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# EXPLAINING THE INFLUENCE OF CHANGE REASONS ON COST AND SCHEDULE PERFORMANCES

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**Abstract:** This research aimed at revealing and characterizing the influence of change events or reasons on cost and schedule performances. The specific objectives were to assess the frequencies of various change reasons with respect to cost and schedule deviations, and to assess the impact intensities of such change events or reasons on performance. Initially, a team of industry experts identified a total of 36 change types and grouped them in 9 major change categories. Then, change log information for 135 completed projects was statistically analyzed to quantify the intensity, frequency, and impact of changes on cost and schedule performances. The most recurrent types of change events for both cost and schedule were associated with issues related to construction productivity; planning; supplier and subcontractor; scope errors and omissions; design or engineering errors and omissions; or engineering productivity issues. In addition, this study quantified the specific impact on cost and/or schedule from a change event or reason. Specifically, this study provides evidence that fairly infrequent change events tend to cause large impacts on performance. The results from this study are likely generalizable, since the retrospective project data was representative of multiple project types, sectors, and organizational roles, among other project facets.

## 1 INTRODUCTION

Events can have a significant impact on cost and schedule deviations (Grau and Back $2013_a$; Grau and Back $2013_b$). As a result, cost overruns and schedule delays are very common in construction projects (Ibbs 2013, 2012; Mulva and Dai 2012). Various construction forecasting methods are used with the intention to ascertain cost and schedule deviations on time, but notably, such methods typically do not provide accurate forecasts (Grau and Back $2014_a$; Grau and Back $2014_b$). In reality, different events cause incremental impacts on cost and schedule performances, but those changes are difficult to foresee and their impacts to forecast. If change events could be detected early, such identification would help to minimize impact on performance and also to improve project outcome predictions. Thus, an early recognition of changes is critical to evaluate and implement changes in a proactive manner (Grau and Back $2013_b$). Importantly, this study tackled the issue of change reasons or events, understood as any unplanned event with a potential impact on cost and schedule.

In reality, the construction industry lacks evidence on the impact of changes on cost and schedule performances or deviations, and on the frequency of such changes. While a perception that the impact of changes vary with the nature of the change reason exists, the reality is that, to date, there is no data to

back up or reject such notion. The extent to which change events or reasons affect both cost and schedule deviations have not yet been documented (Grau and Back $2013_a$; Grau and Back $2013_b$; Ibbs 2005; Westersund 2008). As today, change events with high impacts are compensated with the use of large contingency reserves (Ibbs et al. 2008; McEniry 2007). However, we argue that the early recognition, communication, and proactive action to mitigate the impact of changes on performance are critical to minimize their impact. Reactive or late responses can only lead to significant negative impacts on performance, and increase the use of contingency reserves.

Indeed, questions such as: what are the major change reasons for cost and schedule deviations?; or, what are the types of changes that have the most influence on cost and schedule deviations?, have not yet been answered. This study aims at providing an answer to those and other similar questions with the overarching goal to enable construction industry organizations to be timely alert on the change reasons that can have a higher potential impact on performance, and to proactively manage such changes.

## 2 OBJECTIVES AND SCOPE

This research aimed to reveal the change events or reasons that have significant consequences on cost and schedule deviations. The specific objectives are listed below:

1. To assess the frequencies of various change reasons with respect to cost and schedule deviations; and
2. To assess the impact intensities of such change events or reasons on performance.

The scope of this study is defined as follows: 1) the sample for this study was randomly drawn from projects completed by CII member organizations; 2) the study was performed irrespective of the timing within the project timeline at which a changed occurred; and 3) the study considered the cumulative impacts of changes, regardless of their differences with respect to the controllability of each change.

## 3 LITERATURE REVIEW

A well-understood impact of change events on project performance should guide both owners and contractors to proactively manage changes. However, while the qualitative literature on changes is large, there is limited evidence on the frequency and impact of changes, as presented in the rest of this section. Those studies with a quantitative facet are mostly limited by the type of projects investigated or by the geographical location (e.g. Middle East) of the projects, and hence such results cannot be generalized. Indeed, Hanna et al. (1999) quantified the impacts of change orders on craft labor productivity for mechanical trades. The authors collected data from 61 projects, and developed a statistical model to quantify labor productivity loss from change orders. Al-Momani (2000) studied 130 public projects in Jordan, representative of residential and commercial facilities, to examine the causes of delay. The study identified the key factors in delays for public projects as weather conditions, site conditions, economic conditions, delays in deliverables, increase in quantities, and inadequate design. Hsieh et al. (2004) conducted a statistical analysis to find the root causes of change orders, based on data collected from 90 completed metropolitan public works projects in Taipei. The study indicated that issues in planning and design are the key sources of change orders in such projects. In addition, the study identified thirty-five change-order causes within nine categories, and ranked those as per their impact effect. Ibbs (2005) studied the influence of the timing of actual change implementation in the project delivery process on performance. Importantly, the study results determined that changes implemented late in the project timeline have a more detrimental effect on project performance than changes implemented early in the project timeline. In addition, the study proved that changes have a negative effect on craft labor morale and productivity. Assaf and Al-Hejji (2006) investigated the causes of delay specific to large construction projects. The study identified seventy-three causes of project delay. Additionally, the study conducted a field survey among owners, contractors, and consultants to examine frequency, severity, and importance of identified delay causes. Ibbs et al. (2008) conducted a meta-analysis of previous research studies to

show that incremental project changes have significant impact on productivity. Ibbs developed a statistical model to evaluate the effect of changes on craft labor productivity. Sun and Meng (2009) conducted an extensive literature review on construction project change causes and effects, and developed two taxonomies to explain such causes and effects. Ibbs (2012) statistically analyzed change orders from 226 construction projects to identify change patterns, and quantify change impact on project cost, schedule, and productivity. The study found that the entire impacts of a change upon authorization are not well understood by both owners and contractors. As mentioned earlier, these successful studies have not yet provide a generalizable but specific answer to whether or not a relationship exists among change events and, project cost and, schedule deviation, and how frequently such events occur.

## 4 METHODOLOGY

The research method consisted of three key steps: categorization of change orders, data collection with a survey instrument, and data analysis. First, a detailed review of the existing literature in the topic resulted in a preliminary categorization of change types. The literature review was conducted through key word search, analysis of relevant articles, and further retrieving and analyzing meaningful references in the previously reviewed papers. This preliminary categorization of changes was also contrasted and improved with actual change log categories from 12 industry organizations, and resulted in a broad list of 310 potential change reasons. Through 4 face-to-face research charrettes with a group of 15 industry members over a period of half a year and additional phone call meetings, the list change reasons was sequentially reduced to 36 specific change reasons, and grouped into major 10 types of changes. Table 1 contains the classification of changes by type and category.

Table 1: Change Reasons.

| Change Type | Change Reason |
|---|---|
| **A. Scope Changes** | A.1. Business Drivers Change |
| | A.2. Budget/Finance Change |
| | A.3. Plan Change |
| | A.4. Scope Error/Omission |
| | A.5. Other |
| **B. Standard, Regulatory, and Legal Requirements** | B.6. Health, Safety, Security, and Environmental (HSSE) Issues |
| | B.7. Labor Dispute |
| | B.8. Permitting |
| | B.9. Other |
| **C. Engineering Design** | C.10. Design/Engineering Errors/Omission, Inclusive of Constructability Issues |
| | C.11. Engineering Productivity |
| | C.12. Other |
| **D. Work Planning and Execution** | D.13. Construction Productivity |
| | D.14. Construction Errors/Omissions |
| | D.15. Construction Equipment |
| | D.16. Infrastructure, Site, or Utilities Issues |
| | D.17. Other |
| **E. Commissioning and Start-up** | E.18. Commissioning and Start-up Issues |

| | |
|---|---|
| **F. Control Functions** | F.19. Cost Estimating |
| | F.20. Scheduling |
| | F.21. Cost Forecasting |
| | F.22. Project Management |
| | F.23. Project Team Integration |
| | F.24. Other |
| **G. Vendor/Supplier and Procurement** | G.25. Supplier/Subcontractor |
| | G.26. Market Supply |
| | G.27. Logistics |
| | G.28. Procurement Process |
| | G.29. Other |
| **H Economic Conditions** | H.30. Foreign exchange |
| | H.31. Escalation/Inflation |
| | H.32. Other |
| **I. Legal and Social Conditions** | I.33. Changes in Law |
| | I.34. War/Riots/Crime/Terrorism |
| | I.35. Other |
| **J. *Force Majeure*** | J.36. Natural Threats |

Second, a survey instrument was design to collect general project data on completed projects, their change log data, and also on the corresponding separate impact of changes on cost and schedule deviations, if any. General project data included multiple specific inquiries related to cost and schedule performance, project delivery method, use of incentives, project controls structure (e.g. field vs. home office), among many others. Survey respondents were selected through random sampling within experts on project management and controls affiliated with CII member companies. In total, we collected 135 responses with retrospective data on an equivalent number of completed projects. The aggregate equivalent installed costs for the 135 completed projects was $28.88 billion, with a combined project completion time of about 300 years. Median schedule deviation at completion was 7.91 percent, while the median cost deviation was 5.93 percent. The sample of projects was well distributed between contractors (52%) and owners (48%). Project sector affiliation of was 49% for public, 47% for private, and 5 % for both public and private sectors. The projects were also representative of multiple organizational roles, as Table 2 illustrates. Notice that respondents frequently selected several organizational roles, so that the sum of the percentages in Table 2 actually exceeds 100%. The projects were also representative of multiple industry sectors, as Table 3 illustrates.

Table 2: Roles.

| **Role Function (%)** | | | | | |
|---|---|---|---|---|---|
| **Owner / Client** | Design Build | Architectural / Engineering | Procurement | Contractor | Construction |
| **47** | 19 | 29 | 31 | 30 | 28 |

Table 3: Industry sectors.

| Industry Sector (%) | | | | | |
|---|---|---|---|---|---|
| **General Building** | 7 | Pharmaceutical | 0 | Power | 14 |
| **Pulp &Paper** | 1 | Heavy Industrial | 7 | Petroleum Upstream | 6 |
| **Light Industrial** | 1 | Chemical | 30 | Petroleum Downstream | 18 |
| **Manufacturing** | 7 | Highway & Infrastructure | 2 | Technology & Electronics | 2 |
| **Others** | 18 | | | | |

## 5 RESULTS AND DISCUSSION

Each survey respondent used a 10-point scale (from 1-low to 10-high) to assess the impact of changes in the project on cost and schedule deviations at completion. Respondents separately provided the assessment of change reason types according to the project change log. Table 4 contains the most occurring changes, by frequency of occurrence, with an impact on cost, while Table 5 contains the most occurring changes, by frequency of occurrence, with an impact on schedule. Indeed, order-of-magnitude differences in the frequency of individual change reasons exist. Most recurrent types of change events for both cost and schedule are associated with the following: construction productivity issues; planning; supplier and subcontractor issues; scope errors and omissions; design/engineering errors and omissions; and engineering productivity issues. Virtually any project is likely to face several of these change events. On the contrary, there are other types of change events that show a low recurrence, but, as explained below, tend to have a larger impact on performance.

Table 4: Frequency of Changes with an Impact on Cost.

| Order | | Change Type | Frequency |
|---|---|---|---|
| **1** | C.10 | Design/Engineering Errors/Omission, Inclusive of Constructability Issues | 46% |
| **2** | D.13 | Construction Productivity | 41% |
| **3** | A.3 | Plan Change | 34% |
| **4** | A.4 | Scope Error/Omission | 33% |
| **5** | G.25 | Supplier/Subcontractor | 29% |
| **6** | C.11 | Engineering Productivity | 23% |

In order to assess the importance or influence of changes on cost and schedule performance, we defined the metric of average impact effect, which was separately computed for each change reason with respect to cost and schedule performances. Indeed, the average impact effect for a particular change on cost or schedule responds to the sum of the product between impact value (on a 1–10 scale, from low to high) times the corresponding project cost or schedule deviation, divided by the number of project instances with such cost or schedule change (Back and Grau 2013). The average impact effect scores were then grouped by high, medium, and low intensity. Tables 6 and 7 represent the changes with top ten average impact effect for cost and schedule outcomes respectively and their corresponding frequencies.

Table 5: Frequency of Changes with an Impact on Schedule.

| Order | | Change Type | Frequency |
|---|---|---|---|
| **1** | D.13 | Construction Productivity | 32% |
| **2** | A.3 | Plan Change | 29% |
| **3** | E.18 | Commissioning and Start-up Issues | 24% |
| **4** | G.25 | Supplier/Subcontractor | 23% |
| **5** | A.4 | Scope Error/Omission | 15% |
| **6** | C.10 | Design/Engineering Errors/Omission, Inclusive of Constructability Issues | 15% |

Indeed, it is observed that the frequency of a change does often have an inverse relation with the severity of its impact on cost or schedule performance. Indeed, changes were observed to have a high frequency of occurrence often show a small impact on cost and/or schedule deviations, while those with a low frequency of occurrence often have a large, or severe impact on cost and/or schedule performances. Among the top 10 change events with them most impact on cost, only two of them occur in more than 10 percent of the projects. Change events with the most impact on cost were: standard, regulatory, and legal requirements; project team integration; procurement processes, natural threats; or project management issues. In addition a similar relationship observed between the low-probability change events and a large impact on schedule exists. Labor disputes, infrastructure or site issues, and permitting problems may seldom occur, but when they do, they are likely to have a high negative impact on project completion time. Among the most influential change events affecting schedule is the occurrence of scope changes. Indeed, scope changes have proven to be somewhat more frequent and observed in fifteen percent of sampled projects. Scope changes tend to have ripple effects on the project delivery process, and fundamentally affect core management functions, such as estimating, planning, and execution. The results indicate that the frequency of a change is inversely correlated to its impact on cost and/or schedule deviations, a notion that may have existed in industry but that had not been previously documented.

Table 6: Frequency and Intensity of Change Reasons on Cost.

| Order | | Change Type | Impact Effect | Frequency |
|---|---|---|---|---|
| **1** | B.9 | Other (Standard, Regulatory, and Legal Requirements) | High | 5% |
| **2** | F.23 | Project Team Integration | High | 5% |
| **3** | G.28 | Procurement Process | High | 7% |
| **4** | J.36 | Natural Threats | High | 8% |
| **5** | F.22 | Project Management | High | 9% |
| **6** | H.30 | Foreign Exchange | High | 5% |

Table 7: Frequency and Intensity of Change Reasons on Schedule.

| Order | | Change Type | Impact Effect | Frequency |
|---|---|---|---|---|
| **1** | B.7 | Labor Dispute | High | 1% |
| **2** | D.16 | Infrastructure, Site, or Utilities Issues | High | 6% |
| **3** | A.4 | Scope Error/Omission | Medium | 15% |
| **4** | B.8 | Permitting | Medium | 2% |
| **5** | F.23 | Project Team Integration | Medium | 5% |
| **6** | G.28 | Procurement Process | Medium | 8% |

A probable explanation for the inverse relationship between frequency and average impact effect is that highly recurrent change events are more easily expected, identified, and addressed by the project team. Infrequent events are not likely to be accounted for during the planning of a project and, hence, when they occur, they are not rapidly addressed and result in a significant negative impact (Back and Grau 2013, Ibbs 2013, Westersund, 2008). These types of infrequent events, though, prove to be the most influential on cost and schedule deviations. Ensuring that potential high-impact events are communicated and addressed as soon as they can be predicted or occur is critical to reduce their impact on performance. The information in this section is useful to industry teams so that they inform how to address underlying change reasons that are associated with revisions to cost and schedule performances and forecasts, and how frequently such reasons can be expected.

## 6 CONCLUSIONS

Change management plays a critical role in the effort to identify changes early, and evaluate and implement responses to changes in a proactive and effective manner. The later the recognition of a change, the more difficult it becomes to implement corrective actions, mitigate cost and schedule impacts, and accurately and timely forecast project performance at completion. As important as change management is to industry, to date there is a lack of concrete evidence of what the frequency of a change may be, and what its intensity on cost and schedule performance could be.

In order to fill such gap in the body of knowledge, we have statistically analyzed change log information for 135 completed projects to prove the long-held perception that the impact of change is inverse to their frequency, and thus help industry professionals to recognize change events early. Indeed, this study reveals that change events or reasons tend to have significant different consequences on cost and schedule deviations. We found that the frequency of a change does not necessarily directly correspond to the severity of its impact on cost or schedule performances. Specifically, fairly infrequent change events tend to cause large deviations. Also, we have learnt that different change reasons impact cost and schedule performances with different occurrences and intensity. Indeed, some changes were observed to have a high frequency of occurrence with a small impact on cost and/or schedule deviations, while others were observed to have a low frequency of occurrence with a large or severe impact on cost and/or schedule performances. For instance, permitting issues are rare, but, when they occur, tend to have a very significant impact on schedule, but a moderate impact on cost. In summary, we identified change types that are most frequent, and those which are most influential for both owners and contractors, for both cost and schedule.

Overall, this study provides a better understanding of the severity of impacts associated with various change events, and should be used to enhance risk, contingency, and change management practices. Above all, indications of potential changes should be continuously sought and communicated as early as possible. The early recognition, communication, and remediation of changes are critical to decrease their impact on performance. Changes and events will happen, but they must be recognized and proactively addressed by the project team in order to mitigate their impact.

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