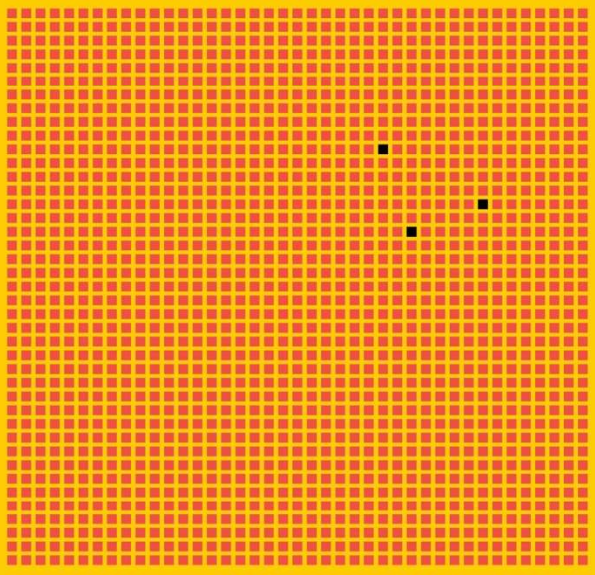
Research Note Series: Follow the Data

The Truth About Change Orders



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AIA Contract Documents

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Research Note Series: Follow the Data

The Truth about Change Orders

AIA Contract Documents *powered by Catina* has launched a large-scale text analytics effort to extract, validate, and analyze text data from their database of 11M+ construction contracts. The resulting **Construction Benchmark Database** is a comparative and predictive integrated dataset of standardized, anonymized construction contract data from a variety of sources.

Text analytics processes used were –

- ***Natural Language Processing*** to extract unstructured text from documents and convert it to structured data tables
- ***Machine Learning*** and statistical analyses to clean and validate the resulting data
- ***Artificial Intelligence*** to identify inconsistencies, errors, and omissions that increase contract risk

Change orders are generally considered to be a major driver of over-budget, over-time construction problems. This ***Research Note*** analyzes data from the **Construction Benchmark Database** to investigate the reality of that belief and to delve into trends, norms, and variations of change orders. Analyses were variously partitioned by building size, building type, and building location to ascertain if there are differences among those profiles.

Analyses addressed the questions –

- What is the average duration for a construction project?
- How many change orders are typical over the life of a project?
- When in the life of a project do change orders occur?
- What is the normal range of cost variation due to change orders?
- What is the normal range of duration variation due to change orders?
- What is the combined effect of change orders on duration and cost of a project?

Data

The Truth about Change Orders

Natural language processing was used to extract and anonymize data from 892,457 change orders and 243,120 substantial completion certifications. Resulting data were checked and cleaned using a variety of statistical and machine learning techniques. Then change orders were aggregated into projects, and only completed projects for the last ten years were selected to create an analytic dataset of 18,229 projects for this ***Research Note***.

These projects represented 22 types of buildings. Representation by type of building within the total ranged from 20.53% for Commercial/Retail projects to 3.85% for Corporate Office projects, or less. The top 9 building types and their representation are seen in Figure 1, with the remaining 13 types grouped together into 'OTHER'. (These 13 building types represented <4% each of the total.)

Figure 1. Types of Building Projects

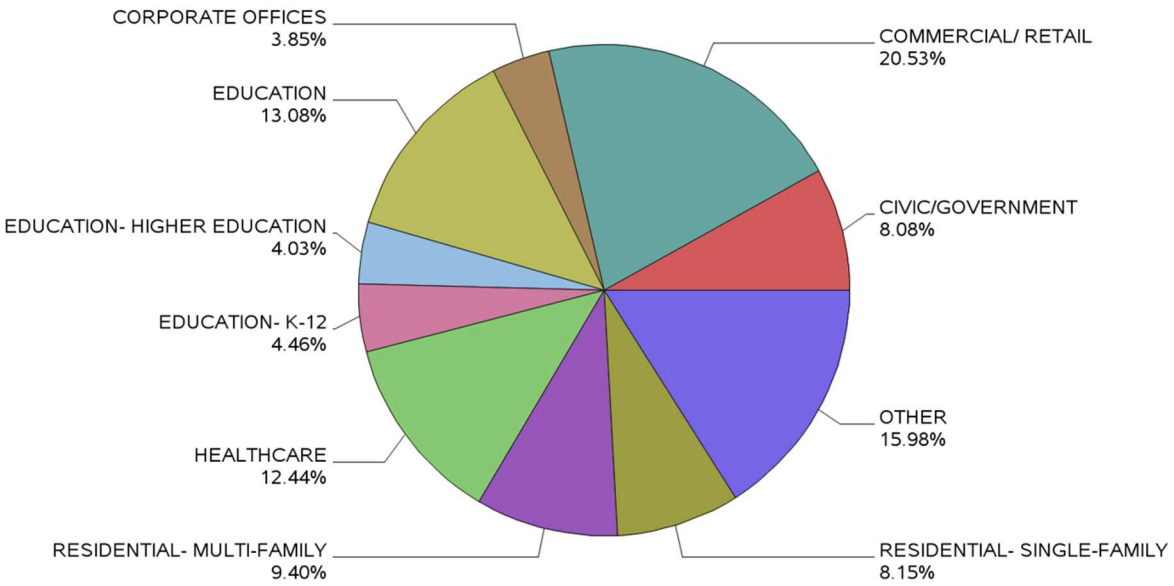
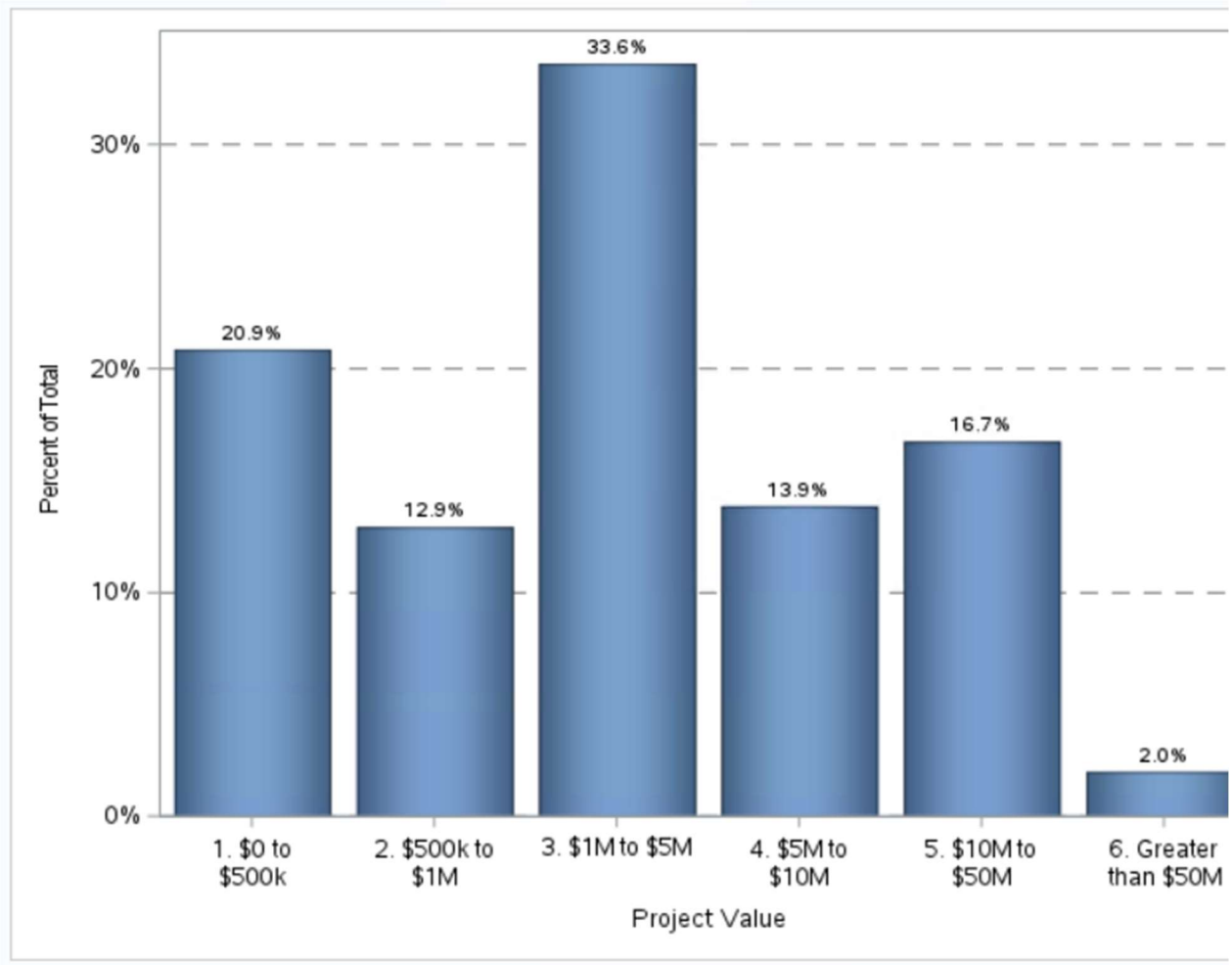


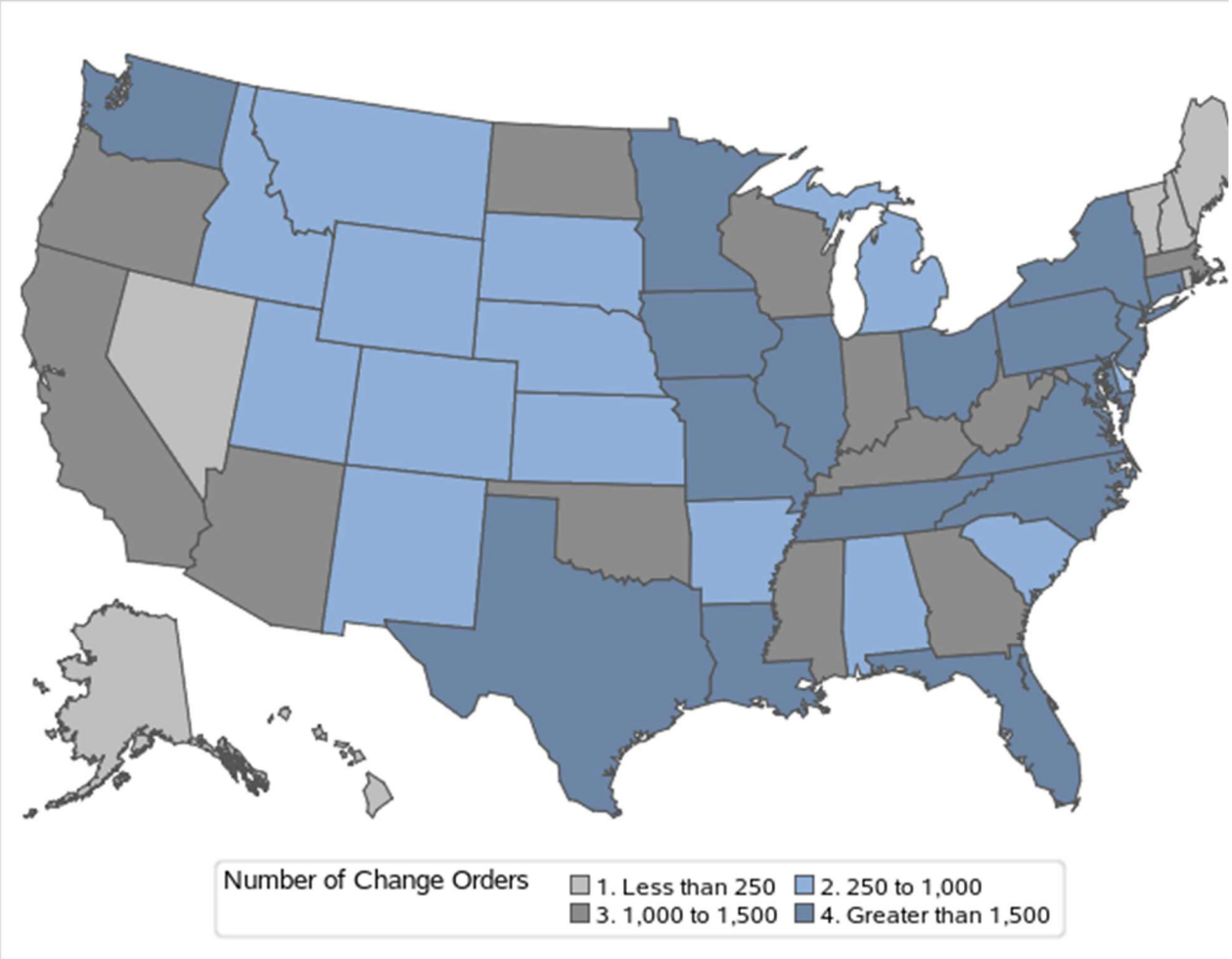
Figure 2 shows the distribution of building projects by construction project value, using the same definition and categories as the U.S. Census Bureau for their 'Value of Construction Put in Place' reports. These categories are based on the total dollar value of completed projects after all change orders have been executed. Most projects (33.61%) fell in the $1-5M range, followed by 20.86% in the $0-500k range, with the fewest projects (1.98%) in the largest category of larger than $50M.

Figure 2. Percent of Buildings by Project Value



While there are projects from multiple countries in the **Construction Benchmark Database**, this research was confined to only United States construction projects. All fifty states are well represented with the fewest change orders coming from the less populated states, as Figure 3 shows.

Figure 3. Location of Building Project Change Orders



Methodology

The Truth about Change Orders

Change orders can primarily impact projects in two ways – project duration and project cost. This research investigates the relationship between change orders and those two metrics, which is foundational for identifying opportunities to mitigate risk and building future predictive models.

Every project has a defined timeline based on the date of commencement of the project and the substantial completion date. Project teams typically report these two dates in the *A101 Standard Form of Agreement Between Owner and Contractor* and the *G704 Certificate of Substantial Completion*. This yields the number of days from start to completion of a project. For these analyses we converted the number of days in the lifetime of a project to a percent of project completion. Then change orders are measured against 'percent complete' of duration, allowing one to compare projects of varying time durations by a standardized measure. This is necessary to correctly ascertain patterns, similarities, and differences among projects of varying durations and sizes. Many analyses also segment the time duration into 10% project completion increments for clearer visualizations and discussion. It should be noted that a number of projects have change orders after the substantial completion date and are seen in analyses as '100%+'.

This research often refers to another metric known as the **Market Standard Range** (MSR). The MSR is the middle 80% of activity, whether that activity is cost or duration-based. MSR is based on percentiles, which is often used to statistically determine measures of "typical" and "atypical", "standard" and "nonstandard" behavior.

The purpose of the **Market Standard Range** is to augment the usual analytic approach of calculating a single measure (the average) with a more accurate measure when data is not normally distributed and/or there is substantial variation in the data. We found that to be the case with change orders even after considering the effect of different project values of buildings. Therefore, we trimmed the lowest 10% and highest 10% of incidences of change orders, leaving the middle 80% as boundaries of typical cost and duration and named it the **Market Standard Range**.

This is the first time such a standard has been created in the industry and is a more robust measure of typical, expected change order behavior than just an average. It is data-driven, created from a large database of construction market data - 892,457 change orders. Thus, the **Market Standard Range** provides data-driven change order transparency which can be used as the basis for substantive discussions on configuring and distributing construction projects.

Although not included in this ***Research Note***, the software version of this analyses allows users to dynamically select project profile MSR's to benchmark themselves against similar peer groups for accurate comparisons.

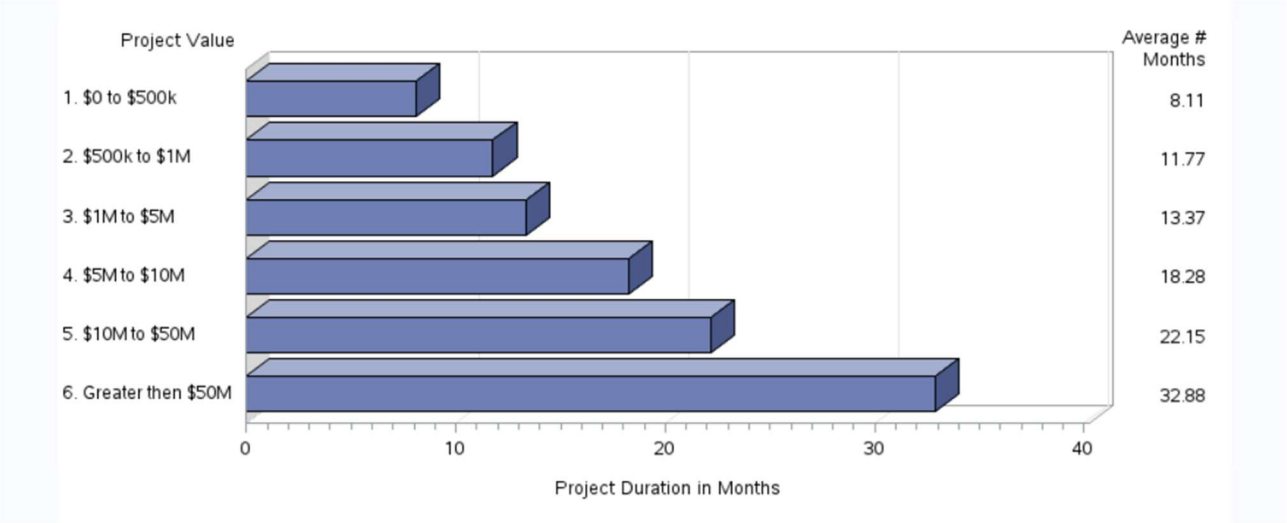
Analyses

The Truth about Change Orders

What is the average duration for a building project?

The 18,229 completed building projects in this research had an average duration of 8.11 to 32.88 months, depending upon the construction project value. Project value is divided into six categories, using the same categories as the U.S. Census Bureau for their 'Value of Construction Put in Place' reports. These categories are based on the total dollar value of completed projects after all change orders have been executed.

Figure 4. Average Duration of Projects



How many change orders are typical over the life of a project?

The average number of change orders over the duration of a project ranged from 1.7 for the smallest projects to 11.18 for the largest ones. **Average** is defined as the arithmetic mean of the total number of change orders per project.

Minimum and **Maximum** are the smallest and largest number of change orders per project respectively for each construction project value category.

The **Market Standard Range** is defined as the middle 80% of the number of change orders per project for each construction project value category. The purpose of the **Market Standard Range** is to develop a benchmark, a measure of "what is typical",

ignoring outlying extreme values. It is a standard derived directly from construction marketplace data in the **Construction Benchmark Database**.

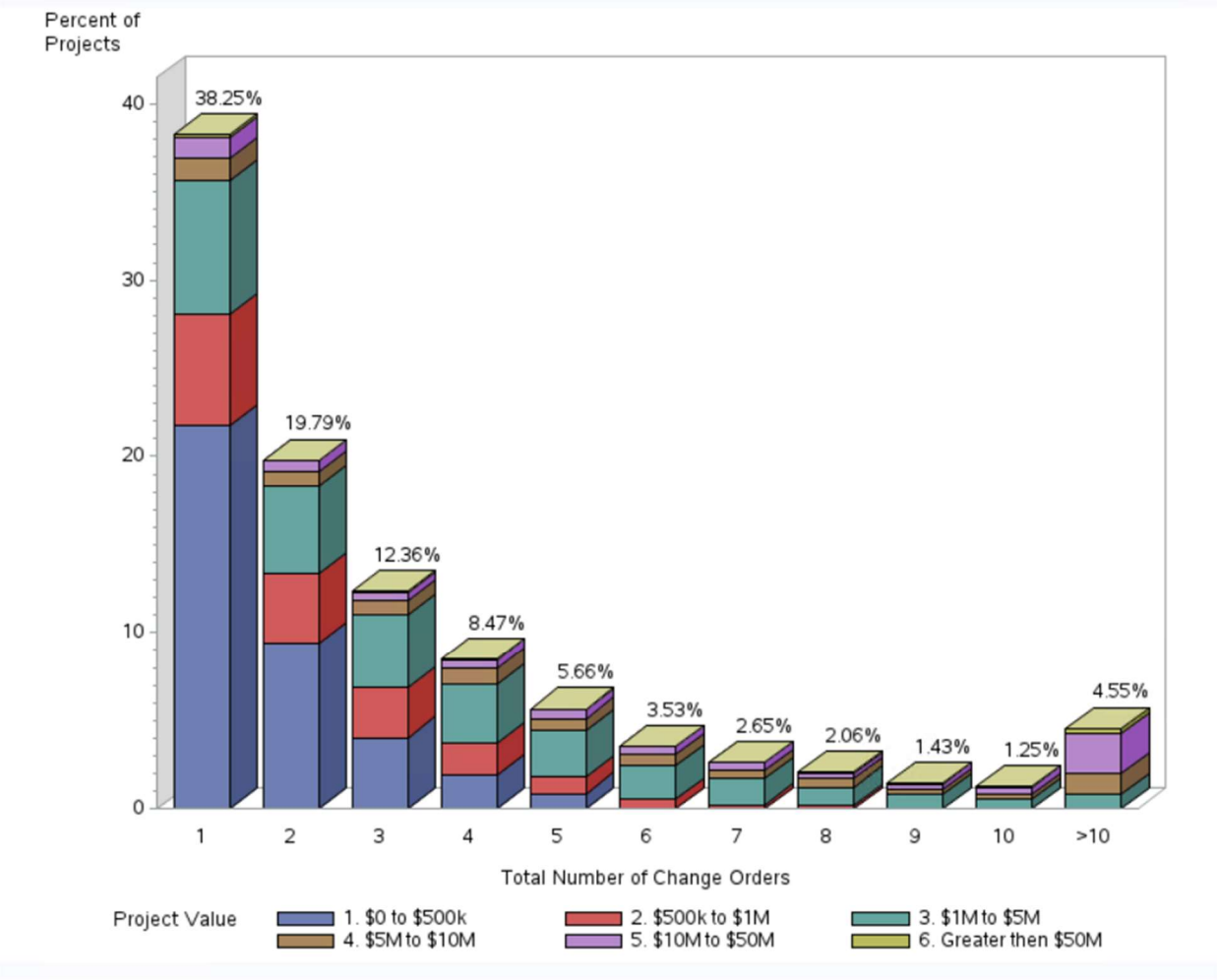
Table 1. Total Number of Change Orders per Project

Project Value	Average	Minimum	Maximum	Market Standard Range
$0 to $500k	1.70	1	5	1 - 3
$500K to $1M	2.45	1	8	1 - 5
$1M to $5M	3.73	1	13	1 - 8
$5M to $10M	5.88	1	22	1 - 13
$10M to $50M	7.93	1	29	1 - 17
Greater than $50M	11.29	1	53	1 - 27

Table 1 reports total number of change orders per project to answer the question, "How many change orders are typical over the life of a project?" Another way to answer this question is to examine the percentage of projects having only one change order, two change orders, etc., over the life of a project, as shown in Figure 5. This figure shows 38.24% of completed construction projects have only one change order over the life of the project. Likewise, 19.79% have two total change orders in total, etc.

Figure 5 also shows the subparts of each total percentage per project within each change order grouping (1,2, 3, …, up to >10). For instance, of the 38.24% of projects that had only 1 change order slightly less than 22% of those were project value '$0-500k', 6% were '$500k-1M', 7% were '$1M-5M', 1-2% each were '$5M-10M' and '10M-50M' each, and less than 1% were 'Greater than $50M'. From examining Figure 5 it is easy to see that as the percentage of projects with each number of change order groupings increases so does the percentage of larger buildings as measured by project value.

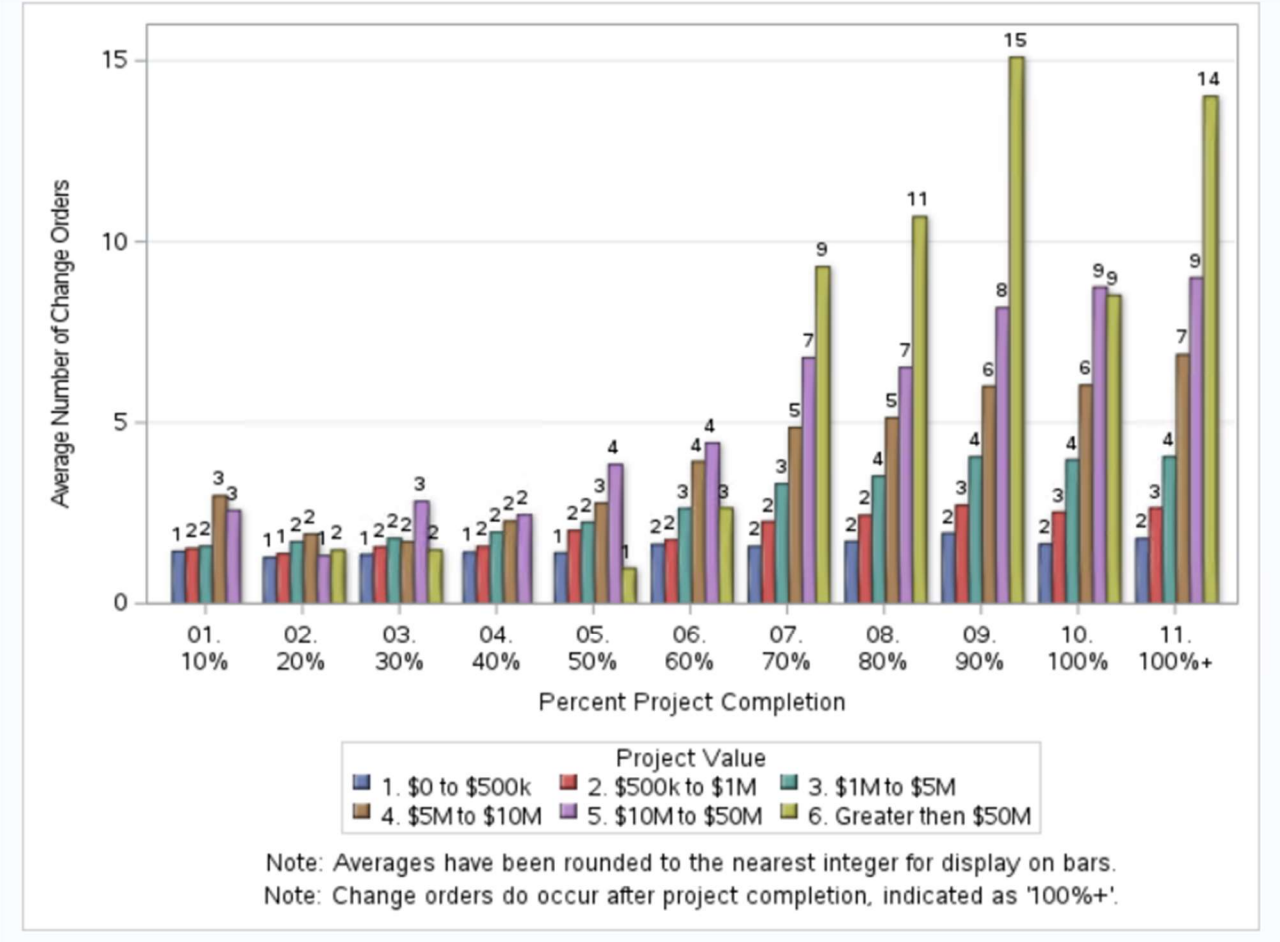
Figure 5: Total Number of Change Orders per Project



When in the life of a project do change orders occur?

Change orders occur at various times in a project, including after substantial completion date, as Figure 6 shows. This graphic also shows that most change orders occur in the final half of a project, more so for larger projects. While the average number of change orders for buildings greater than $50M in value is 11.29 overall (see Table 1) for instance, when that average is broken down across the life of a project it is clear that most change orders occur towards the end of a project. One can see that large buildings have only 1 change order on average in the first 10% of the project but gradually rises to 15 change orders on average at the 90% complete mark. The same is generally true for all project value sizes, as Figure 6 shows.

Figure 6. Pattern of Change Orders Over the Life of a Project



What is the normal range of cost variation due to change orders for a construction project?

Previous analyses examined number of change orders per project. The remaining part of this ***Research Note*** investigates effect of change orders on cost and duration of projects.

The blue line on Figure 7 shows the average percent change in cost over the lifetime of a project, where average is defined as the arithmetic mean. Average percent change starts at about 4% at the beginning of a project and rises only slightly over the life of the project, finishing at about 4% after the project is complete.

The two green lines define the upper and lower boundaries of typical variation in average cost due to change orders. Typical variation, known as the **Market Standard Range**, is defined as the middle 80% of all percent changes in cost for the 18,2229 projects in this analysis. One can see that the lower boundary is 0% until the end of a project when it actually drops slightly negative. The upper boundary shows 15% increase in cost from initial change orders at the 10% project completion mark, varies somewhat over the life of a project, but finishes at essentially the same level. The average varies only slightly between 4% and slightly more than 5% over the duration of all 18,229 projects in this study.

Figure 7. Market Standard Range of Cost Change Over the Life of a Project

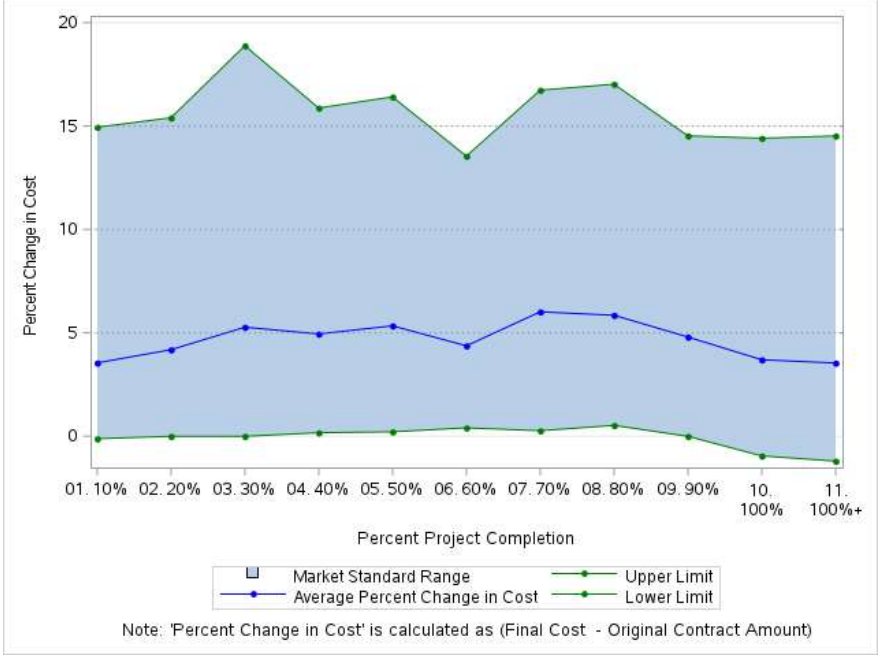


Figure 7 shows the overall percent change in cost for all project values combined. Table 2 dissects this into average percent change in cost by project value. This shows that average percent change in cost varies only slightly from 3.2% for the smallest buildings to 5.04% for $1-5M buildings. The **Market Standard Range** varies far more depending upon project value of a building; lower value buildings have approximately a 24% spread (from -8.02% to +15.88%) while all other project value categories have tighter ranges of cost variation.

Table 2. Percent Change in Cost by Project Value

Project Value	Average Percent Change in Cost	Market Standard Range - Percent Change in Cost
$0 to $500k	3.20	-8.02 – 15.88
$500K to $1M	4.36	-4.32 – 13.95
$1M to $5M	5.04	-2.39 – 15.19
$5M to $10M	4.64	-0.87 – 12.74
$10M to $50M	4.37	-1.18 – 13.17
Greater than $50M	4.60	-0.11 – 14.99

What is the normal range of duration variation due to change orders?

Likewise, when average percent change in duration by project value is examined, as in Table 3, one notices very little change in average duration across all projects, ranging from 1.07% to 1.13%. The same is true for variation in duration change, with the Market Standard Ranges varying only from a low of 0.44% for $500k-$1M project value to a high of 1.69% for $10-50M value buildings.

Table 3. Percent Change in Project Duration by Project Value

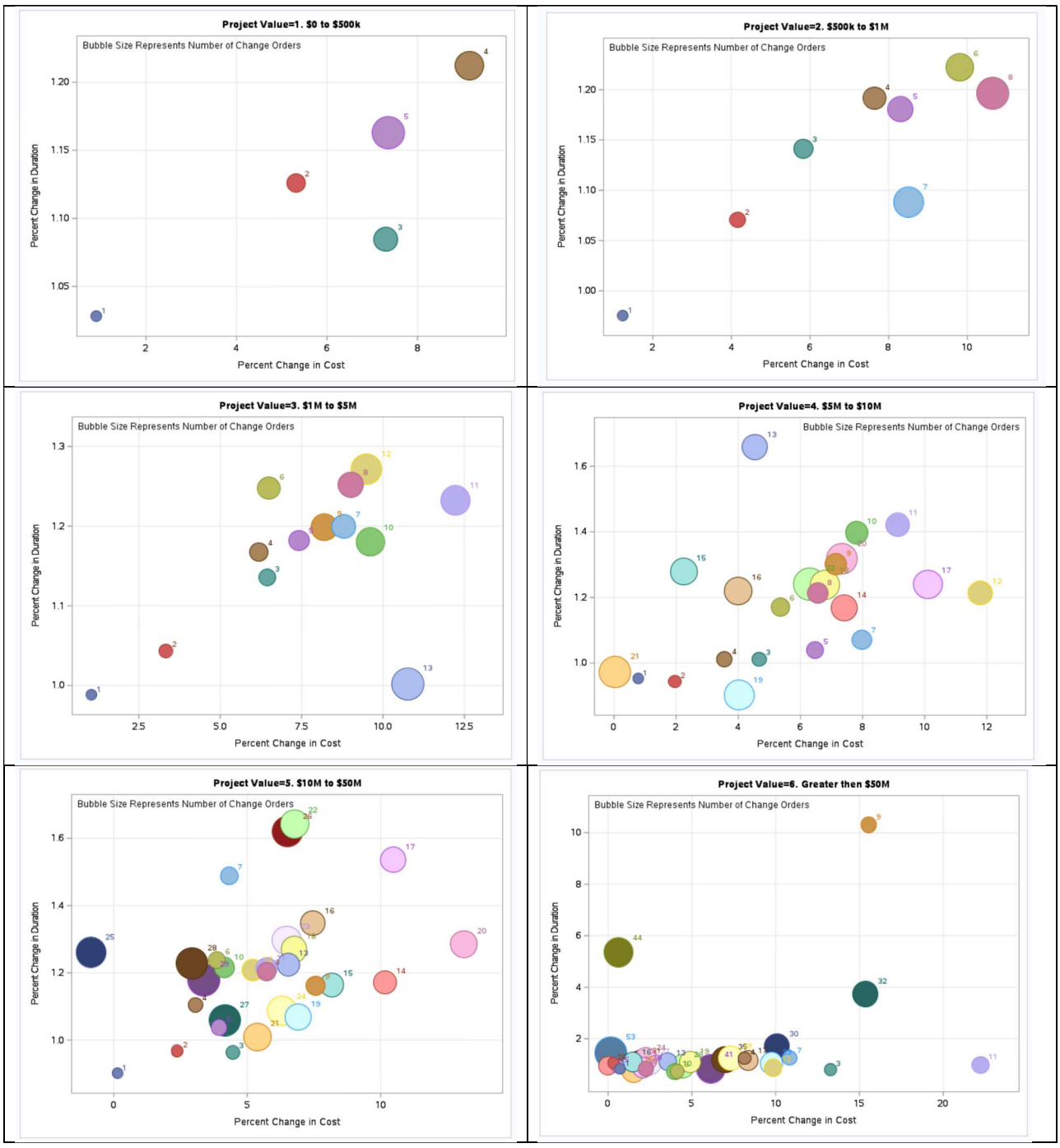
Project Value	Average Percent Change in Duration	Market Standard Range - Percent Change in Duration
$0 to $500k	1.07	0.50 – 1.63
$500K to $1M	1.07	0.44 – 1.64
$1M to $5M	1.11	0.50 – 1.67
$5M to $10M	1.09	0.50 – 1.67
$10M to $50M	1.13	0.50 – 1.69
Greater than $50M	1.07	0.50 – 1.63

What is the combined effect of change orders on duration and cost of a project?
Earlier analyses looked at average cost and duration effects of change orders. The next analysis takes a different approach and examines the effect of each incremental change order on cost and duration instead.

Figure 8 shows the three-way relationship of each incremental increase in number of change orders to their corresponding changes in cost and duration for each of the six project value categories. Each bubble on the chart is labelled and represents an incremental increase in change orders, with larger bubbles representing a larger number of change orders.

This visualization indicates that the higher the project value the lower the relationship between number of change orders and increased cost and longer duration of projects. This does not support the generally accepted belief that increased number of change orders results in increased cost and/or duration of a construction project. Instead, it implies that there are other factors than merely the number of change orders that affect changes in cost and duration of projects, at least for higher value buildings. One such factor may be the types of change orders, meaning site work, electrical, etc. That information is currently being extracted from our database and will be included in future analyses.

Figure 8. Three-Way Relationship of Number of Change Orders to Change in Cost and Change in Duration of Projects



Note: Axes scales vary to accommodate all data points for different Project Values.

Discussion

The Truth about Change Orders

Change orders are to be expected during construction projects. Unexpected site issues, changes in products and materials (availability, models, features, connections needed), changes in project requirements (scope changes, updated owner requirements) or changes in regulations, including advanced insights into future regulations or codes, and the owner's desire to 'future proof' the project are appropriate change orders.

Despite these, it is common belief that as the number of change orders increases there is a correlated increase in project cost and/or duration. These analyses do not support that assumption. In fact, ***there appears to be little relationship between the number of change orders and their effect on increases in cost or duration of a construction project, especially for larger projects*** (see Table 8).

This research also shows that there is considerable variation in number of change orders depending upon the value of the project. That is not surprising; it seems reasonable to expect more change orders for higher value projects. ***But what may not be expected is that there is substantial variation in number of change orders even within a given project value category***. This can be seen by reviewing the Market Standard Ranges in Table 1. It shows typical variation for $10-$50M projects to be anywhere from 1 to 17 change orders. Likewise, projects valued at greater than $50M have anywhere from 1 to 27 change orders. This finding, combined with the one above – that there is little relationship between the number of change orders and increased cost and/or duration of projects – implies a revised paradigm for thinking about construction project change orders.

Along with the traditional belief that an increase in number of change orders results in corresponding increases in cost and/or duration, it is also common practice to focus exclusively on project cost increases in change orders. The **Market Standard Range** for cost variations includes project management and administrative efforts which are folded into the change orders. Separate management efforts and administrative costs incurred by the owner and their consultants per change order, as change orders increase or as duration extends, are not included in the analysis.

Assuming these management and administrative costs are relatively consistent (they may be tiered) across increases in number of change orders or project duration, these analyses suggest that focusing exclusively on change order project cost impact may not lead to best practice in managing project change.

The trinity of duration impact, cost impact, and number of change orders appear to be associated with their timing in the project lifecycle more than simply how many have been issued (see Figures 6 and 8). This suggests that managing the timing of change orders is critical to better change management practice. For example, the later a change order is issued in the project lifecycle, the less alternatives an owner has in responding to the change, which may be a source of the larger increase in cost. This is particularly seen in the data for change order timing in lower value projects (Figure 6) and impact on cost and duration (Figure 8).

This research also suggests there could be other confounding variables driving cost and/or duration changes. One such likely variable is the type of change order, meaning electrical, site prep, etc. That data is currently being extracted for analyses. Further, it could be that the most accurate driver of cost and/or duration impact of change orders is a multivariate combination of number, type, timing, location, and/or size of change order. This will be examined in future analyses using machine learning/artificial intelligence techniques.

Change orders are a critical barometer of a project's health during both the planning and execution phases. In the planning phase, this analysis can enable owners and project teams to be cognizant of standard variations expected and anticipate demands by having a dialogue to understand factors which contribute to them. Such insights contribute to better preparation for change risk exposures, how to mitigate them, and determining impacts on project resiliency strategy. During the project execution phase, change order analysis is foundational to better change management and provides insight into the success of the project's change management system.

This ***Research Note*** presents overall change order norms and trends. The upcoming dynamic software version empowers far more detailed analyses of specific profiles,

where a profile is defined by project value, project type, project location, and new vs. renovation. In addition, clients can see comparisons of market profile metrics to their individual projects. Sample screenshots can be seen below.