Journal of Civil Engineering and Architecture 19 (2025) 9-21
doi: 10.17265/1934-7359/2025.01.002

Identifying the Impact of Preconstruction Elements on Project Time Variances

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Abstract: Working toward an efficient duration and timeline for the preconstruction phase should be one of the main objectives for project owners. Failing to plan for and coordinate preconstruction decisions in order to control preconstruction duration and manage time variances can lead to financial insecurities, incomplete contract documents, permitting issues, and unrealistic schedules and resource allocation during this phase. To minimize time variances and ensure a productive decision-making process, project owners should be familiar with critical elements in a project that cause variances in the preconstruction phase timeline. In this study, the impacts of eleven critical preconstruction elements on time variances were analyzed. These eleven preconstruction elements are considered critical in how they impact time variances during the preconstruction phase. They were determined to be critical based either on significantly impacting time variance during the preconstruction phase or believed to be critical from findings from previous studies, however, the findings from this study showed no significant impact on the time variances. In most previous studies focusing on the elements impacting project schedules, data were collected by surveying construction professionals. In this study, objective and quantitative data related to project preconstruction elements were used as opposed to self-reported data. Using the results of this study, project owners and stakeholders will be able to evaluate the critical preconstruction elements impacting the timing of their projects and prioritize decisions related to the critical elements early on during the preconstruction phase.

Key words: Preconstruction, time variances, critical preconstruction elements, objective data.

1. Introduction

The importance of the preconstruction phase and its impact on overall project success has been investigated before [1-3]. Planning for an accurate time for the prosecution phase is one of the critical decisions during this phase. Failure to plan accurately for the preconstruction time established for a project can lead to financial insecurities, incomplete contract documents, permitting issues, unrealistic schedules for the contract award (buyout) process [4], and unrealistic resource allocation during the preconstruction phase [3].

Time is one of the main risks that exist for every construction project [5]. Therefore, the project team should understand and practice proper standards to mitigate potential delays by managing preconstruction elements [4]. Knowledge of how to manage preconstruction elements helps project owners provide necessary personnel and technology resources (i.e., expert staff, manpower, historical data, consultants, etc.) which can guide project planners to allocate enough time and money to resolve technical, environmental, and constructability issues before the buyout phase begins [3].

For managing time variances during the preconstruction phase, it is critical for the project owners to follow a good decision-making process and prioritize critical preconstruction elements impacting project time [4]. While the causes of delay and time variations during the construction phase have been discussed extensively

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[6-10], information is limited on the causes of time variations that may occur during the preconstruction phase. Due to the limited availability of information, setting up a clear plan for how to prioritize decisions may be more challenging than it would be in the existence of adequate information [4]. As a contribution toward adding to the existing limited information, this paper focuses on the elements of a project during the preconstruction phase that most impact time variances.

For this study, objective data related to the preconstruction elements and time were used for analysis rooted in numeric data. To collect these quantitative data, BIM (building information modeling) and associated software were used to extract and analyze data related to preconstruction elements, as recommended by Tafazzoli [6]. Critical preconstruction elements impacting time variances were identified. Using the results of this study, project stakeholders, specifically owners, will be able to evaluate the relative time impact of their decisions, and the critical elements that they need to prioritize to manage significant time variances during the preconstruction phase.

2. Literature Review

"Preconstruction" refers to the development of a project plan and its construction documents from the early conceptual phase through the contract award [3, 11]. "Preconstruction time" refers to the time required to complete the preconstruction phase. This timeframe starts with the projects' early planning exercise (conceptual phase) and ends when the buyout is completed [4] (review Fig. 1 for preconstruction in the context of the project lifecycle).

Setting up an efficient preconstruction time, avoiding variances in it, and developing proper planning and programming have been identified as important goals of preconstruction [3, 4]. The length of the preconstruction phase is critical to project owners for several reasons. Variations in the preconstruction time can lead to insecurity in project financing and interest rates. It can also lead to not having final drawings and required documents to get final bid numbers, not having productive coordination and permitting with the municipality, and unrealistic timelines for the initiations of hard bid, buyout, and the start of the construction phase [4]. The timing of the preconstruction phase is also critical to the project team to plan for resource allocation. Through observing estimating hours in a case study of two projects, Craigie [3] identified the necessity of investing in preconstruction hours for improving resource allocations (personnel and technology resources including expert staff, manpower, historical data, consultants, etc.) in a project. Improving resource allocations can lead project planners and designers to have enough time and budget to resolve technical, environmental, and constructability issues before buyout is processed.

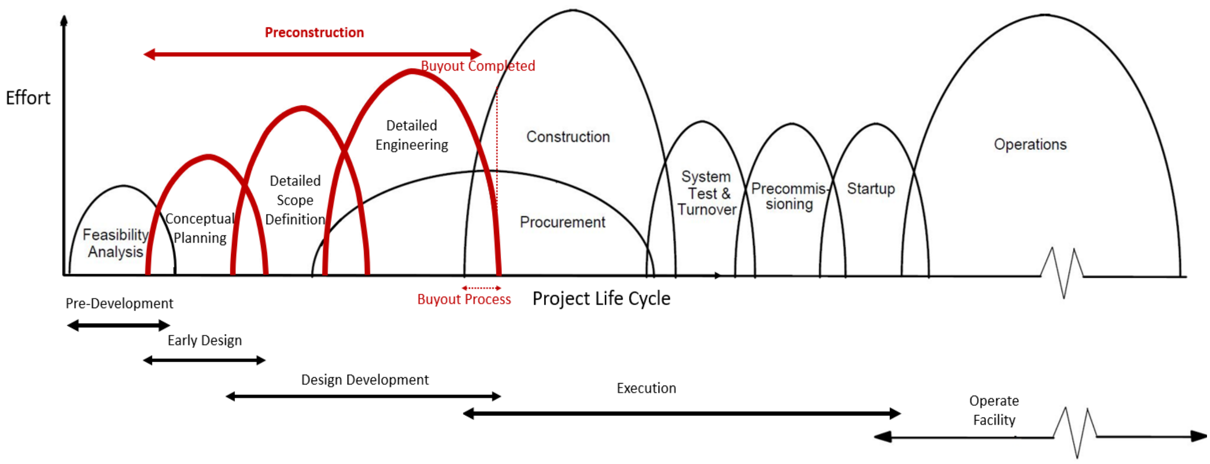

Fig. 1 Preconstruction segment of the project life cycle. Image is an annotated version from the PDRI report from the Construction Industry Institute [12]. Reproduced with permission.

2.1 Elements Impacting Time

To control for time, minimize its variances, and ensure a proper planning process, project owners should be familiar with critical elements that lead to variances in the time during the preconstruction phase [4]. Various studies have been conducted to investigate the causes of variances in a project time and schedule and, for the most part, the focus has been on the construction phase. However, many of the elements that cause time variances occur during the preconstruction phase [4].

Previous studies have contributed to the knowledge of the impact on time of key elements in a construction project. Elements such as escalation, design changes, design errors, and unclear project requirements (i.e. site and equipment-related assessments and information) have been shown to be the elements that are critically impactful to project time [6, 9, 10]. This has long been known and documented in addition to some other more specific elements that are less obvious such as project familiarity [6, 7], construction methods, and poor use of advanced engineering design software [6] in addition to inadequate project funding and financing [9], and contractual related problems [8].

A summary list of these critical elements as identified by other studies is provided in Table 1. Although the studies listed identified a variety of elements, only those that were applicable to the preconstruction phase are included in this table.

Table 1 Existing literature focusing on critical elements and their impact on time.

Author	Elements impacting time
Tafazzoli [6]	1. Poor communication and coordination with other parties 2. Design changes 3. Design errors 4. Complexities and ambiguities of project design 5. Poor use of advanced engineering design software 6. Inadequate site assessment by the designer during phase 7. Equipment allocation problem 8. Shortage of equipment 9. Changes in government and regulation laws 10. Price fluctuations 11. Changes in material types and specifications 12. Escalation of material prices 13. Slowness in decision-making, time-consuming decision-making process of the owner 14. Inadequate contractor experience 15. Unrealistic schedule 16. Inappropriate construction methods 17. Poor site management and QC (quality control) by the contractor 18. Misunderstanding between owner and designer about the scope of work
Hampton, Baldwin, and Holt [7]	1. Project familiarity 2. Poor coordination 3. Poor communication
Yates and Eskander [9]	1. Constant changes in a project requirement 2. Recommendation: making changes as quickly as possible 3. Lack of communication 4. Project funding and financing
Braimah [8]	1. Contractual related problems
Gebrehiwet and Luo [10]	1. Inflation, price increase 2. Unclear and inadequate details and specification of design 3. Lack of quality of material 4. Late design and design documents 5. Design mistakes and errors 6. Misunderstanding of client's requirements 7. Changes in material type and specifications 8. Poor communication and coordination 9. Late in approving and receiving complete work

2.2 Knowledge Gap

The majority of prior research related to the impact of project elements on time is focused on the construction phase. Knowledge on the cause of time variances that may happen during the preconstruction phase is limited. This limitation necessitated additional research to evaluate the time impact of critical elements this time during the preconstruction phase. Furthermore, in most of the studies listed in Table 1, data were collected by surveying construction professionals. While self-reported data can provide valuable insights, they have some inherent limitations, and finding objectivity in measuring the variance elements is difficult. This leads to an opportunity to identify the time impact of critical preconstruction elements using less subjective data collection methods which can be done through using measured data, such as that collected through BIM [6]. Focusing on the preconstruction phase of a project's lifecycle and collecting objective data through using BIM-related platforms, this study aims to provide insight into how project elements impact project time during preconstruction by using objective data.

3. Method

In gathering data for this paper, objective data regarding the impact of preconstruction elements on time variances were collected and analyzed using a BIM-related software developed by JE Dunn Construction. Results of the data analysis are used to inform project owners and preconstruction teams about critical preconstruction elements that should be prioritized and focused on during the early decision-making phase of the project. This study is rooted in numeric data rather than human judgment and opinion to then guide decision making during the preconstruction phase.

3.1 Compiling the List of Preconstruction Elements

For compiling a list of preconstruction elements, a review of existing literature was done to identify important preconstruction elements impacting project time both during the preconstruction and construction phases. Due to the limited existing literature focusing on the preconstruction phase, other research focusing on the construction phase was also included as a way to identify additional elements that are common between the preconstruction and construction phases (i.e., design errors, site assessment, equipment information, etc.) and can be studied for the purpose of this research.

To ensure the data could be collected and analyzed effectively, a pilot study was done using the data from five projects. From the five projects, data on 86 project elements were collected. Through this pilot study, 20 preconstruction elements deemed measurable for this study were compiled and ready to be collected. Refer to Appendix 1 for the list of 20 preconstruction elements.

3.2 Sample Selection

Due to the nature of the data collection, the sample projects had to be ones in which the preconstruction phase was complete (from early planning to when the buyout is began) and on which a BIM-related platform was used for the estimating process and had an accessible and complete database. The final sample was a group of projects developed in three different regions (South-Central, Mid-West, and East) of the United States since 2017, the most recent year for which complete data were available. From a total of 1,398 projects that were identified as potential data sources, 165 (approximately 12%) of them used BIM during the preconstruction phase and were eligible for the study. Of the 165 eligible projects, 104 were excluded due to inaccessible data. The 104 non-eligible projects either had damaged or relocated cost-estimating platforms, had incomplete data, or were still in the budgeting process and did not represent a complete preconstruction phase. After applying the mentioned criteria and clustering the sample projects, a final list of 61 projects was developed to be studied. This number of projects is consistent with exceeding the minimum desired sample size to achieve a valid analysis [13-15].

The sample used is representative of the target population which is projects that used BIM during their preconstruction phase. Each of the 61 projects in the sample includes a vast amount of information (20 measurements each). Therefore, the data collected are very rich, which helped achieve saturation. Lastly, the sample size is appropriate for the analyses used [13, 14], as correlational analyses need at least $n = 30$ while the causal-comparative and experimental methodologies need a minimum of $n = 50$ cases [14]. Thus, a sample size of $n = 61$ is a reliable sample size and meets the requirements discussed by previous studies.

3.3 Data Collection

Data were collected using BIM-related software, measuring elements related to material changes and classifications, scope changes, site, and general mechanical/electrical information. Elements related to the design package (design errors, design changes, detailed material information, etc.), and the team's capability in using the model for cost estimation were measured. The software and its linked cost estimating platform provided additional information about changes in price, materials, scope, and items related to the project team. Data on some elements were available through the BIM-related software and had to be obtained from archived documents. Examples are practicing VE (value engineering) and awarding methods.

3.4 Data Analysis

After reviewing the collected measurements and identifying the missing values and outliers, SPSS (Statistical Package for the Social Sciences) was used to analyze the data. Three statistical analyses were performed to identify the elements that had significant effects on and relationship with project budget variances. *T*-tests and ANOVA (analysis of variance) were used to compare means between and within groups. Correlation analyses were used to identify how values were related to one another. Results identified from the three mentioned analyses were used to develop a list of critical preconstruction elements impacting the budget.

4. Results

From the total of 20 elements examined, eleven elements were identified from the results of the data analysis to either significantly impact time variance or not align with what is believed to be critical based on previous studies. In this section, these eleven elements are reviewed with their description of variables used in the analysis of these elements.

4.1 Insight from the Quality of the Design Package (Design Errors, Major Scope Changes, Model Updates)

In this section, the impacts of three preconstruction elements of Design Errors, Major Scope Changes, and Model Changes are discussed. The results of these three elements highlight information of interest to project owners about the criticality of paying attention to the performance of the design team and the quality of the design packages if managing time during the preconstruction phase is critical for them.

4.1.1 Design Errors

Design errors and deficiencies are one of the predictors of changes in the time of preconstruction. The number of design errors (here measured in the Revit model) also reflects the quality of the delivered design package. In many ways, it is predictable that a low-quality design package requires more effort from the project team to estimate. This assumption is supported by the data. As the number of errors in the design model increases, the average time spent on estimating increases as well. These two variables correlate with each other at a statistically significant, yet weak level, $r(59) = 0.288$, $p = 0.030$.

The result of the analysis indicates and supports our predictions that a low-quality design package with more errors requires more time to estimate. Project owners can see the importance of contracting with and investing in a productive design team that provides high quality design with fewer errors in it. This should be prioritized as one of the earliest decisions that owners should make to avoid adding time to the preconstruction phase.

4.1.2 Major Scope Changes

Change in the scope and sub-scopes of work is another predictor of whether the estimating time will change. It is fair to assume that changes in the main scope of work will add time to the estimating and overall preconstruction phase as this will require updates to the design. The numbers bear this out. As the number of changes in the scope of work increases, the overall preconstruction time increases. These two variables correlate with one another very highly r (60) = 0.271, p = 0.036.

While the numbers justify expectations, this analysis tells us the importance of collaboration between the owner and the design team upfront about what scope will be included in the project and if adjustments are required, they should take place early and be done in a single or very few re-design efforts. Failure to set up what needs to be estimated in terms of scope of work will add time to the project during the preconstruction phase.

4.1.3 Model Updates

The frequency of updating the model refers to the estimating team's efforts in using and updating the Revit model for budget estimating purposes. Interestingly, the model update frequency impacts the preconstruction time. The analysis indicates that there is a moderate inverse correlation between the number of model updates and the average time spent during the preconstruction phase, r (36) = -0.341, p = 0.048. This result is specifically true for negotiated projects.

The results show that the more effort the estimating team puts into updating the model for the budgeting process, the shorter the preconstruction period is likely to be. The result highlights the benefits of working with the design model for the estimating process. For instance, there might be information provided by the model that finding that information from other sources would take longer for the estimating team. Examples of this information could be the site assessment and environmental factors, equipment location, and mechanical, electrical, and plumbing (MEP)-related information. The benefit of having a faster take-off from the model and in-time data interaction between the model and budgeting software are other benefits of working with the design model for the estimating process. Project owners should note that the productivity and quality of their estimating team when working with the model are factors in having a shorter preconstruction period. This is an important factor for owners to consider, particularly if they have a limited time for preconstruction. Not all design teams provide a Revit model to the estimating team. However, providing a high-quality model is a critical consideration for project owners and designers and it is also critical for the project owner to pay close attention to having a capable estimating team that can work with the model and use it to update the budget.

4.2 VE

Practicing VE during the preconstruction phase is another element reviewed in this study. In this analysis, three groups of projects were collected: projects with VEs provided and accepted, projects with VEs provided but not accepted, and projects with VEs not provided. These three groups were compared based on the overall estimating time. Projects with VEs provided and accepted had a mean increase in time of 12.9 months. Projects with VEs provided but not accepted had a mean increase in time of 7.37 months, and projects that had no VEs provided had a mean increase in time of 6.53 months. The difference of 6.378 months between the projects that provided and accepted VEs and projects that did not provide VEs was statistically significant, F (2, 58) = 4.452, p = 0.016.

The results indicate that the duration of the preconstruction phase is greater in projects with VEs provided and accepted when compared to projects with no VEs provided. However, there was no difference found between projects with VEs provided but not accepted and those with no VEs provided at all. The small difference between these scenarios is not clearly evident but is possibly due to little time spent reviewing rejected VEs and after an initial rejection, the VE exercise comes to a close quickly whereas VEs that are accepted would likely result in multiple rounds of fine tuning and additional pricing. Project owners should note that if they are planning to practice VEs, the process of receiving and reviewing VEs can take time and is likely to affect the length of their preconstruction phase. This finding was expected since providing VEs involves the project owners, project team, and even subcontractors in different collaborating and decision-making processes, which typically adds time to the overall preconstruction period. Decisions on VE suggestions by the preconstruction team should be made quickly and lengthy exercises to squeeze every last dollar out of a VE recommendation should be avoided.

4.3 Project Size

Changing the size of a building is one of the biggest predictors of having significant budget variance during the preconstruction phase [4]. It is predictable that if there is more of something to be built, the estimating team will need more time to budget it, and likewise reducing the amount to be built will decrease the amount of time of estimation. The numbers support this assumption. As the physical size of the project increased (change in square feet of a building) the estimating time increases as well with these two variables correlating with one another very highly r (25) = 0.707, $p < 0.001$. This result is specifically true for hard bid projects.

This analysis of the average time spent per square foot of the building tells us a few things. One of the strongest levels for modifying the time of preconstruction is to avoid modifying the amount that you will build. Project owners may understand that adjusting the size of the building will impact the preconstruction time. Therefore, decisions related to this should take place during early phases and be done in one re-design or addendum effort, or at least the fewest possible. Going back to this as a way to control budget [4] and time will only add time to the project. Ignoring collaborations regarding project size may cause unwanted time increases during the preconstruction phase of a project.

4.4 Insight from Tracking Schedule

One interesting finding came through examining the associations between tracking the schedule during the preconstruction phase and project awarding methods. The awarding methods analyzed were negotiated or hard bid processes. Negotiated projects refer to those in which a construction manager CM is involved with developing a plan and budget from early phases to meet project and owners' requirements. Hard bid projects are those in which CMs bid for the project typically awarded to the lowest bidder. The two groups of projects were compared based on whether the schedule was tracked during the preconstruction phase or not, and a significant association between them was found (χ^2 (1, 61) = 10.932, $p = 0.001$).

Negotiated projects, by their nature, have longer preconstruction periods since the hired CM is involved with the estimating process from earlier planning phases. Therefore, it is expected to see project owner's willingness in tracking schedule in these types of projects. Project owners should note that if they are planning to award their project through the negotiating process, they should account for the longer preconstruction phase, track the planning and estimating process progress per the schedule, and get help from the scheduling team to track the preconstruction activities down during this phase.

4.5 Target Budget

Having a planned target budget refers to the owner's predetermined budget, also known as the budget goal, set at the beginning of the early planning and decision-making process. Setting up a target budget positively impacts preconstruction time. In this analysis, the total duration of the preconstruction time periods, from the beginning of the conceptual design and estimating phase to the beginning of the buyout phase, was compared for projects with a target budget to those with no target budget. Projects with a target budget had a mean time of 4.25 months, and projects with no target budget had a mean time of 11.57 months. This difference in means of 7.34 months between the two groups was statistically significant, t (46) = -2.884, p = 0.006.

The results indicate that the overall estimating time is shorter for projects with a set target budget compared to projects with no target budget. The result indicates that one of the strongest levers for managing the time of preconstruction is to set a target budget for the estimating and budget evaluation process. Project owners may know that if a target budget is set and followed by the design and estimating teams, the overall preconstruction time will be more controlled. Different reasons might be behind this result. The estimating and design team may not be able to get involved with additional design and budgeting alternatives when the budget is set for their project. In addition, the design team may need to come up with a set and determined scope of work with detailed information about the required systems, methods, and building codes which would narrow down the list of applicable trade partners, and that would shorten the bidding process since the estimating team would not spend extra time for requesting bids from a vast number of not applicable trade partners. The estimating team would have a clearer vision of what is needed for the project and what needs to be planned to not pass the budget and time set for the project. Decisions related to setting up a budget goal should take place during early stages and be followed by the project team. Going back to this as a means of adjusting the project budget will only add time to the preconstruction phase. Failing to collaborate regarding the target budget may cause unwanted delays during the preconstruction phase.

4.6 Budget Updates

The estimating team's effort in developing and budgeting a project impact how long this phase can last. In this analysis, the goal was to find the association between the number of times the budget is updated and the overall estimating time. The results indicated a strong positive correlation between the number of budget updates and estimating time r (61) = 0.802, p < 0.001. Results indicate that updating the budget more frequently is associated with a longer preconstruction period.

Budget updates may be done because of different factors such as changes or clarifications in the drawings and specifications as well as receiving new information about the project requirements, either from the design team or the owner. Project owners should note that as the estimating team receives more frequent information about a project, in general, the more frequently they are required to update the budget, and this will cause the preconstruction period to be longer.

One implication of these results is that the project owner should set a clear expectation of the required delivered budget updates from the estimating team at each milestone. Another implication of this finding is that the project owner and design team should provide the preconstruction team with discrete update packages of high quality in specific time phases. The updated packages include all the drawings, specifications, requirements, and clarifications about the project. Owners and design teams should avoid providing single pieces of information frequently, such as in multiple addenda. Project owners should plan this upfront with the design team in order to avoid elongating the estimating time.

4.7 Insights from Project Recency and Using BIM

An interesting result from the data analysis is the impact of project recency on preconstruction time. There was a clear trend in the amount of time spent during preconstruction across time. For projects initiated in 2017, the mean preconstruction time was 151.5 days. For projects initiated in 2018, it was 71.95 days and for those initiated in 2019, it was 67.33 days. The mean difference in these is significant, $F(2, 56) = 4.356$, $p = 0.017$. This reduction in time from one year to the next may be due to several factors. For example, recent projects may be more likely to have teams that leverage BIM and other technology that can reduce the time associated with an estimator's activities [6, 16]. Following up on this assumption, an additional analysis was completed to identify if the year a project was developed was related to using BIM. Two different groups of BIM projects were compared based on the year they were developed: projects that did not use BIM for cost estimating purposes although they had the opportunity to use it, and projects that used BIM for cost estimating. Significant results were found (specifically in hard bid projects) as projects that did not use BIM, on average, were mostly developed in 2017. Projects that used BIM for cost estimating purposes were mostly developed in 2018. The difference of one year between the two groups was statistically significant, $t(22) = 2.644$, $p = 0.015$.

The result from the project recency on time implies that the duration of the preconstruction phase is greater in older projects compared to projects developed in recent years. In confirming the findings from previous studies, the results of this study indicate that projects developed in recent years used BIM more often for cost estimating purposes.

From these two results, we can claim that using BIM during the preconstruction phase reduces the length of this phase and may impact the buyout process. We can also conclude that in recent projects, people who worked during the preconstruction and buyout process are more familiar with using BIM for cost estimating purposes. Additionally, CMs, in general, are more willing to use BIM during their preconstruction phase. This is an important element for project owners to note. If they use BIM during the preconstruction phase, they are more likely to have a shorter preconstruction period. Due to the nature of the data for this study, it is possible that this finding is not generalizable to other project teams. However, the insight into the value of a team becoming more familiar and efficient with technology such as BIM to assist in the preconstruction phase is apparent. Project owners have much to gain from investing in teams that leverage technology that is fitting for the project being pursued.

4.8 Insight from Site Management (Site Assessment and Equipment Allocation)

In this section, the impact of two preconstruction elements: Site Assessment and Equipment Allocation, are discussed. The results of these two elements are not consistent with the results found in the literature. Site Assessment and Equipment Allocation are two critical preconstruction elements that have previously been noted to impact the schedule [6]. Two separate analyses were done to measure the impact of these two elements on the project time variances. In the first analysis, results indicated that projects with a site assessment provided had an average time of 33.014 days compared to projects with no site assessment provided with an average time of 36.054. The mean difference of 3.04 between the two groups of projects was not significant, $t(52) = 0.109$, $p = 0.914$.

The focus of the second analysis was on the mechanical equipment allocation. The second result also did not show a significant difference in the average time per day spent on projects with an equipment allocation compared to projects without one. Projects with an equipment allocation had an average time of 0.730 compared to the average time of 0.789 in projects with no equipment allocation $t(53) = -0.347$, $p = 0.730$.

The results of the two analyses do not support the results from the literature and decisions related to providing information about the site and equipment do not cause major variances in the time. Knowing this, project owners can focus their limited available time on more critical elements and give lower priority to these elements.

5. Discussion

One of the main focuses of this study was to determine the critical preconstruction elements causing time variances during the preconstruction phase. Using BIM-related platforms and recorded documents, objective data about preconstruction elements impacting time variances were collected and analyzed from a total of 61 projects nationwide. Design errors, major scope changes, model updates, project size, site assessments, equipment allocation, VEs, awarding methods, target budget, budget updates, and project recency and using BIM are the eleven important elements that either impact a project's time variance or are believed to be critical based on the previous studies and the results showed otherwise. Many of the identified critical elements are related to the quality of the design package and the performance of the design team. Examples of these critical elements are design errors, major scope changes, and the frequency of model updates. A few other identified elements are related to the quality of the performance of the estimating team such as the frequency of the budget update, using BIM for the estimating process, and VEs. Project owners should be aware of the importance of evaluating their design and estimating teams, making sure they all are on the same page with the project's needs and requirements, have the same culture and boundaries, and take responsibility while committing to the project's set timeline.

There were also findings related to elements that were previously reviewed to be critical, but the study results show that they are not impactful. Examples of these results are providing information about site assessment and equipment allocation. These are examples of elements that the project owners can give a lower priority as they are prioritizing other critical decisions. The results of this study will enable project owners to be aware of important preconstruction elements impacting their projects' timelines. The results also help project owners prioritize their decisions to avoid unwanted changes in their project schedule.

6. Conclusion

One of the ultimate goals of the preconstruction phase is to arrive at a price that meets the owner's needs and to do so in a timely manner so as not to delay the start of the construction phase or cause any other adverse outcomes related to the delay. One critical component of this process is controlling time variances during the preconstruction phase since lack of time certainty increases the risk of poor project plannings (planning for finances, schedule, resource allocation, and document management). There are many preconstruction elements, discussed in this study, that significantly impact time variances during the preconstruction phase. There are also elements that are not critical and can be given a lower priority in order to focus on more important decisions. This study detailed the most critical elements that should be reviewed and prioritized by the project owner. The identified list included design errors, major scope changes, model updates, project size, VEs, awarding methods, target budget, budget updates, and project recency and using BIM.

For proper planning and setting up a realistic preconstruction schedule, it is critical to be familiar with the significant preconstruction elements. As important as knowing the critical element, owners should educate the rest of the project team, including designers and CMs, about the criticality of these elements and make them implement decisions related to these elements into their practices during the decision-making process. Therefore, owners should pay attention to investing in teams with a similar culture that are willing to come to the table with ideas, collaborate and understand the criticality of each element, and implement the best practices during the preconstruction phase.

7. Limitations

Measuring and analyzing quantitative data was the focus of this study and other historical data that were subjective were not included. Although a comprehensive list of critical preconstruction elements is included in this research, there may be other important elements that can be measured qualitatively that were not included in the study analyses. In addition, the majority of projects reviewed in this study are private commercial buildings. Therefore, the findings of this study may not be generalizable to federal or other publicly funded projects. The next limitation is related to using BIM as the data collection method in this study. Since studying objective data was the focus of this study, a BIM and related cost estimating platform were used. Inherent even in a seemingly objective environment are the people who manage the preconstruction process and generate BIM data. These people may make decisions based on their own experiences, biases, or, at the very least, based on information available at the time. This means that there may be some subjectivities in how the BIM data are created and subsequently conceived of. In terms of further research, it is recommended that other types of projects (e.g., government-funded) be included.

Acknowledgement

This research was supported by JE Dunn Construction Company through their permission to use the company's advanced BIM tools (LENS), in addition to giving access to project resources that are owned by JE Dunn Construction. The research involved the collaboration of many people including, but not limited to Trent Nichols, JE Dunn National VDC Director, Chalmers Ward, former JE Dunn Regional HR Director, and Jason Hickam, JE Dunn National Director of Preconstruction and Estimating.

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Appendix 1

Variable Table of Preconstruction Elements Collected from BIM-Related Software and Recorded Documents

Preconstruction element	Description	Value
Overall preconstruction time	The overall preconstruction timeframe (in months) from when the first budget is developed until when the last one is submitted	Continuous (range = 0-49)
Average estimating time	Average time (in days) spent on budget updating during the preconstruction phase	Continuous (range = 4-497) Mean: 98
Target budget	Whether or not the budget goals were identified by the owner during preconstruction	Nominal (No, Yes)
VEs	VE was provided by the estimating team to the owner and design team during preconstruction	Dichotomous (No, Yes)
RFIs	Number of RFIs submitted by an estimating team during preconstruction	Continuous (range = 0-318) Mean: 37
Major changes	The number of major-scope and sub-scope changes (major area of work to be performed) made by the design team during preconstruction	Continuous (range = 0-62)
Time of major changes	The time point when major-scope and sub-scope changes happened during preconstruction	Nominal (Early, Middle, Late)
Project size	Changes in the size of the building based on its area	Continuous (range = -78,672sf-1,601,695sf) Mean: 38,179 sf
Design errors	Number of design errors and omissions made by the design team in the Revit model	Continuous (range = 2-4,494)
Budget update	The number of times the budget was updated by an estimating team	Continuous (range = 1-8) Mean: 3
Model update	The number of times the Revit model was updated by an estimating team for cost estimating purposes	Continuous (range = 0-47)
Using BIM for cost estimating purposes	The team's effort in using the provided Revit model for the cost estimating purposes	Nominal (Not a BIM project, Revit model is provided and used for the estimating process, Revit model is provided but not used for the estimating process, Early Revit model is used for the estimating process, but later updated models are not used)
Project recency	The year when the preconstruction phase of a project was developed	Nominal (2017, 2018, 2019)
Construction type	The type of construction i.e. a renovation, new construction, or mix of renovation with new construction	Nominal (renovation, new construction, mix of renovation with new construction)
Location	Regional location of the project	Nominal (East, West, Midwest, South-Central)
Awarding method	The method by which a project was awarded, i.e. a negotiated or hard bid	Nominal (negotiated, hard bid)
Delivery method	The method of delivery, which involves planning, design, and construction teams	Nominal (DB, DBB, CM@R)
Tracking schedule	Project schedule is updated during the cost estimating process	Dichotomous (No, Yes)
DFR	The changes in percentage cost considered for design fee and reimbursement	Continuous (range = -6%-7.5%) Mean: 0.008%
Model site assessment	Site assessment and topography provided by the design team in the Revit model	Dichotomous (No, Yes)
Model equipment allocation	Mechanical equipment location provided by the design team in the Revit model	Dichotomous (No, Yes)
Detailed material in the model	Detail and specific information on different materials, equipment, and systems provided in the model. Examples of the detailed material would be millwork, door and hardware, mechanical and electrical equipment, interior window and storefronts, etc.	Dichotomous (No, Yes)