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The Impact of Mechanical & Plumbing Change Orders on USACE Construction Projects

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This research studied contract change orders at five U.S. Army Corp of Engineers (USACE) Districts over the past twenty-one years with a combined value of $3,689,742,841. These districts represent a broad spectrum of federal contracting across the entire United States and every type of construction contract from major military projects to minor repair work to national civil infrastructure. Of the 44,887 contract changes studied, 4,061 were identified as specifically related to the Mechanical and Plumbing trades. These changes were evaluated for magnitude, frequency and time extension. The Mechanical and Plumbing trades were selected because they are typically among the last major construction features prior to the completion date. Previous research estimates that change orders in the last 20% of a project timeline should be weighted 6 times more heavily than change orders in the first 20% (Hanna et al., 1999). The results indicate that Mechanical and Plumbing change orders do have a higher likelihood of extending the timeline of a project. It also showed that the dollar value impact was relatively low compared to other changes. Ultimately the database of contract changes generated during this research could provide a critical data source for future studies, particularly of federal construction contracting.

Key Words: Change Order, Modification, Mechanical, Plumbing, Federal Contracting

Introduction

In the high-stakes world of construction management everyone hates change orders. These contract changes become even more odious when they occur near the end of a project. Usually at this point the entire project budget is obligated and the occupancy date is imminent. Two of the trades with the largest potential for impact at the end of a project are the Mechanical and Plumbing trades. This research seeks to analyze the magnitude, frequency, and time impact of these types of change orders.

By determining the actual trends in Mechanical and Plumbing change orders we can better understand their impact and develop mitigation strategies. The purpose is to understand the actual statistical frequency of Mechanical and Plumbing change orders on USACE construction contracts to see if there are any strong correlations or tendencies. This work will provide the groundwork necessary to study specific situations and potential solutions for late-stage construction changes.

Measuring the cost and time extension of a very large number of Mechanical and Plumbing contract changes will identify possible correlations that should be further studied to improve end-of-project efficiency. Ultimately, this research could reduce late changes to construction contracts and therefore significantly reduce frustration associated with contract closeout. Previous research shows that design changes and schedule delay (delays caused by others) are the two greatest contributors to project delays (Asmi et al., 2019). This work will seek to identify the underlying factors and see which types of changes are causing the delay.

Data and Terminology

The data for this research comes entirely from U.S. Army Corps of Engineers (USACE) projects. These projects represent nearly all change orders from the 21-year period of 2002 to 2022. Research was limited to five USACE districts: Baltimore, Ft. Worth, Louisville, Seattle and Wilmington. These districts each have significant Military Construction (buildings) and Civil Works (infrastructure) projects and represent a cross-section of the entire continental United States. The result is a comprehensive review of over 44,000 construction change orders. This research will use the common term “change order” throughout. In federal contracting, change orders are more frequently known as “contract modifications” or as “change requests”.

Defining a Change Order

It is important to understand what is considered a change order and how it may differ across the construction industry. Broadly speaking, a change order is any change to a construction contract after the original award of the contract to a contractor or subcontractor. However, this general definition quickly runs into nuances and caveats. A more specific definition would be any material change to a construction contract that causes a change in cost, time or final product.

The federal contracting used in this research has two fundamental types of change orders that can generally be categorized by the approval authority: either Contracting Officer or Administrative Contracting Officer. Contracting Officers typically sign the original agreement between the United States Government and a Prime Contractor. This agreement for construction services (a built product) in exchange for money is called the contract. Contracting Officers also sign contract modifications that are primarily administrative in nature. These include: Notice-to- Proceed, award of contract options, funding updates and any clerical changes. Finally, if a change order during construction exceeds the authority of the Administrative Contracting Officer, then the Contracting Officer can sign. This research seeks to eliminate the administrative types of change orders from consideration, while still retaining any true material changes that may be signed by a Contracting Officer.

Administrative Contracting Officers (ACO) can sign change orders up to an absolute value of $500,000. These change orders are almost always true material changes to the contract. The ACO is the primary signature authority for construction changes that happen after Notice-to-Proceed. The ACO is typically a supervisor with direct involvement on the specific project. Although it is possible for a change order to be approved quickly, the nature of federal contracting tends to result in an extended approval period. This is critically important because construction is very dependent on scheduling and sequencing. An unapproved or delayed change order can significantly impact project duration and cost. This issue has even been brought before the U.S. Congress because of how badly it can affect small contractors even to the point of bankruptcy. (*All Work and No Pay*, 2017)

This research will only address the change orders between USACE and a prime contractor that are signed by the Contracting Officer or the Administrative Contracting Officer. It will not address the numerous changes between prime contractors and subcontractors. It will also not address any unwritten changes or "trades" that can happen during contract performance.

Literature Review

Michael T. Callahan developed an excellent resource for change orders titled "Construction Change Order Claims" (Callahan, 2005). One of his key points is that changes must be "identified and corrected early, when changes cost little or nothing, before the project moves into the high-spending procurement and construction phases". Given the high priority on identifying changes early, this research on mechanical and plumbing changes seeks to identify the types of changes that typically happen late in a project so that they can be avoided.

In James O'Brien's book "Construction Change Orders: Impact, Avoidance, Documentation", he states "Experienced contractors know that there will be unforeseen conditions and unexpected situations for which time extensions will be allowed. The contractor also expects changes on the part of owners and anticipate that either the owners will relax end dates, or, if need be, they will successfully handle any delay claims by the owners." (O'Brien, 1998).

Jieh-Haur Chen and S.C. Hsu developed an Early Warning System (EWS) has been developed to identify change orders with the greatest likelihood of resulting in court claims. Their recommendation is that relatively small projects have a higher probability of costly claims. These small projects tend to get less attention, have less detailed plans and the bidding process is less thorough. They state that "owners and contractors should pay more attention if their projects are relatively smaller (<1 million dollars)". (Chen & Hsu, 2012)

During this review of available information, it was determined that much of the data relies on surveys or a relatively small sample size of change orders. One example of this is a study done for the Illinois Department of Transportation (IDOT). The introduction states that the value of construction change orders in the United States is between $76 billion and $152 billion. However, the study goes on to review just 50 change orders as it seeks to identify root causes that will aid in the management of change orders. (Assaad et al., 2022) Ultimately the IDOT study identified the number one cause of change orders as "Contract Administration" at 28% and found that only 8% were due to design changes and 10% to differing site conditions.

One thing that stands out is the importance of timing in construction changes. Evidence that late changes are particularly troublesome includes an article titled "The impact of change orders on mechanical construction labour efficiency". The authors used a quantitative model to prove that projects with schedule impacts cause a significant decrease in labor efficiency and showed that the later the change occurred in the schedule the greater the decrease in efficiency (Hanna et al., 1999). This means that mechanical and plumbing contractors have the most to lose when projects get delayed.

One resource even goes so far as questioning whether construction contractors can predict and take advantage of potential change orders. A study done at Purdue University and Ball State University reviewed 30 California Department of Transportation (Caltrans) projects that had unit-priced line items. They proved that "more than 70% of the items with final quantity more than estimated ones were priced higher than average by the contractor." (Shafaat et al., 2016).

Additional research on labor efficiency has developed a model for predicting impact for the mechanical trades. (Hanna et al., 2002) One of the key elements in this model is a factor called "Percent Design Changes". This factor uses a ratio of change order types: mechanical vs. all change orders. The larger the ratio of mechanical changes to total changes, the larger the potential impact. The bottom line is that with all other factors held constant, the ratio of change orders determines the probability that impact is happening on a project by approximately 23%. This model could be used in conjunction with this research to more accurately identify and resolve potential impacts before they occur. If we can identify the particular types of changes that are happening in the mechanical and plumbing trades, then we can lower the ratio and reduce the probability of impact. This in turn will improve labor efficiency.

Research Methodology

The design for this research was to gather a very large volume of historical construction change order data and perform trend analysis. The analysis consisted of two basic phases. Phase One sorted and processed 100% of all construction change orders. This phase included a preliminary trend analysis to determine the ratio of Mechanical and Plumbing changes to the total of all changes. Phase Two looked closer at the Mechanical and Plumbing changes only to determine any specific trends related to contract impact that vary from baseline of all changes.

This research is focused on a specific set of construction change orders for which data is available in the USACE *Resident Management System*. This system is known as RMS 3.0 and has been in use by USACE since the late 1990's. However, it really became widespread and fully implemented for construction contract change orders around 2002. This software program is a database of construction contracts between the federal government (USACE) and many prime contractors that meet the standards required to bid on federal work. All Contracting Officer change orders involving time or money and all ACO change orders are required to be recorded in the RMS system. One change order in the RMS system may represent multiple discreet contract changes, but typically they are one-to-one.

The database is organized by USACE district and by specific contract number. This number is typically a 13-digit number consisting of a six-digit district identifier, a two-digit fiscal year, a letter, and a four-digit number. Modifications to contracts are identified by up to six digits but are typically in the form "P00001" for Contracting Officer changes and "A00001" for ACO changes.

Phase One data gathering consists of running a summary report at the USACE District level for all "completed" change orders. The title of the report is "Construction Contract Modifications". This report is generated in Microsoft Excel. Since the report uses database-specific language and formatting, the result is a text field of all the relevant modification data. It is then necessary to process the data using several Excel formulas to create a sortable list of numerical values. In Phase One, it is not necessary to know the specific contract or even the specific timing within the contract. The key data points during this phase are the value in dollars and the time in days. This data will then be further refined by identifying which change orders are specifically related to Mechanical and Plumbing trades. Finally, the data will be scrubbed to remove any purely administrative changes. In this final step, only two types of changes will be removed: Contract Options since they should be considered part of the original contract, and administrative changes with a $0 value and 0 days in time.

Phase Two data gathering consists of identifying and reviewing the Mechanical and Plumbing changes only and comparing the magnitude, frequency, and time extension to the larger body of all

change orders. In this phase we are seeking to identify any statistically significant trend that shows a variation in these change orders. The large volume of data should provide a clear and measurable outcome if the Mechanical and Plumbing changes are truly different. This phase will use a variety of charting strategies to see whether any variations can be observed.

As mentioned in the introduction, none of the data being collected represents change orders between the prime contractor and the subcontractors. The bottom line is that change orders between the owner and the prime contractor are more significant than those with subcontractors because they represent an actual change to the firm-fixed-price agreement. A prime contractor is generally not permitted to pass cost increases or delays to the owner if there is no change to the contract. However, between prime contractors and subcontractors many things are negotiable and could be subject to these types of change orders even if the original contract with the owner is unchanged.

Data Collection and Analysis

Data collection started with RMS database reports for change orders on 11 May 2022. These reports included all the change orders from 2002 to the report date in 2022. This data collection assumes that all contract changes during this period were correctly recorded in the RMS system. This assumption is highly likely because this system is also used to make payments on USACE construction contracts, which cannot happen if the underlying financial data does not match across all systems.

The data initially formed five distinct MS Excel reports, one for each district. Due to the text-style formatting, multiple administrative formulas needed to be used to refine the data to true numbers-based spreadsheets. The title of each modification was retained so that it could be located later for the purposes of future research. The initial set of data returned a total of 44,887 construction contract change orders. This includes contract options, administrative changes, $0 changes as well as every true construction change. Table 1 shows theses totals organized by the dollar value magnitude of the change. This phase of the research is sorted by arbitrary dollar magnitude categories to try to show the frequency of each type of change order Figure 1 demonstrates this.

This initial dataset had some fascinating statistics. Here is a brief overview of some of the highlights. The total absolute value of these change orders was $3,689,742,841.14. The total contract increase came in at just under $3.5 billion. The average cost per change order was $82,200.70.

The impact on the contract duration was also significant. This data represents a total increase of 571,521 days to these federal contracts. Of all the change orders 9,496 had time extensions representing 21% of all changes. The average time extension on changes that included time was 60 days. This two-month extension marks a significant impact on the overall completion schedule. Prior to the start of the project, government management teams typically allow a move-in schedule approximately 90 days after contract completion. This means that the average individual time extension modification is using up two thirds of that buffer.

Table 1

Initial Data Set of Contract Change Orders

Magnitude	Baltimore	Ft. Worth	Louisville	Seattle	Wilmington	Total
$1M+	50	218	209	21	98	596

$500k - $1M	53	187	219	19	65	543
$100k - $500k	517	1,281	1,672	232	352	4,054
$50,000 - $100k	480	1,123	1,656	234	228	3,721
$25,000 - $50,000	551	1,357	2,161	222	245	4,536
$10,000 - $25,000	801	1,815	3,426	268	349	6,659
$5,000 - $10,000	571	1,209	2,358	135	186	4,459
$1 - $5,000	780	1,785	3,742	117	207	6,631
Equal to $0	454	4,056	3,671	202	767	9,150
$0 to ($50,000)	322	1,008	1,691	130	190	3,341
($50,000) to ($500k)	111	432	363	70	139	1,115
($500k)+	7	30	13	5	27	82
Total	4,697	14,501	21,181	1,655	2,853	44,887

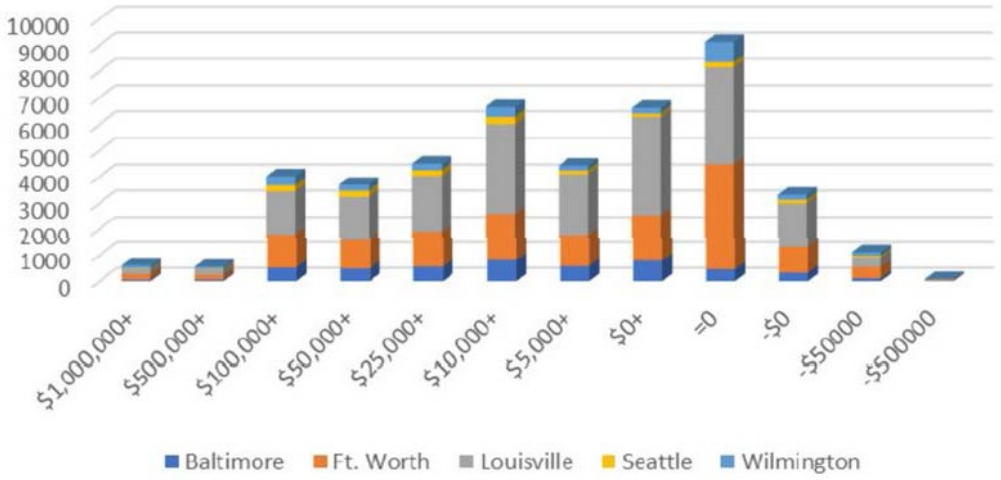

Figure 1. Change Order Frequency and Magnitude

After compiling the initial dataset, the data was reviewed to isolate the change orders that were specifically related to Mechanical and Plumbing. The first step in this process was to eliminate as many of the administrative change orders as possible. Almost all Contract Options were eliminated. These are priced with the original contract bid proposal and should be considered part of the original contract award. Additionally, almost all change orders with a $0 value and 0-day time extension were removed. However, some change orders in this category were retained if they were specifically related to Mechanical or Plumbing work. The goal with this was to eliminate as many purely administrative changes as possible.

The second step involved manually searching through the data for change orders that were most likely specifically related to Mechanical and Plumbing. This review and searching process required judgement and construction contracting experience. For example, a change titled “AHU piping” would make the list, but one titled “AHU structural support” would not. The difference being that second example involves the building structural trades and would typically not involve the mechanical subcontractor. The primary method of this research was key-word searches throughout the entire data

set. Table 2 provides a list of all key words and abbreviations that were used to refine the data.

Table 2

Key Words Used to Refine the Data

Mech*	Plumb*	Exhaust	Fan	Vent	Heat	Cool
Valve	Water	Duct	Gas	Condensate	Sprinkler	Fire
Louver	Chiller	Pip*	AHU	ACCU	VAV	BCU
FCU	MAU	BMS	DDC	MEP	HVAC	

The refined set of data returned a total of 4,061 construction contract change orders specifically related to the Mechanical and Plumbing trades. This means that for federal contracting 9% of all contract changes are specifically Mechanical or Plumbing related. The data by district is summarized in Table 3 and Figure 2.

At this point, we noticed that the most frequent change order type in the full set was equal to $0. These administrative changes dominate the first graph, but in the M&P graph they are one of the smaller totals. We also see that the M&P change orders with by far the greatest frequency are also very small changes. The first is the set ranging from $1 to $5,000 and the second is the set ranging from $10,000 to $25,000. This is an early indication that the M&P change orders might consist largely of very small changes.

The M&P-specific dataset also provided statistics that were important because they showed clear differences from the larger group of change orders. The total absolute value of these change orders was $194,362,596.86. The total contract increase came in at just over $181 million. This represents a small fraction of the $3.5 billion. The average cost per change order was $47,860.77.

Table 3

Refined Data Set of Contract Change Orders

Magnitude	**Baltimore**	**Ft. Worth**	**Louisville**	**Seattle**	**Wilmington**	**Total**
$1M+	3	14	2	0	1	20
$500k - $1M	1	7	7	3	2	20
$100k - $500k	61	88	121	46	16	332
$50,000 - $100k	64	116	130	39	5	354
$25,000 - $50,000	96	156	225	48	11	536
$10,000 - $25,000	183	222	356	60	18	839
$5,000 - $10,000	96	159	251	27	22	555
$1 - $5,000	119	226	440	28	11	824

Equal to $0	23	182	64	7	3	279
$0 to ($50,000)	30	80	109	14	6	239
($50,000) to ($500k)	16	28	14	1	0	59
($500k)+	0	2	1	1	0	4
Total	692	1,280	1720	274	95	4,061

The impact on the contract duration was also significant. This data represents a total increase of 41,447 days. Of all the M&P change orders 15% had time extensions included for a total of 610 discrete changes. The average time extension on changes that included time was 68 days.

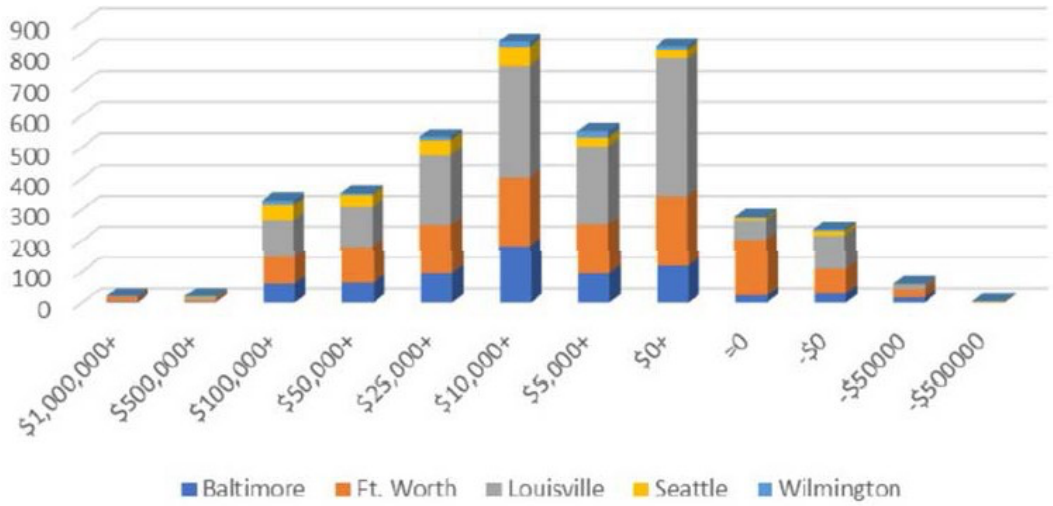

Figure 2. Mechanical & Plumbing Change Order Frequency and Magnitude.

The first comparison review of all the data was not as satisfactory as expected. Especially when analyzing the cost information, it became clear that the M&P data closely mirrored the rest of the data. When plotting all change orders, there is a much higher frequency of "small" change orders and much greater impact from a few "large" change orders. As a result, the research was modified slightly to create change order groupings that best represented equal dollar value magnitudes. The basic approach was to take the total increase amount of $3.5 billion and divide it into 15 equal groups of approximately $228 million each. The "equal value" method stays close to the $228 million target in almost all categories except the range from positive $5,000 to negative $35,000. The absolute value of all the changes in this range is only 20% as much as the target value simply due to the very small values being tracked. Using this method resulted in the categories and results shown in Table 4.

A very important statistical result came from this method of data organization. For M&P change orders, almost half (49%) are found in the 4 groupings from $5,000 to $225,000. In comparison to the full list which has only 26% of the total in these same groupings. In the full list, the top four categories equal 0.5% of all the changes but represent 25% of the total value. To get to the same 25% value mark for the M&P changes you would need the top eight categories and 1% of all the changes.

Table 4
Change order groupings that best represented equal dollar value magnitude

Magnitude	Full Count	M&P Count
$7M - $10M	27	0
$5M - $7M	37	0
$3.5M - $5M	55	0
$2.5M - $3.5M	91	5
$1.75M - $2.5M	118	2
1.2M – 1.75M	159	6
$800k - $1.2M	276	10
$500k - $800k	399	20
$350k - $500k	629	45
$225k - $350k	966	61
$125k - $225k	1,695	139
$75,000 - $125k	2,331	221
$35,000 - $75,000	4,454	470
$5,000 - $35,000	13,438	1,691
$1 - $5,000	6,524	810
Equal to $0	9,150	279
$0 to ($35,000)	3,061	221
($35,000) to ($1M)	1,477	81

In a final round of data analysis, the worst M&P change orders were analyzed by type. This stage looked at only change orders with a dollar value greater than $500,000 (exceeding the ACO authority) or a time extension greater than 180 days (significant impact to the move-in date). Over the 21-year period being reviewed, there were 101 change orders that fit this description as the worst M&P changes. They could be easily categorized into the following sets: Control Systems (DDC), Design, Gas, HVAC, 1:1 Replacement, Sewer, Sprinkler, Temporary Facilities and Water. Of these sets, the Design, 1:1 Replacement and Temporary Facilities are all changes that are likely to have happened early in the construction project. These totaled 14 of the 101 changes and most did not have a time extension. The worst M&P changes with the highest frequency were HVAC changes at 52, Water system changes at 15 and Sprinkler changes at 10.

Conclusions and Recommendations

This research shows that Mechanical and Plumbing change orders are typically a less significant problem than originally anticipated. The time extension associated with certain M&P change orders does show a measurable increase. However, the dollar value associated with these changes is surprisingly low. Mechanical and Plumbing change orders have an average price of $47,860.77 compared to $82,200.70 for all change orders. This is a statistically relevant comparison with a 42% lower dollar value. However, they have an average time extension of 68 days compared to 60 days. This 8-day increase per change order is also significant. It shows that when an M&P change order impacts a project, it is likely to have a greater time extension than other types of impacts. This analysis also shows that in most cases the M&P problems are relatively simple to correct. During the key-word search, it quickly became apparent that many of the changes were things that could be

resolved in a few days. Some very common results had titles like:*Adjust HVAC Ductwork, Replace Chiller Pump, Differing Site Condition – Water Main Location, Relocate Sprinkler Line.*.

The recommendation for all field-level on-site construction management teams is to be prepared for these common M&P changes. Prior to every project, contractors should assume that the existing water main will not be in exactly the right location and that the HVAC design will miss or inaccurately represent at least one room and that the sprinklers will have to be adjusted to match actual conditions. If these problems represent a change to the contract, then be prepared to quickly price them and provide sufficient supporting data to allow quick financial approval by the government official.

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