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An Analysis of Estimated Costs Versus Actual Costs in USACE Section 14 Emergency Streambank Protection Projects

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AN ANALYSIS OF ESTIMATED COSTS VERSUS ACTUAL COSTS IN USACE SECTION 14 EMERGENCY STREAMBANK PROTECTION PROJECTS

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APPROVAL OF THESIS

We, the faculty supervising the work of Hunter Alexander Waugaman, affirm that the thesis, *An Analysis of Estimated Costs versus Actual Costs in USACE Section 14 Emergency Streambank Protection Projects,* meets the high academic standards for original scholarship and creative work established by the Engineering Management and the College of Engineering and Computer Sciences. This work also conforms to the editorial standards of our discipline and the Graduate College of Marshall University. With our signatures, we approve the manuscript for publication.

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ABSTRACT

The U.S. Army Corps of Engineers (USACE) Civil Works projects are designed to provide national management of water resources. These works use emergency streambank protection to protect public facilities, like bridges and highways. The projects under this authority have limited funding, therefore, many design and field studies are omitted, which increases project uncertainties resulting in cost overruns and contract modifications. This study analyzes previously constructed projects by comparing the independent government estimate with the contractor's actual costs and identifying the variables causing these differences via statistical analysis. The variables identified are categorized into those elements that affect the accuracy of the government estimate. From the findings of this categorization, a linear regression model was used in SPSS to identify which variables were predictors for causing cost overruns. From the analysis, it was found that 65.8% of the variance in the fourteen Section 14 projects selected can be predicted from the variable Rip Rap Placement and Material. Furthermore, 78.4% of the variance in these same projects can be predicted from the variables Rip Rap Placement and Material and Filter Fabric. These results serve as a basis for future Section 14 projects to identify which bid items affect the total cost the most and ensure to place adequate effort in estimating those items appropriately.

CHAPTER 1: PROJECT BACKGROUND, PROBLEM STATEMENT, AND METHODOLOGY

BACKGROUND

The U.S. Army Corps of Engineers (USACE) is an engineer formation that focuses on three primary missions: engineer regiment, military construction, and civil works (United States Army Corps of Engineers, 2020). This paper will focus on Civil Works, which involves providing the Nation with management of its water resources, supporting commercial navigation, flood risk management, and restoring, protecting, and managing aquatic ecosystems (United States Army Corps of Engineers, "Civil Works", n.d.). The Corps of Engineers' Civil Works are broken down into work breakdown structures (CW-WBS). These CW-WBS include items like 01-Lands and Damages, 04-Dams, 05-Locks, 11-Leevees and Floodwalls, 16-Bank Stabilization, which this thesis will be focusing on, 30-Planning, Engineering, and Design, and 31-Construction Management, to name a few (Department of the Army, *ER 1110-2-1302 Civil Works Cost Engineering*). The 16 account, Bank Stabilization, is defined as a feature of work that includes revetments, linings, training dikes, and bulkheads for stabilization of banks of watercourses to prevent erosion, sloughing, or meandering (Department of the Army, 2016). Under this account, the Continuing Authorities Program (CAP), whose purpose is to plan and implement projects of limited size, scope, cost, and complexity, has an authority called Section 14 (United States Army Corps of Engineers, "Continuing Authorities Program," n.d.). Section 14, of the Flood Control Act of 1946, provides the Corps of Engineers with the authority to construct emergency shoreline and stream bank protection to protect public facilities, like bridges and highways, and non-profit public facilities, such as churches, hospitals, and schools (Flood Control Act of 1946). The maximum amount the Federal government can pay for these types of projects is $5 million, while the total project cost is cost shared between the Federal and Non-Federal sponsor at 65% and 35%, respectively.

PROBLEM STATEMENT

With this maximum Federal amount being much lower in comparison to other much larger construction contracts that the Corps of Engineers handles, these projects lack funding that would otherwise be used to conduct preliminary studies and analysis. Due to this lack of funding, these projects typically come with a high amount of uncertainty, resulting in design and cost estimate contingencies. When these contingencies are in place, the Corps of Engineers' cost estimate is subject to inaccuracies due to a wide range of assumptions having to be made.

To combat this, this study will look at Section 14 projects that have been awarded to a contractor and analyze the actual costs paid to that contractor versus what the government estimate was. The variables that will be evaluated are the cost variance of the individual bid items for the government estimate and the contractor actual amounts, the total project cost variance between the two, and the contract modifications for each individual project and how that negatively or positively effects the cost variance. These different variables were chosen in efforts to find patterns amongst projects that will allow for future Section 14 projects to avoid cost overruns resulting from contract modifications, quantity adjustments, or scope changes. With the insight found from this project's analysis the Corps of Engineers' cost engineers will also find benefits because many Section 14 projects are being analyzed from differing areas in the United States. With this, a wide range of contractor assumptions and construction methodologies will be highlighted and later be used in future Section 14 projects by USACE personnel. Finally, this study will also provide contributions to project leadership as it will allow for the selection of the best contractor proposal and identify the risk factors found within Section 14 projects.

METHODOLOGY

For these analyses to be successfully completed, the following steps, seen in Figure 1, were completed.

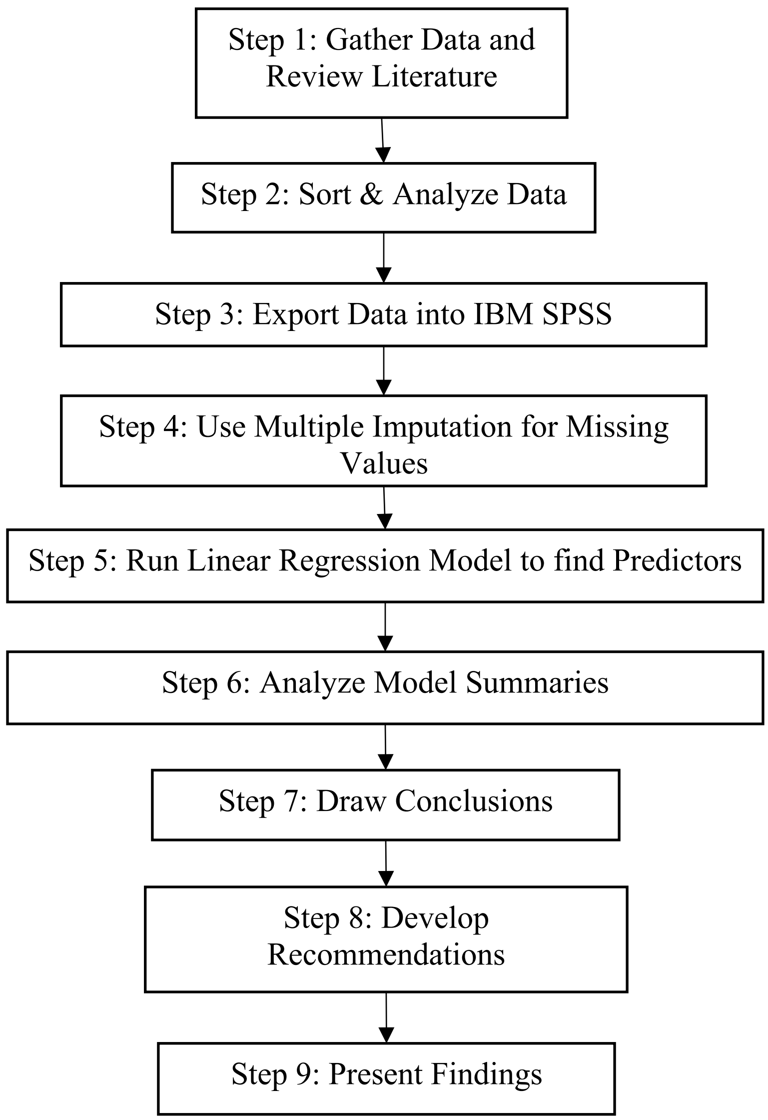

Figure 1: Flowchart of the Study's Methodology

Step 1: Gather Data and Review Literature.

This step consisted of finding Section 14 projects that have been awarded to a contractor across the United States. Once these projects were identified, the contractor's actual costs, along with the government's estimate, were pulled out for further examination. Once these elements were gathered, other project related information like contract modifications, basic change documents, progress payment history, and activity summary by CLIN were also collected in order to obtain an understanding of the project's cost growths. Along with gathering data, a literature review was performed. The types of information the researcher reviewed were other studies that looked into cost overruns and how those cost overruns were analyzed and categorized. This literature review allowed the researcher to grasp an understanding of what has previously been researched and where there is a research gap for this study to close.

Step 2: Sort & Analyze Data.

This step involved compiling the data that was previously gathered and structuring it via Microsoft Excel. This structure is imperative for successful statistical models to be performed so that an accurate analysis between the contractor's actual costs and the government's estimate can be found. This structure included pulling in the bid item names, contractor actual costs, government estimated costs, and then the percent difference between those two costs. Once the percent difference was found, a conditional formatting will be applied to the percentages. This formatting included highlighting the cells green if the percentage falls between -25% and 25% and highlighting the cell red if the percentage is outside of this range. This range was used in order to provide the researcher with a visual representation of the bid items that were over 25% in cost growth.

Once all fourteen projects were formatted in that nature, they were pulled into a master document that places the bid item on the left most column and the associated project that percent difference belongs to in the top row. This formatting technique allowed for a smoother transition into the display of SPSS. In order for the researcher to easily visualize the data, they were clustered into 10 categories outlined by the CSI MasterFormat. Further discussion about this format will be described in Chapter 3.

Step 3: Export Data into IBM SPSS.

Step 3 involved taking the formatted data from Microsoft Excel and importing that information into the statistical modeling software SPSS by IBM.

Step 4: Use Multiple Imputation for Missing Values.

Once the data was imported into SPSS, the many missing values throughout the data set needed to be taken care of, further explanation of missing data is explained in Chapter 3. To take care of these missing values, the researcher utilized the Multiple Imputation function in SPSS. What this function does is populate the missing values in the data set based upon the information that is available for that particular variable. A more detailed description of the multiple imputation process can be found in Chapter 4.

Step 5: Run Linear Regression Model to find Predictors.

Once the missing results were populated with imputed values, the data set was analyzed using a linear regression model. This linear regression model produced tabulated information that the results section will further discuss. The two tables of importance were the Model Summary table and the ANOVA table. The Model Summary table showcased which models the linear regression found for the data set and the ANOVA table outlined if the variables found in the regression model were statistically significant or not. Some of the information found in these tables included statistical results like R-Square, Sig F, Sum of Squares, df, Mean Square, F, and Sig. Those elements are further explained in Chapter 4.

Step 6: Analyze Model Summaries and ANOVA Table

Once the linear regression was run, the models and results that were generated were evaluated in order to analyze their significance.

Step 7: Draw Conclusions

After the Model Summaries and ANOVA table were analyzed, conclusions about the findings were drawn.

Step 8: Develop Recommendations

After conclusions were drawn, recommendations on how to improve based upon the findings were presented.

Step 9: Present Findings

Finally, after all prior analysis was completed, the information obtained was compiled and written into a report and presentation.

CHAPTER 2: LITERATURE REVIEW

This chapter details the results from reviewing existing literature on uncertainties in cost estimation, approaches to capture those uncertainties and other approaches or techniques that are applicable to solving the problem posed by this thesis. The problem of cost uncertainties has been evaluated across many disciplines in an effort to better understand and plan for those uncertainties.

All estimates are subject to uncertainty, and project cost estimation is no exception. Risk cannot be eliminated by any scheduling or estimation method. It arises because of imprecise information about what to do and how long it should take. However, there are several ways to mitigate uncertainty in cost and schedule. The simplest way is to prepare a project budget to include some allowance for contingencies, referred to as reserve analysis. Another way to deal with the uncertainty associated with task durations is to add a time reserve or buffer to the estimated task durations. The application of these methods in practice reveals that contingencies and time reserve do not reduce the risk of running over budget and behind schedule (Hall and Delille, 2012).

One main method to cost risk mitigation is assessing and quantifying the risk in a cost estimate using probability distribution. To get probability distributions for a new project, experts' opinions have been used very often (Hall and Delille, 2012). However, this method has received much criticism because of the bias associated with experts' opinion (Rand, 2017).

Omar et al. (2017) details an approach for cost estimation that combines a maximum likelihood estimator for data transformations with least angle regression for dimensionality reduction. In this approach, 15 different pavement bid items were analyzed across five states in the United States. They were able to evaluate the effectiveness of their proposed approach compared to the current approach that is used, life cycle cost analysis, by applying both approaches to the 15 pay items and comparing the results. Their results show the proposed approach leads to consistent parametric estimates being produced, but that future work could be conducted to include other roadway construction items, such as excavation. Another note the researchers made was that many past studies emphasize the analysis of high visibility, mega-projects, whereas their analysis focused on relatively smaller projects that operate upon fixed budgets. The work in this study will also close the gap on this type of analysis into smaller projects. Section 14 projects have to work within a $5 million limit per project, therefore, finding the leading cost drivers can further enhance the profession by outlining the areas that engineers need to emphasize more over others.

Abderisak et al. (2016) states that construction cost overruns and time delays are an aspect that are of significant concern to the construction industry globally. According to Baloi and Price (2003), approximately 63% out of 1,778 construction projects funded by the World Bank exceeded their budgets. Also, according to The Standish Group Report (2014), 70% of all projects are finished overbudget and behind schedule. The group report concluded that 52% of all projects finish at 189% of their initial budget. (https://www.projectsmart.co.uk/white-papers/chaos-report.pdf).

Given this significant percentage of cost overruns, the authors of the Standish Group Report (2014) set out to explore the factors that are causing these cost overruns and time delays. Their analysis included reading 40 journal articles, compiling a list of factors leading to the overruns and delays, and then ranking the factors according to their occurrences and explanations for the overruns and delays.

Abderisak et al. (2016) displayed the results of their analysis in a kiviat diagram, which mapped out the occurrences of eight items over a time period from 1985-2014. Those eight items included: Communication, which is a lack of communication between the contractor and client; Financial, either delayed payment, poor financial planning, or cost increases; Management, poor site management, monitoring, labor planning, or slow decision making; Material, which includes either a shortage of equipment or poor material planning; Organizational, which involves poor structure, procedures, or unsuitable management structure; Project, meaning project complexities or durations; Psychological, which includes optimism bias or deception, and finally; Weather, which includes harsh conditions or unforeseen ground conditions. From their analysis, it was found that the managerial aspect was a consistent factor across the entire time frame as a reason for cost overruns and time delays. This is because most managerial decisions are created in the early planning phases of a project. Another peculiar facet in their analysis was that communication, and psychology factors presented low scores.

Abderisak et al. (2016) note that project managers should always strive to mitigate these factors, since elimination is not feasible. However, there are external reasons that, more often than not, derail this mitigation process. Politics and the project's best interest do not always coincide, therefore, bringing about challenges. According to the Project Management Body of Knowledge (PMBOK® Guide, 6th edition) external environmental factors such as marketplace conditions, law and regulation, commercial database to estimate projects cost could play a significant role in causing the project to run overbudget.

Famiyeh et. al (2016) state that the duration of construction projects from start to finish is becoming a great concern. These delays cause significant financial difficulties to clients and beneficiaries because of varying interest rates and inflation. Given this, the authors set out to understand what was causing these delays and cost overruns in construction projects. Specifically, they targeted the education sector, in Ghana, in efforts to create practical solutions to address the issue.

In order to perform their study, Famiyeh et. al (2016) conducted a survey among clients, consultants, and representatives of contractors on roughly 60 government school projects. The findings from these surveys were financial problems, unrealistic contract durations, poorly defined scope, and poor inspection/supervision of the projects were the key factors in causing time overruns. The factors that caused cost overruns included delays in payment, design variances, poor feasibility and project analysis, and lack of communications of plans.

In the text, Famiyeh et. al (2016) stated that the cause for delays can be classified into three groups: inadequacies with industry infrastructure, problems with the clients or consultants, and problems with contractor incompetence. This grouping, or clustering, technique allows for a more comprehensive understanding of the data if the data doesn't exactly match a given set of categories. Applying this thought process to this study, the bid items found within the 14 Section 14 projects were grouped into categories based upon the CSI MasterFormat. A more in-depth discussion of this grouping can be seen in Chapter 3.

Sattineni et. al (2020) stated that time contingency in construction projects is often overlooked and little attention is paid to it during contract negotiations. With this, the researchers analyzed 80 different projects in an effort to find the various reasons why there are delays in USACE projects. Of these 80 projects, 26 were delayed for various reasons. These various reasons include 40 different factors in total. These 40 were grouped into seven major categories so that a simple Monte Carlo Simulation could be used to predict time contingencies.

Through their analysis, the following major categories and their percentages of occurrence were found: unforeseen weather 3%; administrative related 7%; design related 38%; regulatory delays 5%; funding related 8%; user requested – additional scope 15%; and different site conditions 23%. Of all 26 projects, design related reasons caused a great majority of schedule delays. From their Monte Carlo Simulation, the model suggested a 10% time contingency, which coincided with the hand calculations performed that showed that 72% of projects extended 10% - 13% of the project's duration. With this, the model was shown to be proven as an effective tool to predict time contingencies.

Odeck (2003) studied the statistical relationship between actual and estimated costs of road construction in Norway over the years of 1992 – 1995. Through this analysis, a mean cost overrun of 7.9% was found and the total range was -59% to +183%, amounting to 519 million Norwegian kroners. Odeck stated that cost overruns are more predominant in smaller projects compared to larger ones.

CONTRACT MODIFICATIONS

Through the data analysis portion of this project, it was found that a large majority of the projects had contract modifications during the construction work. These modifications ranged from quantity adjustments, additional work items, and contractor work limit (CWL) changes, along with many other titles. These modifications both positively and negatively impacted the financial amount of the respective project. Based upon this, the researcher set out to find what had already been researched on the topic of contract modifications.

Kaliba et. al (2009) studied the causes of cost escalations and schedule delays in road construction projects in Zambia. The study consisted of selecting 13 projects in Zambia and structuring interviews and questionnaire surveys in order to gain insight into why there are cost overruns and schedule delays. From this work, the factors that lead to cost escalation are said to be the size of the project, scope enlargement, inflation, and the length of the time to complete the project. On the other hand, the researchers state that there is a relationship between the schedule, scope of work, and project conditions when looking at schedule delays. It states in the article that changes to any of these three characteristics can affect the compensational level and time of completion of a project. According to Ashworth (2002), schedule delays can be grouped into four categories depending on how they operate contractually. The four categories are non-excusable delays, non-compensable excusable delays, compensable excusable delays, and concurrent delays. In this research, contract modifications were categorized as excusable-compensable delays, meaning that they are delays that are found during the work and must be utilized in order for the task to be completed.

In conclusion, this literature review provided the researcher with insight into what has previously been studied along the lines of cost overruns, schedule delays, and contract modifications. From the paper written by Omar et. al (2017), it stated that many high-level mega projects have been analyzed to see why there are cost overruns and schedule delays. However, this same analysis is not being performed on small scale, fixed budget projects. This is also backed up from the paper from Odeck (2003), that stated that small scale projects are actually more susceptible to cost overruns because many corners are cut in the study phase in order for projects funds to be maximized. Along with looking at small scaled projects, there are many external factors that cannot be controlled. From Abderisak et. al (2016), this paper stated that politics and the best interest of the project do not always coincide. Given this information, this thesis will build upon the knowledge previously learnt through the literature review.

CHAPTER 3: DATA COLLECTION

This study identified 14 USACE Section 14 projects from different areas along the Appalachian and Midwest region of the United States. These areas were chosen because of the similar project features that they shared throughout. A list of these 14 projects will follow:

Project 1 – Located in Kanawha County, WV – Total Cost: $3.9M

Project 2 – Located in Washington County, OH – Total Cost: $350k

Project 3 – Located in Kanawha County, WV – Total Cost: $1.7M

Project 4 – Located in Mason County, KY – Total Cost: $6.8M

Project 5 – Located in West Virginia – Total Cost: $700k

Project 6 – Located in Cabell County, WV – Total Cost: $4.5M

Project 7 – Located in Pennsylvania – Total Cost: $1.1M

Project 8 – Located in Pennsylvania – Total Cost: $1.3M

Project 9 – Located in Pennsylvania – Total Cost: $400k

Project 10 – Located in Pennsylvania – Total Cost: $50k

Project 11 – Located in Marion County, WV – Total Cost: $800k

Project 12 – Located in Illinois – Total Cost: $200k

Project 13 – Located in Illinois – Total Cost: $300k

Project 14 – Located in Illinois – Total Cost: $300k

Once these projects were identified, their individual cost information was imported into Microsoft Excel ® for further examination. The information that was imported included the bid item, amount paid to the contractor for that bid item, and the amount the government estimated for that bid item. From this, the percent difference of the contractor's actual cost was compared to against the government's estimate to produce a percent difference. This percent difference value is what will be used to determine what is attributing to cost overruns un these Section 14 projects. An example of the information previously described can be seen in Table 1. From this table, the bottom row titled "Total" is the total cost of the contractor's actual cost and government's estimate. This total amount's percent difference is what will be used as the dependent variable throughout the analysis. From the table, the percent difference is highlighted red if the percentage falls outside the range from -25% to 25% and is green if the percentage falls within the previously referenced range. This range was utilized in order to visually see which bid items were falling within an "awardable range" and which items were not. This awardable range is one that the Corps of Engineers uses on its IFB, invitation for bid, contracts. What this range means is that a contractor's proposal can be deemed awardable if it falls within the -25% to 25% range of the government's estimate. This process was used for visualization reasons only.

Table 1. Project 14 Broken into Bid Items, Contractor Actual Costs, Government Estimate, and the Percent Difference Between Them.

Project 14			
Bid Items	**Contractor**	**Government**	**Percent Difference**
Mobilization and Demobilization	$50,000.00	$13,309.65	73%
Clearing and Grubbing	$25,000.00	$18,258.00	27%
Earthwork, Shaping and Grading	$28,500.00	$45,791.00	-61%
Geotextile Fabric	$2,176.00	$8,825.00	-306%
Bedding Stone			
First 950 Ton	$33,725.00	$41,315.50	-23%
Over 950 Ton	$5,055.05	$7,610.75	-51%
Riprap			
First 2,700 Ton	$122,850.00	$176,229.00	-43%
Over 2,700 Ton	$3,868.20	$32,635.00	-744%
Aggregate			
First 510 Ton	$10,455.00	$24,536.10	-135%
Over 510 Ton	$202.50	$4,815.00	-2278%
Topsoil	$3,500.00	$20,422.00	-483%
Seeding and Site Restoration	$5,000.00	$13,018.00	-160%
Total:	$290,331.75	$406,765.00	-40%

Although the 14 projects were along the same regions, each individual project comes with features that do not always coincide with other projects. To highlight this, two tables have been created below. Table 2 first shows the bid items that were found in at least 7 of the 14 projects. Table 3, Table 4, Table 5, Table 6, and Table 7, outline the bid items that were not found in at least 7 of the 14 projects.

Table 2. Bid Items that are Found Within at Least 7 of the 14 projects.

Bid Items Found in 7 or More Projects
Payment & Performance Bond
Mobilization/Demobilization
Survey
Excavating Soil
Filter Fabric
Silt Fence
Clearing and Grubbing
Seeding
Rip Rap Placement and Material
Piping Install and Material
Bedding Stone Placement and Material

Table 3. Bid Items that are Found in Less Than 7 Projects, Part One

Bid Items Found in Less Than 7 Projects
Quality Control Officer
Site Safety Officer
Temporary Office
General Conditions
Digital Progress Images
Site Security
Personnel Swing Gates
Vehicular Swing Gates
Protection and Maintenance of Vehicle and Pedestri
Traffic Control
Pavement Repair

Table 4. Bid Items that are Found in Less Than 7 Projects, Part Two

Bid Items Found in Less Than 7 Projects
Guardrail Installation
Replace Concrete Sections
As Built Drawings
Concrete Stairs
Bituminous Pavement Removal
Guide Rail
Site Demolition
New Guiderail and Posts
Manhole Adjustment
Precast Concrete Block Wall
Concrete Leveling Pad 4" Thick

Table 5. Bid Items that are Found in Less Than 7 Projects, Part Three

Bid Items Found in Less Than 7 Projects
Modular Pre-Cast Concrete Wall
Gravel Levelin Pad 6" Thick
Concrete for Parking Pad
Aggregate
Granular backfill
Demolition, Removal, and Disposal of Existing Conc
Aggregate Base for Parking Pad
3/4" steel plate
Removal/Disposal of 30' H Pile
Re-Usable lagging for upper slope support
Removal/Disposal of Timber Lagging

Table 6. Bid Items that are Found in Less Than 7 Projects, Part Four

Bid Items Found in Less Than 7 Projects
Pressure Treated Timber lagging
Excavating Vegetation
Access Ramp
Soil, Fabric, Mat'l Placement
Excavating Stone, Flumes, Etc.
Vegetative Slope Protection
Grading and Shaping Bankline
Select Backfill
Suitable Soil Backfill
Topsoil Backfill
Coir Fiber Log

Table 7. Bid Items that are Found in Less Than 7 Projects, Part Five

Bid Items Found in Less Than 7 Projects
Erosion Control Blanket
Shrubs
Site Restoration
Repair of Damaged Turf
Chain Link Fence
Grouting Stabilizaiton
Headwalls Install and Mat'l
Set Salvaged stone
Remove and Dispose Gabion Basket
Temporary Relocation of Foundation Stone and Misce
Turbidity Curtain
Bypass Pumping
Temporary Water Diversion

From the tables above, it can be seen that the vast majority of bid items do not occur in every project. This is because projects come with different needs, some projects are located close to highways, so traffic control is necessary. Others follow alternative plans of action to incorporate steel piling and lagging. Ultimately, only 11 of the total 68 bid items, roughly 16%, actually fall within half of the projects. Given this, these 68 bid items were grouped into 10 categories based on the CSI MasterFormat in order for a more coherent assessment of the data to be completed. The Construction Specifications Institute, CSI, is a national not-for-profit association dedicated to improving the communication of construction information throughout continuous development and transformation of standards and formats, education, and certification of professionals to improve project delivery processes (CSI, 2021). The reason this study chose to narrow the 68 bid items into the CSI MasterFormat was because of the simplicity when viewing the bid items. The CSI format was used to provide clarity to the researchers in the data gathering portion for more simplistic data analysis to occur. Only 11 of the 18 bid items were presented in over 50% of the projects, so a clustered approach was necessary. The 10 categories, seen below, were selected to provide a broader description for the bid items that were found in less than 7 projects.

Division 00 - Procurement and Contracting Requirements

Division 01 – General Requirements

Division 02 – Existing Conditions/Site Construction

Division 03 – Concrete

Division 05 – Metals

Division 06 – Woods, Plastics, Composites

Division 31 – Earthwork

Division 32 – Exterior Improvements

Division 35 – Waterway and Marine Construction

Division 46 – Water and Wastewater Equipment

Table 8, Table 9, Table 10, and Table 11 provide an understanding of the type of bid items that were assigned to these 10 divisions.

Table 8. Division 00 and 01

Division 00 - Procurement and Contracting Requirements
Payment & Performance Bond
Division 01 - General Requirements
Mobilization/Demobilization
Survey
Quality Control Officer
Site Safety Officer
Temporary Office
General Conditions
Digital Progress Images
Site Security
Personnel Swing Gates
Vehicular Swing Gates
Protection and Maintenance of Vehicle and Pedestrians
Traffic Control

Table 9. Division 02 and 03

Division 02 - Existing Conditions/Site Construction
Pavement Repair
Guardrail Installation
Replace Concrete Sections
As Built Drawings
Concrete Stairs
Bituminous Pavement Removal
Guide Rail
Site Demolition
New Guiderail and Posts
Manhole Adjustment
Division 03 - Concrete
Precast Concrete Block Wall
Concrete Leveling Pad 4" Thick
Modular Pre-Cast Concrete Wall
Gravel Levelin Pad 6" Thick
Concrete for Parking Pad
Aggregate
Granular backfill
Demolition, Removal, and Disposal of Existing Concrete
Aggregate Base for Parking Pad

Table 10. Division 05, 06, and 31

Division 05 - Metals
3/4" steel plate
Removal/Disposal of 30' H Pile
Re-Usable lagging for upper slope support
Division 06 - Wood, Plastics, Composites
Removal/Disposal of Timber Lagging
Pressure Treated Timber lagging
Division 31 - Earthwork
Excavating Soil
Excavating Vegetation
Access Ramp
Filter Fabric
Silt fence
Clearing and Grubbing
Soil, Fabric, Materiall Placement
Excavating Stone, Flumes, Etc.
Vegetative Slope Protection
Grading and Shaping Bankline
Select Backfill
Suitable Soil Backfill
Topsoil Backfill
Coir Fiber Log
Erosion Control Blanket

Table 11. Division 32, 35, and 46

Division 32 - Exterior Improvements
Seeding
Shrubs
Site Restoration
Repair of Damaged Turf
Chain Link Fence
Division 35 - Waterway and Marine Construction
Rip Rap Placement and Material
Grouting Stabilizaiton
Piping Install and Mat'l
Headwalls Install and Mat'l
Set Salvaged stone
Bedding Stone Placement and Mat'l
Remove and Dispose Gabion Basket
Temporary Relocation of Foundation Stone and Misce
Division 46 - Water and Wastewater Equipment
Turbidity Curtain
Bypass Pumping
Temporary Water Diversion

After the bid items were assigned to the category that best fit their role, they were formatted to best fit the interface of the statistical analysis software SPSS by IBM. This consisted of transposing the data so that each column of information represented a different variable. Once formatted, the data was then exported to SPSS. This software was utilized to run stepwise linear regression models in efforts to pinpoint which bid items were causing the cost overruns. To see this data in its entirety, refer to Appendix A-1 of this report.

In SPSS, the independent and dependent variables were assigned, and a preliminary regression analysis was conducted. Through this analysis, the missing values were found to be an issue. Therefore, steps to overcome the missing information were conducted prior to further evaluation. More discussion on the data analysis procedures and findings can be seen in the next chapter, Chapter 4.

CHAPTER 4: DATA ANALYSIS

As stated previously, not all 14 projects had the same bid items throughout. This non-fluidity of bid items amongst all projects created gaps in the data of "missing values". The missing values has quotation marks surrounding it because these values aren't actually missing, they are simply not accounted for because the particular bid item was not used in the particular project. As stated previously in Chapter 3, all projects are made of different characteristics, therefore, alternating plans of action have to be taken. This missing information created a challenge for the researcher as it was not entirely straightforward on how to use the data set to run models. Therefore, in order to accurately treat these missing values, two imputation techniques were analyzed to decide which provided the best output regression model. The first option was to use SPSS's built in tool to replace all missing values with the mean of that particular bid item while the second option was to use the multiple imputation function in SPSS. The multiple imputation function in SPSS is an algorithm known as fully conditional specification (FCS) or chained equations imputation. The basic idea of this algorithm is to impute the incomplete variables one at a time by using the filled-in variable from one step as a predictor in all subsequent steps (Enders, 2010). In this case, SPSS is using linear regression because the variables are continuous.

The purpose of using a stepwise linear regression approach in this instance is because this strategy involves regressing multiple variables while also simultaneously removing those that are not important. In this case, stepwise linear regression proves effective because it removes the bid items that are only found within a few projects and then focuses on the bid items that appear more often. These bid items that show themselves in over 50% of the projects are the leading prospects to be predictors in this type of analysis as they show more validity in the regression approach.

When performing the stepwise linear regression using the mean for missing values, the output produced two models. The first model concluded that Rip Rap Placement and Material was a predictor and the second model concluded the prior variable and Filter Fabric as predictors. What Model 1 shows is that Rip Rap Placement and Material can be attributed to predicting 65.8% of the variance in the cost of the 14 Section 14 projects. Furthermore, when Filter Fabric is added to Model 2, it attributes to predicting an additional 13.3% of the variance in the cost of the selected Section 14 projects. The results of this model summary can be seen in Table 12.

Table 12. Model Summary of the Stepwise Linear Regression Using the Mean for Missing Values

Model Summary									
					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.811[a]	0.658	0.630	16.82%	0.658	23.126	1	12	0.000
2	.889[b]	0.791	0.753	13.74%	0.133	6.989	1	11	0.023

a. Predictors: (Constant), Rip Rap Placement and Material

b. Predictors: (Constant), Rip Rap Placement and Material, Filter Fabric

On the other hand, when performing the stepwise linear regression using imputed values for the data set, the output produced differing model amounts based upon which data set was used. In total, there were five data sets, those five being the 5 iterations simulated through the imputation process. This imputation process involved assigning all 68 bid items as independent variables and allowing the software to run for 5 iterations in order to produce adequate values for the missing areas in the data set. The type of imputation process that SPSS used in this scenario was multiple imputation by chained equations (MICE). As explained by Azur et. al (2011), the chained equation process can be broken down into these general steps:

- Step 1: A simple imputation, such as imputing the mean, is performed for every missing value in the dataset. These mean imputations can be thought of as “place holders.”
- Step 2: The “place holder” mean imputations for one variable (“var”) are set back to missing.
- Step 3: The observed values from the variable “var” in Step 2 are regressed on the other variables in the imputation model, which may or may not consist of all of the variables in the dataset. In other words, “var” is the dependent variable in a regression model and all the other variables are independent variables in the regression model. These regression models operate under the same assumptions that one would make when performing linear, logistic, or Poisson regression models outside of the context of imputing missing data.
- Step 4: The missing values for “var” are then replaced with predictions (imputations) from the regression model. When “var” is subsequently used as an independent variable in the regression models for other variables, both the observed and these imputed values will be used.
- Step 5: Steps 2–4 are then repeated for each variable that has missing data. The cycling through each of the variables constitutes one iteration or “cycle.” At the end of one cycle all of the missing values have been replaced with predictions from regressions that reflect the relationships observed in the data.
- Step 6: Steps 2–4 are repeated for a number of cycles, with the imputations being updated at each cycle.

Imputation 1 produced three models with two statistically significant predictors Rip Rap Placement and Material, Filter Fabric, and Piping Install and Material. From Imputation 1, it can be seen that from the R Square value, 65.8% of the variance seen in the selected Section 14 projects can be predicted from Rip Rap Placement and Material. Furthermore, Filter Fabric and Piping Install and Material attribute an additional 14.2% and 7.2%, respectively, to the variance of these projects. Looking to the far-right column, the Sig. F Change denotes how significant of a change these additional predictors made when being added to the model. In Imputation 1, it can be seen that when adding Filter Fabric, the Sig. F Change is 0.017, and adding Piping Install and Material increases that Sig. F Change to 0.039, which means that as these variables were added to the model, the value produced indicates the amount of change each predictor brought to the model.

Imputation 2 shows that only two models were created, where, based on statistically significant variables, Rip Rap Placement and Material and Filter Fabric were the two predictors selected. From this imputation, the statistical results for model 1 reflect that of model 1 in Imputation 1 because the original data set did not have any missing values for Rip Rap Placement and Material. This bid item was the only one of 68 that did not have a missing value. As for model 2 in Imputation 2, it can be seen that the R Square of Filter Fabric decreased from that of Imputation 1, however, the Sig. F Change increased. This relationship shows that incorporating Filter Fabric as a second predictor in Imputation 2 created a greater change in the predictability than it did in Imputation 1. It should be noted that due to SPSS's method of imputation, any independent variable that had any missing value will produce differing statistical results throughout the multiple different iterations of imputation.

Imputation 3 produced three models with the previously stated variables, as well as, Piping Install and Material as the third predictor. As stated previously, the statistical results for model 1 were unchanged. The results for model 2 differed slightly from the previous two iterations and the results for model 3 showed that adding Piping Install and Material as a predictor attributed to an additional 6.8% of the variance found within these projects. Another peculiar piece of information from Imputation 3 is that Piping Install and Material produced the largest Sig. F Change, at 0.048. What this signifies is that by adding Piping Install and Material, the prediction was improved significantly more than any other predictor of the five imputations.

Imputation 4 and Imputation 5 both produced two models with the same predictors as Imputation 2. In these instances, the statistical results varied slightly from those found in Imputation 2. This can be attributed to the previously stated information that the data within Imputation 2, 4, and 5 only differs slightly because of the imputation method SPSS used. A table outlining the previously described information for Imputation 1 through 5 can be seen below in Table 13.

Table 13. Model Summary of the Stepwise Linear Regression Using Imputed Values

Model Summary[a]

Imputation Number		R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
						R Square Change	F Change	df1	df2	Sig. F Change
1	1	.811[b]	0.658	0.630	16.8%	0.658	23.126	1	12	0.000
	2	.895[c]	0.800	0.764	13.4%	0.142	7.803	1	11	0.017
	3	.934[d]	0.872	0.834	11.3%	0.072	5.618	1	10	0.039
2	1	.811[b]	0.658	0.630	16.8%	0.658	23.126	1	12	0.000
	2	.885[c]	0.783	0.744	14.0%	0.125	6.335	1	11	0.029
3	1	.811[b]	0.658	0.630	16.8%	0.658	23.126	1	12	0.000
	2	.893[c]	0.797	0.760	13.5%	0.139	7.536	1	11	0.019
	3	.930[d]	0.866	0.825	11.6%	0.068	5.074	1	10	0.048
4	1	.811[b]	0.658	0.630	16.8%	0.658	23.126	1	12	0.000
	2	.885[c]	0.784	0.745	14.0%	0.126	6.390	1	11	0.028
5	1	.811[b]	0.658	0.630	16.8%	0.658	23.126	1	12	0.000
	2	.887[c]	0.787	0.748	13.9%	0.129	6.634	1	11	0.026

a. There are no valid cases in one or more split files. Statistics cannot be computed.

b. Predictors: (Constant), Rip Rap Placement and Material

c. Predictors: (Constant), Rip Rap Placement and Material, Filter Fabric

d. Predictors: (Constant), Rip Rap Placement and Material, Filter Fabric, Piping Install and Mat'l

From the two tables above, there are slightly different values that are produced from using the Mean and Imputed Values for missing values in the data set. The difference between these two scenarios is the way in which SPSS is producing the values for these missing data points. In the first scenario, using the Mean, SPSS is looking at all available data in a particular variable and calculating the mean of those values to place in the missing areas. In the second scenario, SPSS is using Multiple Imputation to create algorithms to impute the incomplete variables one at a time by using the filled-in variable from one step as a predictor in all subsequent steps. Given the overview of how each scenario was performed and viewing the tabulated results, the researcher decided that the multiple imputation approach would best fit this study. This was because of the range of possibilities each iteration of the imputation provided for the model.

Now that the imputed value method has been decided upon, the next decision was to choose which of the five imputation sets populated by this method would be best to move forward with in the final analysis. To do this, an Automatic Linear Modeling Regression was performed and from this analysis, it was found that Imputation 4 had an accuracy of 99.8%. What this percentage is showing is the adjusted R square value for the linear modeling regression performed. From that process, it was found that the independent variables predict 99.8% of the variance of the dependent variable in model 4, based upon adjusted R square. This information can be seen in Figure 2 and Figure 3 below.

Split Groups

Imputation_	Accuracy	Model Size (Coefficients)	Records
0	67.7%	3	11
1	50.8%	2	8
2	93.9%	4	8
3	74.5%	3	8
4	99.8%	5	8
5	74.6%	3	8

Figure 2: Split Groups Showcasing Accuracies with Each Imputation.

Model Summary

Target	Dependent Variable
Automatic Data Preparation	On
Model Selection Method	Forward Stepwise
Information Criterion	19.923

The information criterion is used to compare to models. Models with smaller information criterion values fit better.

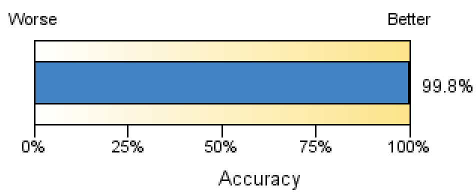

Figure 3: Model 4 Summary

Based upon the information that Imputation 4 is the most accurate of all, the two variables that are attributing to cost overruns in Section 14 projects are Rip Rap Placement and Material and Filter Fabric. To provide a more in-depth description of what these two bid items are, Rip Rap is the stone that is placed by the contractor, typically on the bank, in order to armor the bank from further erosion. The stone can vary in size, but the typical size is 15-inch stone. It is placed on the bank by an excavator and clam bucket, which is either on land or on a floating plant.

Filter Fabric is a type of fabric material that allows water to pass through while keeping soils in place. In Section 14 projects, it is laid out on the newly excavated surface prior to the Rip Rap being placed on top of it. Filter Fabric also creates a barrier between the newly excavated soil and the rock. This barrier is necessary because it protects the soil from being penetrated by the rock when experiencing fluid force from the stream bank. This fabric is typically placed with the help of an excavator and some crew members to guide the placement.

With a descriptive understanding of the two bid items attributing to cost overruns in the fourteen Section 14 projects. A deeper analysis into the models and statistical behaviors of the two variables was conducted. In Table 14, a condensed version of Table 13 can be seen showing the first and second model of Imputation 4. Reiterating what was previously stated in this chapter, looking at R Square, also known as the coefficient of determination, shows that 65.8% of the variance in the fourteen Section 14 projects can be predicted from the variable Rip Rap Placement and Material. Furthermore, 78.4% of the variance in these same projects can be predicted from the variables Rip Rap Placement and Material and Filter Fabric. Reflecting on these results and the fact that these projects continually have to omit preliminary studies before designing a plan of action. A direct relationship between having to make assumptions on the amount of stone and the area to place the filter fabric generates a larger variance in cost seen across the fourteen projects.

Table 14. Model Summary of the Stepwise Linear Regression for Imputation 4

Model Summary									
					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.811[a]	0.658	0.630	16.82%	0.658	23.126	1	12	0.000
2	.885[b]	0.784	0.745	13.97%	0.126	6.390	1	11	0.028
a. Predictors: (Constant), RipRapPlacementandMaterial									
b. Predictors: (Constant), RipRapPlacementandMaterial, FilterFabric									

Building upon the statistical results from Table 14, an ANOVA table, seen in Table 15, shows the Regression, Residual, and Total values for differing statistical measures along Model 1 and Model 2. The Total variance is partitioned into two subsets. The first is Regression, which signifies the variance which can be explained by the independent variables and the second, Residual, signifies the variance not explained by the independent variables, sometimes called Error. It should be noted that the Sum of Squares for Regression and Residual add up to the Total, further backing that the Total is partitioned into Regression and Residual. Also, from equation (1), dividing the Sums of Squares value for Regression from that of the Total produces the R Square value found in Table 10.

$$\frac{SSRegression}{SSTotal} = R\ Square \qquad (1)$$

The df column denotes the degrees of freedom and the way it is calculated can be seen in equation (2). In Total, there were 14 variables, in Model 1 only one variable was chosen, therefore, the Regression had one degree of freedom and the Residual has twelve. For Model 2, another variable was added so the degrees of freedom equation (2) for Regression increased by one and decreased by one for Residual.

$$N - 1 = df \qquad (2)$$

The Mean Square is the Sum of Squares divided by their respective df value, where n indicates whether Regression or Residual is selected. This equation can be seen in equation (3).

$$\frac{Sum\ of\ Squares}{df_n} = Mean\ Square\ Error \qquad (3)$$

In the two rightmost columns of Table 15, F and Sig. are used to answer the question, “Do the independent variables reliably predict the dependent variable?”. This question is answered by the analysis conducted to come to the result of F and Sig. For F, the Mean Square Regression is divided by the Mean Square Residual, which was previously explained in equation (3), to yield an F value. In this case, the two F values are 23.126 and 19.952 for the Regression in Model 1 and Model 2, respectively. From these two F values, the p-value associated with them is very small (.000). This p-value is associated to the alpha level, 0.05, and since both p-values are less than the alpha value, it can be said that the two groups of variables, Rip Rap Placement and Material as a standalone, and Rip Rap Placement and Material, along with, Filter Fabric, can be used to reliably predict cost overruns, the dependent variable, in the fourteen selected Section 14 projects.

Table 15. ANOVA (Analysis of Variance) Table for Imputation 4

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	6540.397	1	6540.397	23.126	.000[b]
	Residual	3393.844	12	282.820		
	Total	9934.242	13			
2	Regression	7787.500	2	3893.750	19.952	.000[c]
	Residual	2146.741	11	195.158		
	Total	9934.242	13			

a. Dependent Variable: DependentVariable

b. Predictors: (Constant), RipRapPlacementandMaterial

c. Predictors: (Constant), RipRapPlacementandMaterial, FilterFabric

Since the two models previously described have been verified to prove the hypothesis of this study as true, a deeper investigation into the equations that make up these models was conducted to show how each variable would interact to changes in data. From Table 16, the coefficient(s) for each model can be seen.

Table 16. Coefficients for Model 1 and Model 2 in Imputation 4

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-3.368	4.581		-0.735	0.476
	RipRapPlacementandMaterial	0.313	0.065	0.811	4.809	0.000
2	(Constant)	10.550	6.693		1.576	0.143
	RipRapPlacementandMaterial	0.248	0.060	0.643	4.148	0.002
	FilterFabric	0.111	0.044	0.392	2.528	0.028

a. Dependent Variable: DependentVariable

These coefficients, in the column titled B, represent the coefficient that accompanies the regression equation used to predict the dependent variable from the independent variable. The general equation for this can be seen in equation (4).

$$Y_{predicted} = B_0 + B_1 x_1 + B_2 x_2 + \cdots + B_n x_n \qquad (4)$$

Where B_0 is the constant, B_1 is the first variable's coefficient, x_1 is the first variable in the model, B_2 is the second variable's coefficient, x_2 is the second variable in the model.

The equation for Model 1 would replicate that of equation (5).

$$CostOverrun_{predicted} = -3.368 + 0.313 * RipRapPlacementandMaterial \quad (5)$$

The equation for Model 2 would replicate that of equation (6).

$$CostOverrun_{predicted} = 10.550 + 0.248 * RipRapPlacementandMaterial + 0.111 * FilterFabric \qquad (6)$$

What equation (5) and (6) show is the relationship between the independent variable(s) and the dependent variable. In plain terms, these equations tell the amount of increase in cost overruns dependent upon a 1 unit increase in the predictors, also known as Rip Rap and Filter Fabric. Equation (5) can be best represented to say that for every 1 unit increase in Rip Rap Placement and Material variance, an approximately 0.313 increase in cost overruns is expected. For every 1 unit increase in equation (6) for Rip Rap and Filter Fabric variance, an increase of approximately 0.248 and 0.111, respectively, can be expected for cost overruns.

Discussion

With the linear equations previously mentioned, the Corps of Engineers should take action in reducing these coefficient values. This could be done by performing deeper studies into Section 14 projects and dissecting how the contractor estimated the job, their actual performance on site, and how those two outcomes vary. This type of study would provide the Corps of Engineers with an insightful tool that could save their projects money. On the other hand, the Corps of Engineers could also perform studies on the way the government is estimating these Section 14 jobs. This study could examine the methods that each cost engineer is considering in their estimate and base them upon the findings of the previously mentioned study. With the execution of both previously mentioned possibilities, it could be proposed that the accuracy of future estimates and reduction of cost overruns could be drastically improved.

CHAPTER 5: DISCUSSION AND CONCLUSION

The U.S. Army Corps of Engineers' Section 14 Emergency Streambank Protection projects are designed to assist local city and state agencies with funding for areas where the streambank is failing. Section 14 projects come with a $5 million limit that the federal government can spend per project. This amount includes labor, studies, and construction. With this small amount, these projects carry higher uncertainties because in depth studies at the site cannot be performed. Skipping these studies results in higher design and cost estimate contingencies. With these contingencies in place, the Corps of Engineers' cost estimates are subject to many inaccuracies as a wide range of assumptions are made.

In efforts to combat this, this study set out to analyze the contractor's actual cost, essentially what the government paid the contractor upon completion of the work, versus what the government estimated the cost to be. This analysis was performed on fourteen Section 14 projects along two regions in the United States, the Appalachian and Midwest region. Individual bid items for each project were pulled into a spreadsheet and the percent difference between the contractor's actual costs and the government's estimate was used as a data point. As was previously stated in Chapter 3, not all projects had the same type or same amount of bid items. In total, there were 68 different bid items across the 14 projects. In order to make the data collection and analyzing process less confusing, the researcher utilized the CSI MasterFormat, which is a format to group bid items into more generalized terms. Through this grouping process, the researcher was able to visually see the number of projects that had a particular amount of bid items.

With the data collected and understood, the researcher exported the data to SPSS and ran linear regression models to indicate which predictors were attributing to the cost overruns. With missing data causing an issue, the researcher used SPSS's built in multiple imputation tool to generate five imputations and select the most accurate through automatic linear regression modeling. Through the analysis, it was found that two predictors could be directly related to causing cost overruns. These two bid items were Rip Rap Placement and Material and Filter Fabric. The model summary stated that 65.8% of the variance in fourteen Section 14 projects could be predicted from the variable Rip Rap Placement and Material, and that 78.4% of the variance could be attributed to both Rip Rap Placement and Material and Filter Fabric.

Looking at the results of the linear regression model and applying them to future Corps of Engineer's practices. It should be said that placing more focus on correctly designing and estimating the amount of stone needed to armor the bank would be a step in the right direction to lowering these variances. Moving forward, cost engineers need to ensure to place extra emphasis on these two bid items when generating their estimates. Some steps to improve the estimated amount of these two bid items would be to continually reach out to stone quarries and ensure the most accurate price is being received. This should be done for four to five vendors in order to feel assured that the best price is in their estimate. Another idea to improve the estimating of these two items is to have entry-level and student cost engineers be on the site of active Section 14 projects. While on site, these team members could complete timed evaluations of how the contractor is completing the construction of the filter fabric and placing the stone. By doing this, an accurate reading of the actual crew output can be reported back for use. These engineers on site could also document the methods the contractor is using to place the stone or construct the filter fabric. These methods include, but are not limited to, the amount of people they assign to each crew, whether the filter fabric is constructed by hand or with a machine, and whether the stone is placed by machinery on land or machinery on a floating plant. All of these scenarios are often uncertainties in cost estimates, therefore, if the proper homework is completed up front, future estimates will undoubtably benefit.

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APPENDIX A-1 PROJECT DATA

Project	PaymentandPerformanceBond	Mobdemob	Survey	QualityControlOfficer	SiteSafetyOfficer
1	-38.45%	-6.71%	58.79%	-97.75%	-88.70%
2	-46.42%	-57.28%	-149.75%	-97.75%	-88.70%
3	-16.17%	-87.14%	33.70%	-97.75%	-88.70%
4	-18.80%	-359.24%	-34.67%	-97.75%	-88.70%
5	-35.44%	-6.68%	12.57%	-97.75%	-88.70%
6	-18.43%	93.44%	-18.32%	-97.75%	-88.70%
7	-17.89%	-48.57%	-16.47%	-97.75%	-88.70%
8	-68.83%	-18.37%	2.38%	-97.75%	-88.70%
9	-0.86%	-22.05%	14.24%	-97.75%	-88.70%
10	-185.71%	11.60%	10.27%	-97.75%	-88.70%
11	-55.92%	73.69%	56.89%	-97.75%	-88.70%
12	-43.18%	-26.74%	-16.02%	-97.75%	-88.70%
13	-47.67%	-20.60%	-11.52%	-97.75%	-88.70%
14	-31.97%	73.38%	-13.28%	-97.75%	-88.70%

Project	TemporaryOffice	GeneralConditions	DigitalProgressImages	SiteSecurity	PersonnelSwingG
1	100.00%	22.42%	-210.45%	-41.20%	43.55%
2	100.00%	22.42%	-186.67%	-41.20%	43.55%
3	100.00%	22.42%	-214.37%	-41.20%	43.55%
4	100.00%	22.42%	-202.36%	-41.20%	43.55%
5	100.00%	22.42%	-180.89%	-41.20%	43.55%
6	100.00%	22.42%	-181.20%	-41.20%	43.55%
7	100.00%	22.42%	22.58%	-41.20%	43.55%
8	100.00%	22.42%	-529.43%	-41.20%	43.55%
9	100.00%	22.42%	-29.86%	-41.20%	43.55%
10	100.00%	22.42%	-257.14%	-41.20%	43.55%
11	100.00%	22.42%	-210.21%	-41.20%	43.55%
12	100.00%	22.42%	-203.76%	-41.20%	43.55%
13	100.00%	22.42%	-193.18%	-41.20%	43.55%
14	100.00%	22.42%	-209.19%	-41.20%	43.55%

Project	VehicularSwingGate	ProtectionandMain	TrafficControl	PavementRepair	GuardrailInstallat
1	34.56%	-1073.50%	45.77%	-24.46%	-28.08%
2	34.56%	-1073.50%	10.23%	-35.68%	-28.08%
3	34.56%	-1073.50%	7.30%	-42.39%	-28.08%
4	34.56%	-1073.50%	-8.59%	-26.68%	-28.08%
5	34.56%	-1073.50%	56.85%	-20.63%	-28.08%
6	34.56%	-1073.50%	-95.73%	-26.77%	-28.08%
7	34.56%	-1073.50%	3.92%	-65.10%	-28.08%
8	34.56%	-1073.50%	1.26%	-26.17%	-28.08%
9	34.56%	-1073.50%	2.77%	7.02%	-28.08%
10	34.56%	-1073.50%	10.58%	-22.83%	-28.08%
11	34.56%	-1073.50%	2.09%	-31.84%	-28.08%
12	34.56%	-1073.50%	-9.40%	-19.21%	-28.08%
13	34.56%	-1073.50%	7.08%	-32.09%	-28.08%
14	34.56%	-1073.50%	11.86%	-20.68%	-28.08%

Project	ReplaceConcreteSectio	AsBuiltDrawings	ConcreteStairs	BituminousPavementRemoval
1	81.96%	100.00%	-80.26%	-612.82%
2	81.96%	100.00%	-80.26%	-594.53%
3	81.96%	100.00%	-80.26%	-564.39%
4	81.96%	100.00%	-80.26%	-576.37%
5	81.96%	100.00%	-80.26%	-654.85%
6	81.96%	100.00%	-80.26%	-204.87%
7	81.96%	100.00%	-80.26%	-599.70%
8	81.96%	100.00%	-80.26%	-610.91%
9	81.96%	100.00%	-80.26%	-1008.50%
10	81.96%	100.00%	-80.26%	-625.59%
11	81.96%	100.00%	-80.26%	-602.16%
12	81.96%	100.00%	-80.26%	-627.17%
13	81.96%	100.00%	-80.26%	-610.03%
14	81.96%	100.00%	-80.26%	-582.73%

Project	GuideRail	SiteDemolition	NewGuiderailandPosts	ManholeAdjustment
1	-156.54%	-1238.59%	-62.05%	-136.11%
2	-190.35%	-1238.59%	-62.05%	-136.11%
3	-189.46%	-1238.59%	-62.05%	-136.11%
4	-154.67%	-1238.59%	-62.05%	-136.11%
5	-182.04%	-1238.59%	-62.05%	-136.11%
6	-403.50%	-1238.59%	-62.05%	-136.11%
7	-179.04%	-1238.59%	-62.05%	-136.11%
8	-173.72%	-1238.59%	-62.05%	-136.11%
9	55.11%	-1238.59%	-62.05%	-136.11%
10	-181.91%	-1238.59%	-62.05%	-136.11%
11	-171.71%	-1238.59%	-62.05%	-136.11%
12	-170.52%	-1238.59%	-62.05%	-136.11%
13	-161.52%	-1238.59%	-62.05%	-136.11%
14	-183.51%	-1238.59%	-62.05%	-136.11%

Project	PrecastConcreteBlockW	ConcreteLevelingPad	ModularPreCastConcrete	GravelLevelinPad6Thick
1	38.42%	-3.16%	-29.65%	-83.29%
2	38.42%	-3.16%	-29.65%	-83.29%
3	38.42%	-3.16%	-29.65%	-83.29%
4	38.42%	-3.16%	-29.65%	-83.29%
5	38.42%	-3.16%	-29.65%	-83.29%
6	38.42%	-3.16%	-29.65%	-83.29%
7	38.42%	-3.16%	-29.65%	-83.29%
8	38.42%	-3.16%	-29.65%	-83.29%
9	38.42%	-3.16%	-29.65%	-83.29%
10	38.42%	-3.16%	-29.65%	-83.29%
11	38.42%	-3.16%	-29.65%	-83.29%
12	38.42%	-3.16%	-29.65%	-83.29%
13	38.42%	-3.16%	-29.65%	-83.29%
14	38.42%	-3.16%	-29.65%	-83.29%

Project	ConcreteforParkingPad	Aggregate	Granularbackfill	DisposalofExistingConc	AggregateBasefor
1	4.04%	-254.40%	-27.09%	-271.50%	-1062.00%
2	4.04%	-288.65%	-27.09%	-271.50%	-1062.00%
3	4.04%	-252.33%	-27.09%	-271.50%	-1062.00%
4	4.04%	-254.15%	-27.09%	-271.50%	-1062.00%
5	4.04%	-284.16%	-27.09%	-271.50%	-1062.00%
6	4.04%	-277.38%	-27.09%	-271.50%	-1062.00%
7	4.04%	-261.95%	-27.09%	-271.50%	-1062.00%
8	4.04%	-283.45%	-27.09%	-271.50%	-1062.00%
9	4.04%	-268.86%	-27.09%	-271.50%	-1062.00%
10	4.04%	-267.45%	-27.09%	-271.50%	-1062.00%
11	4.04%	-354.10%	-27.09%	-271.50%	-1062.00%
12	4.04%	-262.30%	-27.09%	-271.50%	-1062.00%
13	4.04%	-274.10%	-27.09%	-271.50%	-1062.00%
14	4.04%	-175.40%	-27.09%	-271.50%	-1062.00%

Project	SteelPlate	RemovalDisposalof30HPile	ReUsablelagging	RemovalDisposalofTimberLagging
1	-113.64%	51.96%	98.93%	5.75%
2	-113.64%	51.96%	98.93%	5.75%
3	-113.64%	51.96%	98.93%	5.75%
4	-113.64%	51.96%	98.93%	5.75%
5	-113.64%	51.96%	98.93%	5.75%
6	-113.64%	51.96%	98.93%	5.75%
7	-113.64%	51.96%	98.93%	5.75%
8	-113.64%	51.96%	98.93%	5.75%
9	-113.64%	51.96%	98.93%	5.75%
10	-113.64%	51.96%	98.93%	5.75%
11	-113.64%	51.96%	98.93%	5.75%
12	-113.64%	51.96%	98.93%	5.75%
13	-113.64%	51.96%	98.93%	5.75%
14	-113.64%	51.96%	98.93%	5.75%

Project	PressureTreatedTimber	ExcavatingSoil	ExcavatingVegetation	AccessRamp	FilterFabric
1	46.31%	-23.10%	69.78%	-53.90%	-142.67%
2	46.31%	-293.50%	69.78%	-71.50%	-88.42%
3	46.31%	-107.90%	69.78%	-59.73%	-135.99%
4	46.31%	19.97%	69.78%	-41.77%	-22.08%
5	46.31%	-47.47%	69.78%	-117.80%	-83.56%
6	46.31%	35.56%	69.78%	68.37%	-10.76%
7	46.31%	50.55%	69.78%	-51.22%	-119.98%
8	46.31%	32.34%	69.78%	-38.55%	-6.24%
9	46.31%	-49.90%	69.78%	-60.08%	-288.19%
10	46.31%	-36.41%	69.78%	-132.29%	-277.72%
11	46.31%	-79.30%	69.78%	-62.34%	-116.05%
12	46.31%	-32.27%	69.78%	-58.62%	-135.48%
13	46.31%	64.62%	69.78%	-59.24%	-127.54%
14	46.31%	-60.67%	69.78%	-41.66%	-305.56%

Project	Siltfence	ClearingandGrubb	SoilFabricMatlPlacem	ExcavatingStoneFlumes
1	-39.21%	22.71%	-125.78%	-76.91%
2	-43.73%	32.15%	-141.90%	-76.91%
3	-34.65%	31.25%	63.07%	-76.91%
4	-21.36%	-11.62%	-131.46%	-76.91%
5	-136.55%	62.47%	-109.57%	-76.91%
6	90.85%	-9.20%	-185.18%	-76.91%
7	58.97%	96.30%	-134.52%	-76.91%
8	42.98%	25.85%	-122.81%	-76.91%
9	-118.10%	40.03%	19.66%	-76.91%
10	-104.31%	67.46%	-149.42%	-76.91%
11	-70.15%	-38.01%	-124.82%	-76.91%
12	-37.82%	66.44%	-152.23%	-76.91%
13	-58.22%	42.58%	-128.04%	-76.91%
14	-34.77%	26.97%	-483.49%	-76.91%

Project	VegetativeSlopeProtection	ShapingBankline	SelectBackfill	SuitableSoilBackfill	TopsoilBackfill
1	-66.27%	37.94%	57.27%	75.09%	24.28%
2	-66.27%	45.68%	57.27%	75.09%	24.37%
3	-66.27%	17.70%	57.27%	75.09%	12.63%
4	-66.27%	26.55%	57.27%	75.09%	19.91%
5	-66.27%	21.67%	57.27%	75.09%	20.35%
6	-66.27%	27.25%	57.27%	75.09%	18.63%
7	-66.27%	26.50%	57.27%	75.09%	8.99%
8	-66.27%	39.85%	57.27%	75.09%	60.96%
9	-66.27%	37.55%	57.27%	75.09%	30.37%
10	-66.27%	21.00%	57.27%	75.09%	15.59%
11	-66.27%	-0.54%	57.27%	75.09%	-16.86%
12	-66.27%	57.31%	57.27%	75.09%	28.93%
13	-66.27%	29.17%	57.27%	75.09%	31.51%
14	-66.27%	26.98%	57.27%	75.09%	13.40%

Project	CoirFiberLog	ErosionControlBlanket	Seeding	Shrubs	SiteRestoration	RepairofDamagedTurf
1	58.74%	21.31%	-70.45%	-67.63%	-613.03%	-32.28%
2	58.74%	21.31%	-48.61%	-66.27%	-613.03%	-32.28%
3	58.74%	21.31%	-52.56%	-82.07%	-613.03%	-32.28%
4	58.74%	21.31%	-35.94%	-71.56%	-613.03%	-32.28%
5	58.74%	21.31%	35.01%	-83.26%	-613.03%	-32.28%
6	58.74%	21.31%	-69.37%	-69.70%	-613.03%	-32.28%
7	58.74%	21.31%	-51.73%	-54.55%	-613.03%	-32.28%
8	58.74%	21.31%	-37.07%	-69.15%	-613.03%	-32.28%
9	58.74%	21.31%	38.56%	64.31%	-613.03%	-32.28%
10	58.74%	21.31%	-41.48%	-203.03%	-613.03%	-32.28%
11	58.74%	21.31%	38.32%	-51.98%	-613.03%	-32.28%
12	58.74%	21.31%	-47.48%	-65.04%	-613.03%	-32.28%
13	58.74%	21.31%	-122.82%	-51.46%	-613.03%	-32.28%
14	58.74%	21.31%	-160.36%	-56.50%	-613.03%	-32.28%

Project	ChainLinkFence	RipRapPlacementandMaterial	GroutingStabilizaiton	PipingInstall	HeadwallsInstalla
1	39.09%	16.44%	54.59%	24.06%	-25.96%
2	34.42%	3.83%	33.00%	35.07%	18.32%
3	41.10%	4.06%	-3.43%	80.68%	78.49%
4	42.95%	-20.59%	41.13%	-14.25%	-43.99%
5	39.69%	8.24%	34.17%	-4.06%	-1.68%
6	38.63%	17.48%	36.00%	87.23%	42.30%
7	27.03%	47.66%	35.33%	34.75%	8.63%
8	53.00%	13.72%	37.27%	26.51%	8.21%
9	40.69%	60.91%	33.42%	27.12%	25.99%
10	36.52%	-239.19%	28.79%	29.49%	8.41%
11	40.73%	0.40%	41.24%	-11.91%	2.00%
12	42.25%	-12.77%	33.56%	24.83%	-0.89%
13	40.20%	-25.79%	25.07%	41.34%	28.33%
14	42.98%	-64.83%	34.36%	36.77%	6.02%

Project	SetSalvagedstone	BeddingStonePlacementandMatl	RemoveandDisposeGabionBasket
1	60.37%	-87.64%	-539.55%
2	69.15%	-38.13%	-539.55%
3	70.46%	29.52%	-539.55%
4	70.46%	1.03%	-539.55%
5	65.97%	-0.84%	-539.55%
6	61.67%	23.75%	-539.55%
7	69.74%	-12.82%	-539.55%
8	66.98%	-11.67%	-539.55%
9	64.93%	32.59%	-539.55%
10	68.86%	-14.70%	-539.55%
11	62.24%	-7.55%	-539.55%
12	64.82%	-9.84%	-539.55%
13	64.88%	-35.20%	-539.55%
14	67.44%	22.68%	-539.55%

Project	TempRelocateStone	TurbidityCurtain	BypassPumping	TempWaterDiversion	DependentVariable
1	-9.33%	-57.08%	-140.56%	-315.45%	15.34%
2	-9.33%	-57.08%	-140.56%	-315.45%	-6.31%
3	-9.33%	-57.08%	-140.56%	-315.45%	18.81%
4	-9.33%	-57.08%	-140.56%	-315.45%	-8.56%
5	-9.33%	-57.08%	-140.56%	-315.45%	0.45%
6	-9.33%	-57.08%	-140.56%	-315.45%	17.45%
7	-9.33%	-57.08%	-140.56%	-315.45%	-11.07%
8	-9.33%	-57.08%	-140.56%	-315.45%	12.30%
9	-9.33%	-57.08%	-140.56%	-315.45%	-14.82%
10	-9.33%	-57.08%	-140.56%	-315.45%	-84.96%
11	-9.33%	-57.08%	-140.56%	-315.45%	-14.81%
12	-9.33%	-57.08%	-140.56%	-315.45%	13.63%
13	-9.33%	-57.08%	-140.56%	-315.45%	-4.03%
14	-9.33%	-57.08%	-140.56%	-315.45%	-40.10%

APPENDIX A-2 IRB APPROVAL LETTER

MARSHALL UNIVERSITY
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Office of Research Integrity

October 29, 2020

Hunter Waugaman
93 Division Street
Huntington, WV 25702

Dear Mr. Waugaman:

This letter is in response to the submitted thesis abstract entitled *"An Analysis of Estimated Costs Versus Actual Costs in USACE Section 14 Emergency Streambank Protection Projects."* After assessing the abstract, it has been deemed not to be human subject research and therefore exempt from oversight of the Marshall University Institutional Review Board (IRB). The Code of Federal Regulations (45CFR46) has set forth the criteria utilized in making this determination. Since the information in this study does not involve human subjects as defined in the above referenced instruction, it is not considered human subject research. If there are any changes to the abstract you provided then you would need to resubmit that information to the Office of Research Integrity for review and a determination.

I appreciate your willingness to submit the abstract for determination. Please feel free to contact the Office of Research Integrity if you have any questions regarding future protocols that may require IRB review.

Sincerely,

Bruce F. Day, ThD, CIP
Director

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