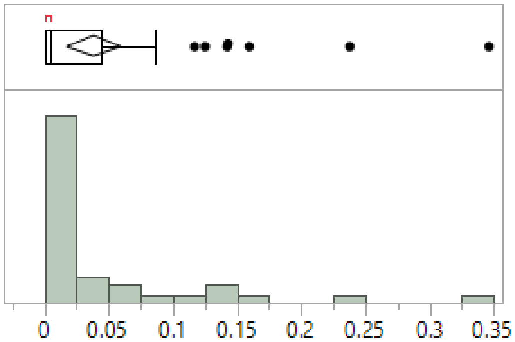
Mean	0.0151615
Std Dev	0.0291964
N	50

Figure 8. CSE Descriptive Statistics

Just over 10% of the data set is represented by the CSE WBS element, which yielded only 50 values for analysis. Its distribution lacks any major shape, with data points spread several standard deviations from the mean value of 0.015. The lack of distribution shape suggests the cost analyst must employ discretion when modeling the CSE factor.

Site Activation

Site Activation mirrored the limited availability quality of CSE, offering only 47 data points, or 11.29% of the total factors, for analysis. The 47 data points exclude three upper extreme values beyond three standard deviations. The majority of the values (78.7%) for the Site Activation WBS element are comprised of the aircraft and electronic/automated software commodity types. The Site Activation descriptive statistics are summarized in Figure 9. The individual descriptive statistics for Site Activation—broken out by commodity type, contract type, development type, contractor designation, and service—are found in Appendix A.



Quantiles

100%	maximum	0.346422893
75%	quartile	0.043293824
50%	median	0.004073782
25%	quartile	0.000564161
0%	minimum	9.29461e-6

Summary Statistics

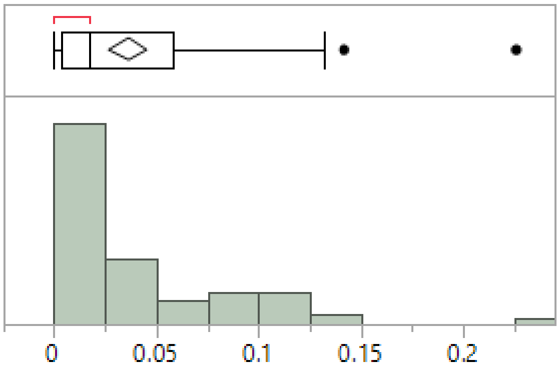
Mean	0.0386819
Std Dev	0.0706161
N	47

Figure 9. Site Activation Descriptive Statistics

Almost 90% of the data set was excluded from the Site Activation WBS element's analysis, and such a small sample size yielded a distribution devoid of a dominant shape. Therefore, cost analysts must employ discretion when modeling the site activation factor.

Spares

The Spares WBS element exhibited a low number of data points. Only 84 values were analyzed after removing the 358 blanks and one upper extreme value that was above 100% of PME. The concentration by commodity type for the Spares WBS element is similar to the Training, Site Activation, and Other WBS elements with 86.9% of the data points coming from aircraft and electronic/automated software. The descriptive statistics and distribution for Spares is shown in Figure 10. The individual descriptive statistics for Spares—broken out by commodity type, contract type, development type, contractor designation, and service—are found in Appendix A.



Quantiles		
100%	maximum	0.226030455
75%	quartile	0.057498319
50%	median	0.0174865055
25%	quartile	0.003555311
0%	minimum	0.000025983

Summary Statistics	
Mean	0.0362014
Std Dev	0.0436054
N	84

Figure 10. Spares Descriptive Statistics

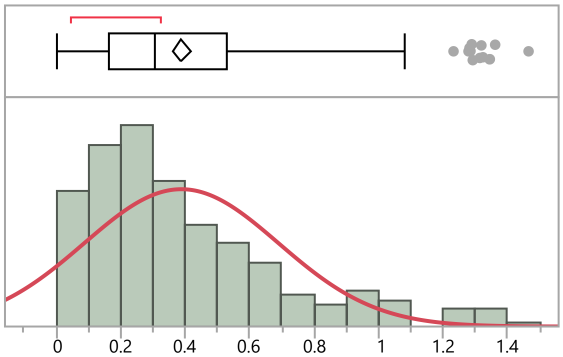
Less than 20% of the data set was available for analysis for the Spares WBS element. Its values were not characterized by large disparities like several other WBS elements' values, with a standard deviation just slightly higher than the mean. Its data points were concentrated between 0.01 and 0.05.

Stage 2: Results by Category

This section first presents the findings for each WBS element by category from the Shapiro–Wilk test. The null hypothesis for the Shapiro–Wilk test assumes normality for each data set. The results of the nonparametric testing conducted after determining non-normality for each WBS element are then detailed. The null hypothesis for the Kruskal–Wallis test asserts that all group medians being tested are equal. An alpha value of 0.05 was utilized for all statistical testing in this analysis. The five categories examined were commodity type, contract type, development type, contractor type, and service.

Shapiro–Wilk Test Results

Conducting the Shapiro–Wilk test for normality revealed findings of non-normality. Figure 11 illustrates results for the SE/PM data.



Goodness-of-Fit Test

Shapiro-Wilk W Test

W	Prob<W
0.885540	<.0001*

Figure 11. SE/PM Shapiro–Wilk Test

As shown in Figure 11, the null hypothesis is rejected with a *p* value of less than 0.0001. Similar Shapiro–Wilk testing results for the subsequent seven WBS elements (not shown) rejected the null, necessitated nonparametric testing to be applied throughout the remainder of the analysis. Nonparametric testing identifies similarities of locations in the data elements analyzed. Histograms of the data in this analysis reveal a consistent right-skewed profile. Due to the similarities in the shape of the histograms, the nonparametric tests can be considered to be testing medians (Hollander et al., 2014). Therefore, subsequent discussion of nonparametric results will discuss differences in the medians of the data.

Commodity Type

The first category analyzed is commodity type. The Kruskal–Wallis test revealed statistical differences between WBS element median values (see Table 6). Specific differences were identified within the SE/PM, ST&E, and Site Activation WBS elements.

Table 6. Kruskal–Wallis for Commodity Type

WBS Element	Alpha	Chi-Square	*P* value	Null Hypothesis Test Result	*N*
SE/PM	0.05	49.2441	<0.0001	Reject	406
ST&E	0.05	32.3203	<0.0001	Reject	374
Training	0.05	6.9636	0.2234	Do Not Reject	192
Data	0.05	6.1052	0.2961	Do Not Reject	267
PSE	0.05	2.2603	0.8121	Do Not Reject	149
CSE	0.05	1.0203	0.9609	Do Not Reject	50
Site Activation	0.05	14.4899	0.0059	Reject	47
Spares	0.05	3.7434	0.2905	Do Not Reject	84

After determining that statistical differences exist, the Steel–Dwass multiple comparison test was employed to identify which commodity types exhibited differences. Table 7 summarizes the findings for each WBS element, with the number of differences annotated by commodity type. The aircraft commodity type contained the most statistical differences (with five), followed by the space and electronic/automated software systems (with three each). For the WBS elements, SE/PM and ST&E contain 85.7% of all differences. The implications for practical usage are that analysts employing standard factors for SE/PM and ST&E should be careful to ensure delineation by commodity type and not modeled at aggregated levels. This is especially important for these two WBS elements, as they have the highest factor values with respect to PME among all the elements.

Table 7. Commodity Differences Summary

	Aircraft	Electronic/Automated Software	Missile	Ordnance	Space	UAV
SE/PM	2	1	1	0	0	0
ST&E	2	1	1	0	3	1
Training	0	0	0	0	0	0
Data	0	0	0	0	0	0
PSE	0	0	0	0	0	0
CSE	0	0	0	0	0	0
Site Activation	1	1	0	0	0	0
Spares	0	0	0	0	0	0

Contract Type

The Kruskal–Wallis test resulted in rejection of the null hypothesis in four areas. Differences in median values are found for SE/PM, ST&E, Data, and PSE (see Table 8).

Table 8. Kruskal–Wallis for Contract Type

WBS Element	Alpha	Chi-Square	*P* value	Null Hypothesis Test Result	*N*
SE/PM	0.05	32.8151	<0.0001	Reject	406
ST&E	0.05	34.4853	<0.0001	Reject	374
Training	0.05	5.6801	0.683	Do Not Reject	192
Data	0.05	19.4757	0.0125	Reject	267
PSE	0.05	18.7037	0.0165	Reject	149
CSE	0.05	6.8419	0.4455	Do Not Reject	50
Site Activation	0.05	9.8514	0.1972	Do Not Reject	47
Spares	0.05	9.4857	0.2196	Do Not Reject	84

Conducting the Steel–Dwass multiple comparison test across all contract types revealed significant differences across all but one contract type (see Table 9). Fixed-Price Incentive (FPI) contracts displayed the most statistical differences (with eight). Any project expecting an FPI contract should place increased scrutiny on the programs that contribute to the composite factor calculation and the specific contract type utilized. Additionally, SE/PM and ST&E found 10 differences each. The concentration of differences in the SE/PM and ST&E WBS elements suggests estimators should afford extra time and research for estimates in those areas. Note that the PSE WBS element displayed statistical differences according to the Kruskal–Wallis test in Table 8, but no individual pair differences were found with the Steel–Dwass test. This is due to the extremely low *n* values for several subcategories.

Table 9. Contract Type Differences Summary

	CPAF	CPFF	CPIF	Cost-Other	FFP	FPI	FPIF	Unknown
SE/PM	2	2	0	1	2	3	0	0
ST&E	1	1	0	1	1	5	0	1
Training	0	0	0	0	0	0	0	0
Data	0	0	1	0	0	0	0	1
PSE	0	0	0	0	0	0	0	0
CSE	0	0	0	0	0	0	0	0
Site Activation	0	0	0	0	0	0	0	0
Spares	0	0	0	0	0	0	0	0

Development Type

The third category analyzed is development type. The Kruskal–Wallis test revealed differences in five WBS areas: SE/PM, ST&E, Data, PSE, and Spares (see Table 10).

Table 10. Kruskal–Wallis for Development Type

WBS Element	Alpha	Chi-Square	*P* value	Null Hypothesis Test Result	*N*
SE/PM	0.05	18.3391	0.0026	Reject	406
ST&E	0.05	15.3905	0.0088	Reject	374
Training	0.05	6.7041	0.2436	Do Not Reject	192
Data	0.05	13.8759	0.0164	Reject	267
PSE	0.05	11.4644	0.0429	Reject	149
CSE	0.05	6.3575	0.273	Do Not Reject	50
Site Activation	0.05	8.5601	0.128	Do Not Reject	47
Spares	0.05	13.0157	0.0232	Reject	84

The Steel–Dwass test results identified median value statistical differences for each development category, as shown in Table 11. All development categories had at least one significant difference except for commercial derivatives, which was the smallest category comprising less than 1% of the data set. The new MDS designator and new design subcategories had the most differences at four and three respectively.

Projects in these two subcategories should ensure factor development does not have other development types in their composite factors.

Table 11. Development Type Differences Summary

	Modification	New Design	Prototype	Subsystem	New MDS Designator	Commercial Derivative
SE/PM	1	2	0	0	1	0
ST&E	0	0	0	1	1	0
Training	0	0	0	0	0	0
Data	0	0	1	0	1	0
PSE	1	0	0	0	1	0
CSE	0	0	0	0	0	0
Site Activation	0	0	0	0	0	0
Spares	1	1	0	0	0	0

Contractor Type

The fourth category analyzed is contractor type. The CCDR data set consisted of prime contractor data and subcontractor data. The majority of the data, 69.5%, is prime data. Because there are only two subcategories, the Steel–Dwass test is not needed. The identification of differences through the Kruskal–Wallis test is sufficient. Results are shown in Table 12.

Table 12. Kruskal–Wallis for Contractor Type

WBS Element	Alpha	Chi-Square	*P* value	Null Hypothesis Test Result	*N*
SE/PM	0.05	0.7777	0.3778	Do Not Reject	406
ST&E	0.05	12.064	0.0005	Reject	374
Training	0.05	0.0811	0.7759	Do Not Reject	192
Data	0.05	2.66	0.1029	Do Not Reject	267
PSE	0.05	5.3186	0.0211	Reject	149
CSE	0.05	1.6912	0.1934	Do Not Reject	50
Site Activation	0.05	0.0571	0.8111	Do Not Reject	47
Spares	0.05	0.087	0.768	Do Not Reject	84

Differences in the contactor-type category are only found for two WBS elements: ST&E and PSE. The small number of differences suggests that composite factor development does not require large amounts of time and effort dedicated to determining whether the data is from the prime or a sub. Rather, aggregated-factor models consisting of both contractor types may be sufficient.

Service

The fifth category analyzed is military service. The data is subcategorized by Air Force, Army, Navy, and Multiple—as designated on the CCDRs. The Kruskal–Wallis test for the Service category identified statistically different median values in two areas: SE/PM and ST&E (see Table 13).

Table 13. Kruskal–Wallis for Service

WBS Element	Alpha	Chi-Square	*P* value	Null Hypothesis Test Result	*N*
SE/PM	0.05	20.1146	0.0002	Reject	406
ST&E	0.05	9.1187	0.0278	Reject	374
Training	0.05	3.7819	0.286	Do Not Reject	192
Data	0.05	1.6337	0.6518	Do Not Reject	267
PSE	0.05	2.666	0.446	Do Not Reject	149
CSE	0.05	2.1053	0.5508	Do Not Reject	50
Site Activation	0.05	1.222	0.7477	Do Not Reject	47
Spares	0.05	1.0621	0.588	Do Not Reject	84

Despite only two WBS elements containing statistical differences in median values, the Steel–Dwass multiple comparison test was able to identify a total of 12 significant interactions (see Table 14). The Army SE/PM factor was found to be different from all other services, while the ST&E factor for multiple services was also different from all others. For these two WBS elements, practitioners should ensure appropriate delineation in composite factor development.

Table 14. Service Differences Summary

	Air Force	Army	Navy	Multiple
SE/PM	1	3	1	1
ST&E	1	1	1	3
Training	0	0	0	0
Data	0	0	0	0
PSE	0	0	0	0
CSE	0	0	0	0
Site Activation	0	0	0	0
Spares	0	0	0	0

Contractor Comparison

The Kruskal–Wallis test was conducted for each WBS element to determine if statistical differences existed between individual contractors. The five contractors utilized for this analysis were identified based on the number of factors each represented across the entire data set of 443 factors. These five contractors represented 201 of the 443 total factors (45.37%). A lower bound time frame of 1998 was established based on relevant mergers between major contractors. Table 15 illustrates the Kruskal–Wallis test results for this subset of data across all commodity types.

Table 15. Kruskal–Wallis for Top 5 Contractors by Commodity Type

WBS Element	# Remaining	% of Original Data Set	Alpha	*P* Value
SE/PM	184	41.53%	0.05	0.1293
ST&E	175	39.50%	0.05	0.9093
Training	94	21.22%	0.05	0.2025
Data	112	25.28%	0.05	0.4682
PSE	44	9.93%	0.05	0.3215
CSE	24	5.42%	0.05	0.7137
Site Activation	22	4.97%	0.05	0.2299
Other	189	42.66%	0.05	0.9272
Spares	34	7.67%	0.05	0.5622

No statistical differences were identified between contractors. This result prompted a further analysis examining only the aircraft and electronic/automated software commodity types, which again resulted in no statistical differences. This suggests that cost estimators do not need to segregate data by contractor during composite factor development.

Time Frame Specific Analysis

The initial data set exclusion criteria (see Table 1) removed 27 programs due to inaccessible files or illegible data entries. These excluded programs were primarily from the 1980s or earlier. Exclusion of these programs may raise concerns of bias in the analysis. To determine whether the exclusion of these older programs had an effect on the factors developed, a time frame–specific analysis on a subset of the data spanning the past two decades was accomplished using 1998 as the cut-off date. Table 16 displays the descriptive statistics for the SE/PM WBS element for the original data set, as well as the revised data set spanning the most recent 20 years.

Table 16. SE/PM Descriptive Statistics Comparison

Commodity	Original Mean	1998–Pres Mean	Original Median	1998–Pres Median	Original CV	1998–Pres CV
Aircraft	0.3025	0.3433	0.2292	0.2727	78.84	71.78
Electronic/Automated Software	0.5463	0.5479	0.4875	0.4875	64.27	66.76
Missile	0.5014	0.5014	0.3897	0.3897	65.77	65.77
Ordnance	0.3426	0.3484	0.285	0.3409	50.7	52.22
Space	0.3825	0.4059	0.3109	0.3109	80.86	83.38
UAV	0.4913	0.5154	0.3655	0.3887	65.49	64.32

The descriptive statistics of the subset of data for SE/PM are similar in most cases, and identical in some, to the original data set. Analysis of other WBS elements (not shown) yielded similar results. The consistency displayed between the subset and original data set leads to the conclusion that the 27 programs excluded due to inaccessible files or illegible entries are unlikely to affect the descriptive statistics or statistical analysis results.

Purpose-Specific Analysis

The results of the Kruskal–Wallis tests by WBS element for each of the five examined categories, as well as the number of significant interactions found by the Steel–Dwass multiple comparison tests, would lead to the conclusion that as a general rule, factor values have a low level of statistical difference across commodity type, contract type, development type, contractor type, and service. However, the distributions and descriptive statistics of the values for each WBS element reveal large coefficient of variation (CV) values (standard deviations divided by mean) in each category. Table 17 shows the CV means for each WBS element.

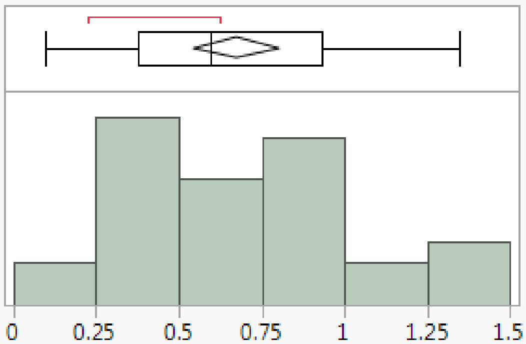
Table 17. Coefficient of Variation Summary

WBS Element	Collective Mean	Collective Std Dev	CV
SE/PM	0.3802	0.2732	71.86%
ST&E	0.2117	0.1822	86.07%
Training	0.0295	0.0503	170.51%
Data	0.0331	0.0477	144.11%
PSE	0.0538	0.0749	139.22%
CSE	0.0149	0.0268	179.87%
Site Activation	0.0307	0.0526	171.34%
Spares	0.0787	0.1375	174.71%

Because the standard deviations are so large for this data set, the statistical analysis did not identify differences in certain instances where a cost analyst may identify differences through practical analysis. An example scenario is provided to demonstrate the utility of filtering data down to lower levels through utilization of program-specific information in a hypothetical initial cost estimate.

Scenario Example—Army Electronic/Automated Software System

This scenario pared the data set down to only prime contractor data for Army MDAPs in the electronic/automated software commodity type. The development type category was examined, looking only at the SE/PM WBS element. Figure 12 shows the descriptive statistics for this scenario.



Quantiles

100%	maximum	1.345342466
75%	quartile	0.9319295673
50%	median	0.596985006
25%	quartile	0.3752669638
0%	minimum	0.093962336

Summary Statistics

Mean	0.6737858
Std Dev	0.345058
N	30

Figure 12. Scenario 2 Descriptive Statistics

As shown in Figure 12, the SE/PM coefficient of variation (the standard deviation as a percent of the mean) for this sample is 0.34 / 0.67 = 50.7%. In comparison, the SE/PM coefficient of variation from the full data set in Table 17 is 71.86%. Thus, there is approximately a 21% reduction (71.86 – 50.7 = 21.16) in coefficient of variation by utilizing knowledge about the intended program type. In other words, the average cost estimating error was reduced by approximately 21%. This scenario illuminates just one example (of numerous) where program-specific knowledge can utilize the factors developed here to create more accurate estimates.

Conclusions

Research Questions Answered

The first research objective was to develop new standard cost factors through a diverse set of project types. This resulted in 443 new cost factors created from a multitude of diverse programs. Factors were developed by *development type* (commercial derivative, modification, new design, prototype, new MDS designator, and subsystem), *contractor type* (prime and sub), *service* (Air Force, Army, Navy, Multiple), *contract type* (various), and *commodity type* (aircraft, electronic, missile, ordnance, space, UAV). Composite factors for the six development types are displayed in Table 18 with full summary factors provided in Table 5 and Appendix A.

Table 18. Factors by Development Type

	Modification	New Design	Prototype	Subsystem	New MDS Designator	Commercial Derivative
SE/PM	0.3484	0.4738	0.1906	0.373	0.3249	0.184
ST&E	0.2155	0.2143	0.2673	0.1744	0.2934	0.1804
Training	0.0245	0.0395	0.0029	0.0277	0.0543	0.0134
Data	0.0448	0.0297	0.006	0.0333	0.0441	0.024
PSE	0.0477	0.0573	0.0118	0.0485	0.0978	0.0039
CSE	0.0129	0.0148	0.0001	0.0378	0.0108	0.0018
Site Activation	0.0495	0.05	0.004	0.0046	0.0276	0.0001
Other	0.0874	0.0812	0.0328	0.0726	0.0459	0.2406
Spares	0.0222	0.0438	0.0279	0.0283	0.0504	0.0054

The second research objective was to examine the estimating error and implications for practical implementation. The descriptive statistics were examined for each category, as well as each Level 2 WBS element. This revealed large standard deviation values and large CV values, pointing to the conclusion that each MDAP presents unique characteristics that must be explored and understood to make the inclusion of its data truly meaningful in the context of constructing a cost estimate. The practicality of achieving an in-depth understanding of each program utilized for a factor-and-analogy cost estimate is not realistic in many cases. Thus, many factor-and-analogy estimates are preliminary in nature. These generic composite factors represent a starting point for analysts in instances where MDAP characteristics may be unrefined (i.e., broad capability deliverable(s) with undefined processes). Given the fluid nature of estimates at this stage of developing requirements, a robust data set remains appropriate. Once a program's requirements have been solidified and the manner in which they will be accomplished is well-defined, analysts can begin to refine their data set to MDAPs with direct application to their program. The intent of the research results provided here is to make the data set utilized for analysis available to DoD analysts to enable an approach to factor creation that can be tailored to the needs of the individual.

The third research objective was to help cost analysts understand the level of detail required to properly utilize the factors. This knowledge directly affects the time and effort that should be allocated. This paper aimed to aid in that endeavor through statistical testing of relevant categorical (commodity, contract type, development type, contractor, and service) groupings. As discussed above, the factor technique is often applied early in the life cycle when requirements may be unrefined, making a robust data set the appropriate starting point. Delineation on key categories within that robust data set becomes the distinguishing characteristic to achieve a more realistic estimate.

Specific findings from statistical testing indicated that knowledge of the anticipated contract type is highly desirable. The contract-type category had the highest amount of statistical differences between the subcategories. While it would be most advantageous to develop composite factors based on the precise contract type (e.g., cost plus award fee), even broader classifications into the two general categories of cost-reimbursable or fixed-price contracts are useful. The commodity type category was found to have the second most differences in median values after contract type. Commodity information should be readily available for any project, allowing for ease of analyst calibration. The results also indicate those areas where analysts should economize their time. Specifically, the results showed little differences in the contractor-type category. The implication is that deriving the factor from prime or subcontract data has little effect.

In addition to the category analysis, specific findings shed light on the individual WBS elements. Interestingly, the SE/PM and ST&E elements were identified as statistically different in virtually every categorical test. Making the distinction more compelling is the fact that these two elements are also typically the highest in raw dollar value of the WBS elements analyzed. Coupling the high dollar value with the statistical testing results suggests that analysts' time and energy should be allocated to these areas. In contrast, elements such as data and training rarely found statistically significant differences. Aggregated factors are therefore likely to be sufficient in these areas.

Significance of Results

This paper represents one of the largest Department of Defense (DoD) factor studies for MDAPs in the EMD phase conducted to date. Previous efforts within the Air Force Life Cycle Management Center (Wren, 1998; Otte, 2015) established factor values for specific purposes and system program offices, whereas this effort is intended for wider-access distribution accessible to analysts across the DoD to accomplish individualized analysis. The compilation of EMD data contained in 443 separate Cost Data Summary Reports into a single location provides DoD analysts the ability to streamline estimate formulation while also increasing the breadth of data from which estimates are based. The descriptive statistics for each WBS element and accompanying summary tables provide analysts the ability to create an initial estimate quickly. Furthermore, the statistical analysis provides guidance to perform the iterative process of refining the data and applying statistical and/or practical analysis to arrive at a defensible estimate. The importance of efficient and effective cost estimating in the acquisition workforce within the DoD is evident based on budgetary restrictions, political climate, and many other factors. Thus, the results of this research are an important component enabling the expansion of the cost analyst's tool kit while identifying areas for cost analysts to economize on time and effort.

Future Research

The ability to expand upon this research is vast. Specifically, expansion outside of the EMD phase is warranted. The establishment of Production phase factors could be accomplished utilizing the same methodology as this research. Also, non-MDAP Science and Technology (S&T) program factors could be created to better serve cost analysts supporting efforts not contained within a SPO. The approach to this type of factor development would hinge upon cost data reporting requirements and availability of data.

Appendix A—Descriptive Statistics by WBS Element

SE/PM Summary Table								
	Mean	**Std Dev**	***N***	**Max**	**75%**	**Median**	**25%**	**Min**
Service								
Air Force	0.3685	0.2755	177	1.324	0.4894	0.2972	0.159	0.0043
Army	0.508	0.3372	91	1.3453	0.6989	0.4426	0.2514	0.0098
Navy	0.3393	0.3039	115	1.4655	0.465	0.2551	0.1421	0.0105
Multiple	0.3142	0.2053	23	1.0007	0.4047	0.2699	0.1626	0.0903
Development Type								
Modification	0.3484	0.2555	124	1.3191	0.4954	0.2845	0.1539	0.0043
New Design	0.4738	0.3472	131	1.4655	0.6582	0.3759	0.219	0.0053
Prototype	0.1906	0.1472	8	0.39	0.3417	0.1783	0.0627	0.0126
Subsystem	0.373	0.2816	101	1.324	0.5343	0.2793	0.161	0.0105
New MDS Designator	0.3249	0.2924	39	1.3619	0.3887	0.2517	0.1154	0.0445
Commercial Derivative	0.184	0.1011	3	0.2676	0.2676	0.2128	0.0716	0.0716
Contractor Type								
Prime	0.3849	0.3068	284	1.3619	0.4896	0.2947	0.1609	0.012
Subcontractor	0.3966	0.2898	122	1.4655	0.5613	0.3336	0.1724	0.0043
Commodity Type								
Aircraft	0.3025	0.2385	227	1.3619	0.4115	0.2292	0.1421	0.0105
Electronic/Automated Software	0.5463	0.3511	107	1.4655	0.7816	0.4875	0.2568	0.0098
Missile	0.5014	0.3297	20	1.2822	0.7695	0.3897	0.2682	0.0576
Ordnance	0.3426	0.1737	11	0.6117	0.5007	0.285	0.2439	0.0811
Space	0.3825	0.3093	31	1.3191	0.4972	0.3109	0.1488	0.0043
UAV	0.4913	0.3217	10	1.324	0.5435	0.3655	0.303	0.2617
Contract Type								
CPAF	0.4128	0.2641	66	1.2792	0.5792	0.3649	0.2206	0.0337
CPFF	0.5189	0.3896	37	1.3453	0.7022	0.4233	0.2387	0.0053
CPIF	0.3905	0.2987	61	1.2924	0.522	0.2729	0.18	0.0276
Cost-Other	0.4082	0.3103	126	1.4655	0.5874	0.3175	0.1767	0.0043
FFP	0.2457	0.2531	25	1.0786	0.3494	0.156	0.0871	0.0105
FPI	0.2118	0.2232	17	1.0081	0.2349	0.1694	0.0729	0.0484
FPIF	0.4203	0.2811	19	1.2822	0.5578	0.3931	0.2218	0.0675
Fixed-Other	0.572	0.2327	4	0.8384	0.8026	0.5427	0.3707	0.3643
Unknown	0.3131	0.2573	51	1.3144	0.4426	0.243	0.1275	0.0385

ST&E Summary Table								
	Mean	**Std Dev**	***N***	**Max**	**75%**	**Median**	**25%**	**Min**
Service								
Air Force	0.2251	0.2074	166	0.9641	0.328	0.1672	0.0668	0.0013
Army	0.2157	0.1915	80	1.0575	0.2784	0.1992	0.0793	0.0012
Navy	0.2201	0.215	105	1.0776	0.3083	0.1582	0.0697	0.0032
Multiple	0.1059	0.1027	23	0.3312	0.1821	0.0642	0.0207	0.0021
Development Type								
Modification	0.2155	0.2193	119	1.0776	0.2986	0.1396	0.0623	0.0013
New Design	0.2143	0.188	114	1.0575	0.304	0.1817	0.0611	0.0016
Prototype	0.2673	0.1028	9	0.4561	0.325	0.282	0.1792	0.1177
Subsystem	0.1744	0.1883	89	0.8523	0.2378	0.1038	0.0428	0.0012
New MDS Designator	0.2934	0.2281	39	0.9436	0.4288	0.2456	0.0987	0.0083
Commercial Derivative	0.1804	0.1432	4	0.3659	0.328	0.1585	0.0548	0.0388
Contractor Type								
Prime	0.2294	0.2019	274	1.0776	0.3089	0.1838	0.0754	0.0012
Subcontractor	0.1733	0.2001	100	1.0575	0.2396	0.0999	0.0305	0.0016
Commodity Type								
Aircraft	0.2498	0.2139	225	1.0776	0.3515	0.2036	0.021	0.0013
Electronic/Automated Software	0.1702	0.1924	88	1.0575	0.2199	0.1038	0.0348	0.0012
Missile	0.2041	0.1772	18	0.7363	0.2615	0.1842	0.0619	0.0243
Ordnance	0.1513	0.0998	11	0.3389	0.2468	0.0961	0.0704	0.0596
Space	0.0778	0.0879	23	0.3797	0.1157	0.0448	0.021	0.003
UAV	0.2068	0.1273	9	0.3924	0.3266	0.1893	0.0887	0.0444
Contract Type								
CPAF	0.1802	0.1964	63	1.0575	0.2761	0.1072	0.038	0.0025
CPFF	0.1671	0.2095	31	0.8523	0.2213	0.0791	0.0253	0.0016
CPIF	0.2586	0.22	55	1.0677	0.3796	0.1997	0.0829	0.0021
Cost-Other	0.1824	0.1748	113	0.9641	0.2618	0.1277	0.0474	0.0012
FFP	0.1777	0.1503	20	0.4561	0.3426	0.13	0.0588	0.0118
FPI	0.3907	0.1991	20	0.9436	0.5222	0.3267	0.2803	0.1276
FPIF	0.2876	0.2168	17	0.7307	0.3371	0.2167	0.1233	0.0226
Fixed-Other	0.2714	0.2483	4	0.6104	0.5283	0.2227	0.0632	0.0298
Unknown	0.2248	0.2163	51	1.0776	0.2416	0.1608	0.0968	0.0044

Training Summary Table								
	Mean	**Std Dev**	***N***	**Max**	**75%**	**Median**	**25%**	**Min**
Service								
Air Force	0.0319	0.0643	95	0.3849	0.0297	0.0093	0.0034	0.0006
Army	0.0398	0.0673	45	0.5237	0.0482	0.0148	0.004	0.0006
Navy	0.0329	0.0653	50	0.3837	0.0274	0.0071	0.0021	0.0006
Multiple	0.0482	0.0647	2	0.094	0.094	0.0482	0.0024	0.0024
Development Type								
Modification	0.0245	0.0406	64	0.1746	0.028	0.0051	0.0026	0.0006
New Design	0.0395	0.0772	76	0.4237	0.0384	0.0166	0.0038	0.0008
Prototype	0.0029	0.0019	2	0.0042	0.0042	0.0029	0.0015	0.0015
Subsystem	0.0277	0.0475	23	0.2214	0.0376	0.0063	0.0021	0.0006
New MDS Designator	0.0543	0.0886	24	0.3837	0.0897	0.0166	0.0023	0.0006
Commercial Derivative	0.0134	0.0118	3	0.0253	0.0253	0.0133	0.0016	0.0016
Contractor Type								
Prime	0.0344	0.0674	163	4237	0.0318	0.01	0.0031	0.0006
Subcontractor	0.0329	0.0486	29	0.2214	0.0471	0.0109	0.0031	0.0006
Commodity Type								
Aircraft	0.0307	0.0544	111	0.3837	0.0298	0.0055	0.0022	0.0006
Electronic/Automated Software	0.0527	0.0922	53	0.4237	0.0503	0.0254	0.005	0.0006
Missile	0.0117	0.0122	7	0.0388	0.0109	0.0079	0.0042	0.0032
Ordnance	0.0081	0.0039	6	0.0148	0.0121	0.0062	0.0051	0.0051
Space	0.0142	0.0119	9	0.0344	0.0233	0.0146	0.0029	0.001
UAV	0.0176	0.018	6	0.0486	0.0335	0.0123	0.0019	0.0015
Contract Type								
CPAF	0.0468	0.0785	30	0.3849	0.0515	0.0275	0.004	0.0006
CPFF	0.0491	0.0981	18	0.4237	0.049	0.0167	0.0039	0.0013
CPIF	0.0371	0.0736	27	0.3532	0.0396	0.0079	0.0028	0.0006
Cost-Other	0.0313	0.0608	59	0.3837	0.0285	0.0065	0.0023	0.0006
FFP	0.0526	0.064	8	0.1594	0.1171	0.0178	0.002	0.0008
FPI	0.0142	0.0124	15	0.0424	0.0244	0.0159	0.0022	0.0006
FPIF	0.0266	0.0554	13	0.2086	0.0155	0.0102	0.005	0.0034
Fixed-Other	0.0016	-	1	0.0016	0.0016	0.0016	0.0016	0.0016
Unknown	0.021	0.0271	21	0.0962	0.0354	0.0047	0.0017	0.0006

Data Summary Table								
	Mean	**Std Dev**	***N***	**Max**	**75%**	**Median**	**25%**	**Min**
Service								
Air Force	0.0385	0.0608	126	0.3935	0.0404	0.0217	0.0097	<0.0001
Army	0.0405	0.0646	50	0.3191	0.0514	0.018	0.0048	0.0001
Navy	0.0319	0.0473	85	0.254	0.0342	0.0148	0.0063	0.0003
Multiple	0.0194	0.0103	6	0.0322	0.0282	0.0189	0.0137	0.002
Development Type								
Modification	0.0448	0.0664	84	0.3365	0.0479	0.0243	0.0079	<0.0001
New Design	0.0297	0.0457	85	0.3022	0.0364	0.0134	0.0074	0.0001
Prototype	0.006	0.0065	6	0.0154	0.013	0.0042	0.0003	<0.0001
Subsystem	0.0333	0.0616	54	0.3935	0.03381	0.018	0.0044	<0.0001
New MDS Designator	0.0441	0.0543	34	0.254	0.0527	0.0269	0.0126	0.0016
Commercial Derivative	0.024	0.0187	4	0.0522	0.0431	0.0152	0.0139	0.0137
Contractor Type								
Prime	0.0384	0.0572	206	0.3365	0.0442	0.0205	0.0085	<0.0001
Subcontractor	0.0296	0.0555	61	0.3935	0.031	0.0175	0.0056	0.0001
Commodity Type								
Aircraft	0.0355	0.0498	174	0.3365	0.04	0.0206	0.0083	<0.0001
Electronic/Automated Software	0.0407	0.0736	59	0.3935	0.0306	0.0164	0.0077	<0.0001
Missile	0.0418	0.0861	12	0.3022	0.0212	0.0107	0.0069	0.0007
Ordnance	0.01	0.0109	4	0.0256	0.0212	0.0071	0.0017	0.0003
Space	0.024	0.0291	10	0.076	0.0564	0.0076	0.0031	<0.0001
UAV	0.0449	0.0534	8	0.1642	0.0667	0.028	0.0126	<0.0001
Contract Type								
CPAF	0.0376	0.0635	39	0.3935	0.0403	0.0217	0.0095	0.0003
CPFF	0.0362	0.0401	19	0.1389	0.0529	0.0246	0.0015	<0.0001
CPIF	0.0243	0.0409	43	0.2338	0.0269	0.0092	0.0032	<0.0001
Cost-Other	0.0351	0.0571	74	0.3348	0.032	0.0206	0.0065	<0.0001
FFP	0.0262	0.0396	18	0.1482	0.0274	0.0133	0.0032	<0.0001
FPI	0.0358	0.0251	19	0.0964	0.0598	0.0333	0.0134	0.0067
FPIF	0.0691	0.1041	16	0.3365	0.09	0.0167	0.008	0.0007
Fixed-Other	0.006	0.004	4	0.0113	0.0102	0.0049	0.0028	0.0027
Unknown	0.0468	0.0631	35	0.3191	0.0458	0.0294	0.0121	0.0024

PSE Summary Table								
	Mean	**Std Dev**	***N***	**Max**	**75%**	**Median**	**25%**	**Min**
Service								
Air Force	0.0646	0.0922	79	0.44	0.0775	0.0282	0.0112	0.0003
Army	0.0399	0.0626	28	0.2929	0.0535	0.0115	0.0071	0.0023
Navy	0.0592	0.0917	40	0.3846	0.0636	0.0177	0.0057	0.0001
Multiple	0.0593	0.0565	2	0.0993	0.0993	0.0593	0.0194	0.0194
Development Type								
Modification	0.0477	0.088	60	0.44	0.0465	0.0177	0.0035	0.0001
New Design	0.0573	0.077	46	0.3054	0.0626	0.0286	0.0084	0.0001
Prototype	0.0118	0.0049	3	0.0175	0.0175	0.009	0.0088	0.0088
Subsystem	0.0485	0.0609	13	0.1836	0.1025	0.0194	0.0047	0.0005
New MDS Designator	0.0978	0.107	26	0.3846	0.1906	0.0481	0.0167	0.0026
Commercial Derivative	0.0039	-	1	0.0039	0.0039	0.0039	0.0039	0.0039
Contractor Type								
Prime	0.0497	0.0778	120	0.3846	0.0513	0.0186	0.007	0.0001
Subcontractor	0.0945	0.111	29	0.44	0.1502	0.0545	0.0134	0.0006
Commodity Type								
Aircraft	0.0549	0.0789	98	0.3846	0.0618	0.0216	0.0076	0.0001
Electronic/Automated Software	0.0468	0.0565	12	0.1644	0.0948	0.0094	0.0038	0.0004
Missile	0.0716	0.0993	11	0.2929	0.1707	0.0085	0.007	0.0001
Ordnance	0.0235	0.0193	9	0.0624	0.0373	0.0182	0.0081	0.0023
Space	0.1247	0.1673	11	0.44	0.3195	0.0477	0.0079	0.0003
UAV	0.0496	0.0632	8	0.1934	0.0693	0.0213	0.0094	0.0063
Contract Type								
CPAF	0.054	0.0637	14	0.1934	0.069	0.0347	0.0111	0.0006
CPFF	0.0203	0.0279	13	0.0973	0.0265	0.0092	0.0009	0.0003
CPIF	0.0398	0.0542	28	0.2351	0.0412	0.0214	0.0065	0.0001
Cost-Other	0.0699	0.1099	44	0.44	0.0636	0.0186	0.0094	0.0004
FFP	0.0238	0.0249	11	0.0775	0.0414	0.0175	0.0026	0.0006
FPI	0.1098	0.1167	14	0.3846	0.1906	0.0619	0.0199	0.0018
FPIF	0.0338	0.0686	9	0.2133	0.0341	0.0042	0.0034	0.0004
Fixed-Other	0.0041	-	1	0.0041	0.0041	0.0041	0.0041	0.0041
Unknown	0.0929	0.0925	15	0.3221	0.1686	0.0798	0.0194	0.0001

CSE Summary Table								
	Mean	**Std Dev**	***N***	**Max**	**75%**	**Median**	**25%**	**Min**
Service								
Air Force	0.0136	0.0313	22	0.1272	0.0043	0.0014	0.0008	<0.0001
Army	0.0211	0.0331	14	0.1237	0.0317	0.0088	0.0009	<0.0001
Navy	0.01186	0.0224	13	0.0767	0.0096	0.0011	0.0006	0.0002
Multiple	0.0063	-	1	0.0063	0.0063	0.0063	0.0063	0.0063
Development Type								
Modification	0.0129	0.0319	19	0.1272	0.0049	0.0013	0.0008	<0.0001
New Design	0.0148	0.0206	18	0.0767	0.0218	0.0067	0.0013	<0.0001
Prototype	0.0001	0.0001	2	0.0002	0.0002	0.0001	0.0001	0.0001
Subsystem	0.0378	0.0537	5	0.1237	0.0908	0.0063	0.0006	0.0006
New MDS Designator	0.0108	0.0171	5	0.0411	0.0242	0.0038	0.0008	0.0006
Commercial Derivative	0.0018	-	1	0.0018	0.0018	0.0018	0.0018	0.0018
Contractor Type								
Prime	0.0133	0.0268	41	0.1272	0.0082	0.0015	0.0006	<0.0001
Subcontractor	0.0235	0.039	9	0.1237	0.0259	0.0095	0.0008	0.0005
Commodity Type								
Aircraft	0.0125	0.0309	31	0.1272	0.0081	0.0018	0.0008	<0.0001
Electronic/Automated Software	0.0149	0.028	7	0.0767	0.0186	0.0015	0.0006	<0.0001
Missile	0.0218	0.0212	6	0.0486	0.0429	0.0202	0.0005	0.0004
Ordnance	0.0353	0.0493	2	0.0702	0.0702	0.0353	0.0004	0.0004
Space	0.0013	-	1	0.0013	0.0013	0.0013	0.0013	0.0013
UAV	0.0209	0.0327	3	0.0578	0.0578	0.0021	0.0002	0.0002
Contract Type								
CPAF	0.0069	0.0103	10	0.0332	0.0089	0.0024	0.0009	0.0005
CPFF	0.0365	0.0301	2	0.0578	0.0578	0.0365	0.0152	0.0152
CPIF	0.0215	0.0404	9	0.1237	0.0253	0.0081	0.0005	<0.0001
Cost-Other	0.0103	0.0193	14	0.0702	0.0102	0.0017	0.0008	<0.0001
FFP	0.0004	0.0002	3	0.0006	0.0006	0.0006	0.0001	0.0001
FPI	0.0028	-	1	0.0028	0.0028	0.0028	0.0028	0.0028
FPIF	0.029	0.0459	9	0.1272	0.0627	0.0018	0.0005	0.0004
Fixed-Other	-	-	-	-	-	-	-	-
Unknown	0.0057	0.0064	2	0.0102	0.0102	0.0057	0.0011	0.0011

Site Activation Summary Table								
	Mean	**Std Dev**	***N***	**Max**	**75%**	**Median**	**25%**	**Min**
Service								
Air Force	0.049	0.0798	23	0.3464	0.0654	0.0235	0.0004	<0.0001
Army	0.0299	0.0319	4	0.0687	0.0623	0.025	0.0024	0.0009
Navy	0.0309	0.0686	18	0.2378	0.0057	0.002	0.0005	0.0001
Multiple	0.0065	0.0049	2	0.01	0.01	0.0065	0.003	0.003
Development Type								
Modification	0.0495	0.0968	12	0.3464	0.059	0.0141	0.001	<0.0001
New Design	0.05	0.059	19	0.1595	0.1168	0.0241	0.0009	0.0001
Prototype	0.004	-	1	0.004	0.004	0.004	0.004	0.004
Subsystem	0.0046	0.004	4	0.01	0.0088	0.041	0.0011	0.0005
New MDS Designator	0.0276	0.0788	9	0.2378	0.0032	0.0013	0.0003	0.0001
Commercial Derivative	0.0001	<0.0001	2	0.0001	0.0001	0.0001	0.0001	0.0001
Contractor Type								
Prime	0.0405	0.0737	40	0.3464	0.059	0.0042	0.0005	<0.0001
Subcontractor	0.0277	0.0519	7	0.1424	0.0345	0.003	0.0009	0.0005
Commodity Type								
Aircraft	0.0168	0.0476	26	2378	0.0088	0.0015	0.0004	<0.0001
Electronic/Automated Software	0.0917	0.1018	11	0.3464	0.143	0.0687	0.0069	0.0005
Missile	0.0009	-	1	0.0009	0.0009	0.0009	0.0009	0.0009
Ordnance	-	-	-	-	-	-	-	-
Space	0.0602	0.0591	6	0.1424	0.1232	0.0494	0.0023	0.0005
UAV	0.0024	0.0017	3	0.004	0.004	0.0028	0.0005	0.0005
Contract Type								
CPAF	0.0498	0.0511	5	0.1168	0.1014	0.0426	0.0017	0.0005
CPFF	0.0277	0.0316	6	0.0687	0.0662	0.0152	0.0013	<0.0001
CPIF	0.0723	0.0777	6	0.1595	0.1471	0.0649	0.0008	0.0005
Cost-Other	0.0355	0.0675	15	0.2378	0.0345	0.004	0.0013	0.0005
FFP	0.0008	0.0009	3	0.0018	0.0018	0.0005	0.0001	0.0001
FPI	0.0023	0.004	4	0.0084	0.0064	0.0004	0.0002	0.0001
FPIF	0.009	0.0152	3	0.0267	0.0267	0.0002	0.0001	0.0001
Fixed-Other	-	-	-	-	-	-	-	-
Unknown	0.079	0.1505	5	0.3464	0.1948	0.0044	0.0006	0.0001

Spares Summary Table								
	Mean	**Std Dev**	***N***	**Max**	**75%**	**Median**	**25%**	**Min**
Service								
Air Force	0.043	0.0558	33	0.226	0.0846	0.0113	0.0018	<0.0001
Army	0.0221	0.0259	10	0.0644	0.0538	0.0107	0.0016	0.0006
Navy	0.0341	0.0347	41	0.1134	0.0434	0.0225	0.0047	<0.0001
Multiple	-	-	-	-	-	-	-	-
Development Type								
Modification	0.0222	0.0479	25	0.226	0.0177	0.0046	0.0014	<0.0001
New Design	0.0438	0.0394	34	0.1319	0.0779	0.0332	0.0091	0.0001
Prototype	0.0279	-	1	0.0279	0.0279	0.0279	0.0279	0.0279
Subsystem	0.0283	0.0288	7	0.0884	0.0368	0.0225	0.0101	0.0004
New MDS Designator	0.0504	0.0493	15	0.1418	0.1117	0.0303	0.0069	0.0008
Commercial Derivative	0.0054	0.0069	2	0.0103	0.0103	0.0054	0.0005	0.0005
Contractor Type								
Prime	0.0372	0.0468	62	0.226	0.0536	0.0174	0.0034	<0.0001
Subcontractor	0.0331	0.0336	22	0.1073	0.0623	0.0195	0.0046	0.0004
Commodity Type								
Aircraft	0.0397	0.0498	52	0.226	0.0781	0.0168	0.0035	<0.0001
Electronic/Automated Software	0.0239	0.0284	21	0.1073	0.0434	0.0152	0.0015	0.0001
Missile	-	-	-	-	-	-	-	-
Ordnance	-	-	-	-	-	-	-	-
Space	0.0356	0.0304	6	0.0757	0.0703	0.025	0.0098	0.0091
UAV	0.0519	0.0353	5	0.092	0.0905	0.0302	0.0242	0.0205
Contract Type								
CPAF	0.0255	0.0298	17	0.0943	0.036	0.0113	0.0034	0.0012
CPFF	0.0045	0.0074	4	0.0156	0.0121	0.0012	0.0002	0.0001
CPIF	0.0255	0.0192	11	0.0516	0.0449	0.0275	0.0048	0.0001
Cost-Other	0.0439	0.0438	18	0.1167	0.0897	0.0226	0.0065	0.0002
FFP	0.041	0.0824	7	0.226	0.034	0.0047	0.0014	<0.0001
FPI	0.0593	0.0545	10	0.1418	0.1168	0.0432	0.0127	<0.0001
FPIF	0.0152	0.0195	4	0.0419	0.0359	0.0092	0.0006	0.0005
Fixed-Other	-	-	-	-	-	-	-	-
Unknown	0.044	0.0428	13	0.1134	0.0927	0.0236	0.0072	0.0006

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