EPiC Series in Built Environment
Volume 5, 2024, Pages 668–676
Proceedings of 60th Annual Associated Schools of Construction International Conference

Analyzing Billing Patterns in The Construction Industry Using Earned Value Analysis

Bharath Chandrasekar, MSc.
Colorado State University
Fort Collins, Colorado

John Killingsworth, Ph.D.
Colorado State University
Fort Collins, Colorado

Kevin Bright
Pronovos
Atlanta, Georgia

Earned Value Analysis is an effective tool to manage project schedule and cost controls. However, it is not widely used because of the time resources required from construction managers. This research considered whether a central tendency exists in construction projects with same, or similar durations regarding cumulative earned value. An analysis was performed of a dataset containing 967 projects with durations primarily spanning 12 to 14 months. By examining the monthly billing percentages, average monthly billing percentages were calculated alongside their standard deviations, leading to the determination of minimum and maximum confidence intervals. An Earned Value Analysis (EVA) curve was then constructed based on these findings. The research found that a generalizable EVA curve can be established with relatively minimal variation from the mean. Key findings include an established average monthly billing percentage and a predictive EVA curve, which aids in identifying minimum and maximum confidence intervals for project billings. The study contributes to EVA knowledge by laying a foundation for predictive modeling in project billing, with implications for future research.

Key Words: Earned Value Analysis, Predictive Model, Construction Finance

Introduction

An essential component in the successful execution of construction projects is sound financial management, with cash flow being of paramount importance (Narbaev & De Marco, 2014). Proper cash flow management ensures that projects meet set timelines and quality benchmarks (Zayed et al., 2009), without significant margin erosion. Project management, especially in the construction sector, is a complex task that requires precise and consistent monitoring. One of the tools available to help in this is earned value analysis (EVA) (Kerkhove & Vanhoucke, 2017). EVA is a method that offers a clear picture of how a project is performing by looking at costs, schedules, and work completed. However, many avoid using EVA, because they find it complicated or time-consuming, especially when considering its application for just one project. This study addressed the complexity and time-consuming nature of Earned Value Analysis (EVA) by developing a more streamlined approach. By calculating the cumulative earned values to an extensive dataset of 967 construction projects of similar durations, we established a central tendency of behavior. An established EVA curve from such an extensive number of project serves as an initial, generalizable guideline – thus removing the time-consuming process of setting up the project specific EVA curve. This research sought to establish that curve, and create a tool that CM's can use to monitor their project controls – within reasonable limitations.

The underlying issue here is that without EVA, contractors often find themselves unsure about the progress of their projects. They might be halfway through their timeline but unsure if they are halfway through their budget. This uncertainty can lead to problems, including increased costs and missed deadlines (Nour et al., 2012). Consider a contractor who does not realize they are behind schedule until it is too late. If they had known earlier, they might have been able to employ additional resources or explore creative ways to catch up (Kim et al., 2003). Being informed in a timely manner is critical. If contractors know where they stand - if they are ahead or behind schedule, over or under budget - they can make necessary adjustments (Ball & Nikolaev, 2022). They can allocate more resources or use their backup plans to ensure they finish on time.

The study presented in this manuscript originates from recognizing these challenges in the construction sector. Recognizing the complexity and time-resource requirements to use EVA, we began to explore methods for automating such an endeavor. By providing a clearer way to monitor and adjust project progress, the expectation is to develop an EVA model with which contractors can improve their project's budget and schedule performance.

Literature Review

To better understand the potential uses and current limitations of EVA, a literature review was first performed. Abuelnasr et al., (2021) introduced an optimization model to understand the relationship between cash flow and material procurement plans. Their research highlighted the potential of a well-structured procurement strategy to optimize cash flow in construction projects, thus fostering an environment for efficiency and growth.

Zayed & Liu, (2014)conducted an exploration into the intricacies of construction projects, highlighting the critical importance of adept cash flow management in an environment fraught with risks. Their study aimed to illuminate the diverse factors that unpredictably influence a project's cash flow. Utilizing the analytic hierarchy process (AHP) in tandem with simulation techniques, their research yielded noteworthy findings: cash outflows exhibited substantial variation, when considering all factors based on a total cost variation. The results from this investigation underscored the considerable influence of each determinant on contractor cash flow performance. The conclusions drawn from their analysis further bolstered the imperative of accurate cash flow forecasting and established a foundational backdrop for the current study's pursuit of creating a predictive model from extensive datasets.

Gilchrist & Himmelberg, (1995) explored the role of cash flow in driving investment decisions, specifically within the context of the "financial accelerator" mechanism. Their research suggests that firms, especially those financially constrained, display an elevated sensitivity to cash flow, reinforcing the interplay between investment dynamics and capital market imperfections. The meticulous observation and control of financial outflows and inflows become even more critical when considering projects spanning 12 to 15 months. This significance was captured by (Bhosekar & Vyas, 2012), who delved into EVA as an effective tool to oversee and predict financial facets of construction projects. Their findings shed light on EVA's capability to anticipate potential delays, offering stakeholders a preemptive strategy.

Recent innovations in financial methodologies for construction underscore the industry's recognition of evolving challenges. Proaño-Narváez et al., (2022), for instance, explored the efficacy of Earned

Value Management (EVM) in construction, highlighting its importance in monitoring deviations between planned and actual costs. Kerkhove & Vanhoucke, (2017), on the other hand, proposed the incorporation of the Earned Incentive Metric (EIM) to refine the EVA methodology. Their work was indicative of the industry's desire for improved accuracy in financial forecasting.

Narbaev & De Marco, (2014) examined the integration of traditional forecasting tools with novel methodologies. Their findings indicated that such integrative approaches could pave the way for more holistic financial management in construction. Zohoori et al., (2019) suggested a hybrid methodology combining EVA with adaptive fuzzy control to respond better to dynamic project conditions, complementing this notion, Song et al., (2022) combined EVA and schedule risk analysis, suggesting an enhanced control over project costs, especially for complex undertakings. With increasing complexity and varying durations in today's construction projects, it becomes essential to address unique challenges head-on(Nour et al., 2012b). The research bridges existing gaps by offering a systematic exploration of billing and earned value, thus equipping stakeholders with a robust tool for enhanced financial forecasting and strategic project planning in the construction sector. Thus, the study aimed to answer the following research questions:

1) Can a predictive EVA curve be established for a construction project; with central behaviors such as means and standard deviations?
2) Does the EVA curve statistically differ significantly based on contractor type?

A notable gap in the literature on EVA exists because of the previous limitations and access to large quantities of project data. With the advent of wide-spread, web-based data analytics, sizable databases, from many construction companies, across many U.S. states now exists. Access and analysis of this database thus allows an exploration into EVA which had previously not been available to the research community. Therefore, with new-found access to such data, this research sought to address these two fundamental EVA research questions.

Methodology

To answer these research questions, a quantitative methodology was employed that used descriptive statistics to determine central tendency behaviors in EVA. This section describes the data collection process, the cleaning, and the analysis of data.

The data for this study was sourced from a database of a construction analytics provider, safeguarded by nondisclosure agreements for participant confidentiality. The study concentrated on 967 projects, each lasting 10-14 months, undertaken by 47 contractors. To standardize the time variable, the analysis focused on projects with a 12-month duration. Projects were considered complete if they achieved 100% progress in exactly 12 months. Projects with billing delays of three months or more were omitted to maintain data integrity, aiming to develop a predictive model for contractor billings in typical 12-month projects. This refined the dataset to 472 projects.

For each project and for each invoice, the invoiced amount was divided by the total contract amount – establishing the percentage completed in each month of each project. A fundamental assumption of this study was that the percentage billed is directly proportionate to the earned value. This is rooted in the understanding that contractors *should* invoice upon completion of specific tasks or milestones. This relationship between billing and work completion is pivotal for the predictive model constructed, which seeks to present a generalized behavioral pattern of contractors across a 12-month project duration.

Each project underwent a thorough review, focusing on the billed percentage every month. A consolidated average and standard deviation for each of these monthly billed percentages was computed. This methodology established the minimum and maximum confidence intervals, essential for gauging the reliability and consistency of the monthly billing data. Furthermore, projects that had more than three of the twelve months of behavior outside beyond two standard deviations were eliminated. This decision is rooted in the statistical likelihood that such deviations might skew the overall results, thus affecting the reliability of the predictive model. This last data-screening process yielded a final list of 345 qualified projects. The 345 construction projects were performed by a total of 47 construction companies, representing all nine regions of the United States (regions defined by the U.S. Census Bureau), and one company from Canada. The companies ranged in size (annual sales revenue) and type: General and, or Heavy Civil Contractors and Specialty Contractors. General (qty. 16) and heavy civil (qty. 5) contractors (21 of the total 47) handle larger-scale vertical and infrastructure construction projects, respectively. The data consisted of 177 projects performed by General Contractors and 58 projects from Heavy Civil & Excavation Contractors, for a sum of 235 projects performed by this contractor type, or stratum. Their annual sales revenues ranged from approximately $3M to about $2.4B. Specialty contractors primarily focus on niche construction activities or tasks, such as electrical, mechanical, fire protection, and other specialized services. The dataset comprised 110 projects from 26 specialty contractors, whose annual sales revenue ranged from approximately $13 M to $339 M.

Results

The progression of billings within a typical 12-month construction project was characterized by an S-curve with fundamentally three unequal trimesters. Each trimester of the construction project varies in terms of earned value and time. The aggregate results of 345 construction projects established the mean for each month and the standard deviation from that central tendency. This S-curve, representing the mean score for each month (depicted in Figure 1), helped to visualize the varied progression in each trimester. For the aggregate dataset and the subsequent strata, the second trimester consistently represented the timeframe within which the greatest project value was earned. However, that second trimester began in either the third or fourth month of the twelve-month duration. Regardless of the strata, we found that the fourth month always demonstrated the highest earned value of any of the twelve months. This was true whether stratified by project size (contract revenue), or contractor type. For the aggregate dataset of all contractors, the second trimester was completed by the 6th month. At this point, earned values per month dropped under 10% - which defined the four (one third of the project duration) highest-earning months. Figure 1 provides a graphical representation of the aggregate data, with the center line representing the average of the cumulative percent billed each month. This average is framed by an upper and lower limit, respectively depicting the two standard deviations from the mean scores.

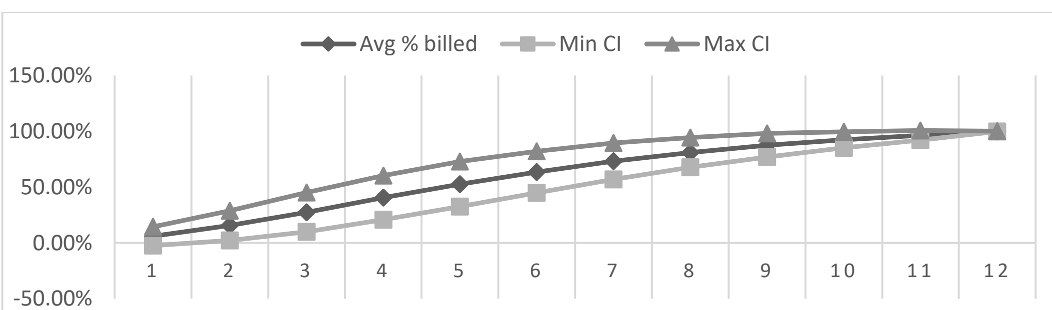

Figure 1: Aggregate S-Curve For All Contractor Types

Figure 1 shows the average percent billed as an aggregate and shows the minimum and maximum confidence interval. To better understand the earned value patterns between contractor types, the dataset was stratified into two types. The first type, Group 1, included all General Contractors, Heavy Civil and Excavation Contractors, which comprised 21 out of the 47 Contractors. The remaining 26 contractors were classified into the second type, Group 2, as Specialty Contractors.

Table 1: Monthly Comparison of Average Percentage Billed and Earned Value Between Two Strata

	Group 1		Group 2		Aggregate of All Types	
Month #	Cumulative Average % Billed	Earned Value Each Month	Cumulative Average % Billed	Earned Value Each Month	Cumulative Average % Billed	Earned Value Each Month
1	5.44%	5.44%	7.32%	7.32%	6.04%	6.04%
2	14.92%	9.48%	17.15%	9.82%	15.64%	9.60%
3	26.37%	11.45%	29.96%	12.82%	27.52%	11.88%
4	38.46%	12.09%	45.22%	15.26%	40.64%	13.12%
5	50.43%	11.96%	57.50%	12.28%	52.70%	12.06%
6	61.77%	11.35%	66.87%	9.38%	63.41%	10.71%
7	72.18%	10.40%	75.43%	8.56%	73.22%	9.81%
8	81.14%	8.97%	81.02%	5.59%	81.10%	7.88%
9	88.16%	7.02%	86.50%	5.48%	87.63%	6.53%
10	93.15%	4.98%	91.21%	4.71%	92.52%	4.89%
11	97.04%	3.90%	95.20%	4.00%	96.45%	3.93%
12	99.98%	2.94%	99.97%	4.76%	99.98%	3.53%

Despite the similarities in percent billings per month, the comparison between strata was anything but uniform. From table 1, it can be observed that the peak in the earned value for both groups was recorded in the 4th month. For Group 1, this was 12.09% while Group 2 surged to a 15.26% earned value at a 45.22% billed rate. This disparity between billed percentage and earned value, particularly pronounced in this month, signaled the need to measure the statistical differences in the mean scores.

The financial variability within the billing process was reflected in the standard deviation and confidence intervals, which presented a high degree of variability at the beginning of the year, especially for Group 2. However, as the months progressed, a decline in standard deviation was observed, indicating a stabilization in billing practices as projects neared completion. The narrowing confidence intervals further substantiated this trend, revealing a reduction in uncertainty and an increase in predictability of billing percentages.

When examining the combined average of both groups, the billing pattern reflects the broader industry trend, with the 4th month serving as a significant financial milestone. The combined average earned value in this month was an impactful 13.12% against an average billing rate of 40.64%. Such a pattern underscores the importance of the 4th month in project financial management and potentially in the planning of cash flows and resource allocation.

The detailed analysis of billing and earned value over a year offers a comprehensive view of the financial evolution within construction projects. The peak in earned value in the 4th month across both groups, irrespective of the average billed percentage, is particularly illuminating, indicating a possible industry standard or a common project phase where higher earnings are recognized. The initial variability in billing, as depicted by the standard deviation and confidence intervals, gives way to a more stable pattern as projects approach completion. These insights not only enhance the understanding of billing practices but also provide a valuable forecasting tool for future project financial planning.

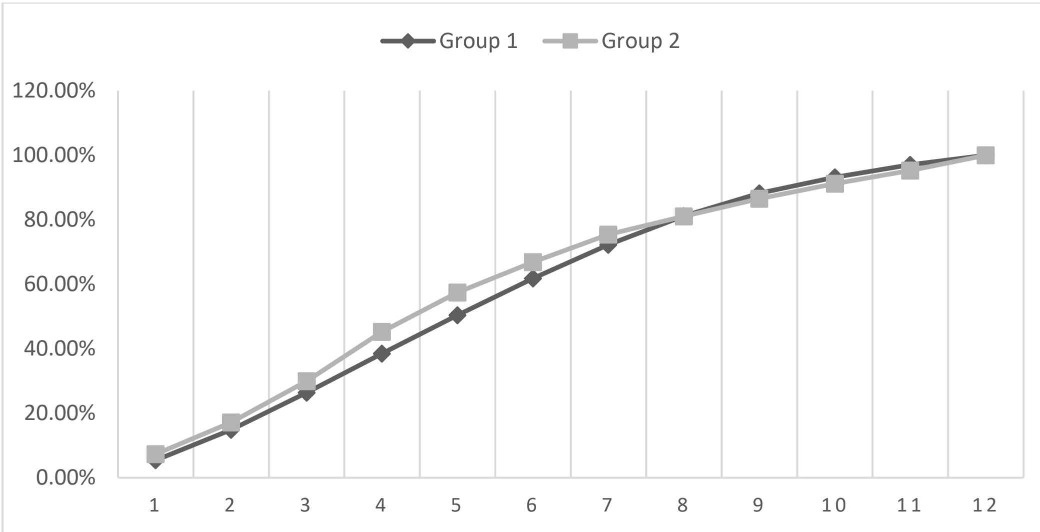

Figure 2: 12-Month Billing Trends for Group 1 & Group 2

The line chart depicting the Average Percent Billed versus Project Duration unfolds the billing progression across a 12-month period for two primary contractor groups. The shape-coded lines—diamond for Group 1 comprising General Contractors, Heavy Civil, and Excavation Contractors, square for Group 2 consisting of Specialty Contractors like Mechanical and Electrical, and grey for the combined average—chart a steady climb reflective of the billing milestones achieved as the projects mature. From the outset, Group 2 edges ahead with a higher initial billing percentage, suggesting a more rapid onset into the billing cycle—a likely consequence of the nature of specialty contract work. Such contractors typically engage in discrete project components that are often critical in the early stages, thereby enabling an earlier billing opportunity compared to the more extensive and phased work of General Contractors.

As the months roll on, both groups exhibit a consistent ascent, with Group 2 maintaining a slender lead over Group 1. This persistent disparity hints at underlying differences in project management and billing practices inherent to the types of contracts and work undertaken by each group. The convergence of the billing lines toward the end of the 12-month cycle is particularly telling. It not only signifies a harmonization in the completion of billing but also reflects the culmination of various project phases where the final billing percentages are recorded. This convergence may mask the initial discrepancies but points to a sector-wide standardization in project completion and financial closure.

Table 2: T stat & P-values from One-tail and Two-tail T-tests between Group 1 and Group 2

Month	P (T<=t) One Tail	P (T,=t) Two Tail	T Stat
1	0.0838	0.1677	-1.3853
2	0.0728	0.1457	-1.4603
3	0.0315	0.0631	-1.8676
4	0.0007	0.0015	-3.1979
5	0.0005	0.0015	-3.3311
6	0.0036	0.0073	-2.7054
7	0.0236	0.0472	-1.9948
8	0.4459	0.8919	-0.136
9	0.1408	0.2816	1.0793
10	0.0173	0.0346	2.1254
11	0.0004	0.0008	3.3939
12	0.1922	0.3844	0.8727

The statistical analysis conducted via one-tail and two-tail tests as shown in table 2 provides compelling evidence of the billing pattern discrepancies between General Contractors and Specialty Contractors. The p-values obtained from the one-tail test are particularly illuminating, with months 4, 5, and 11 showing statistically significant results ($p < 0.05$). The low p-values in the earlier months suggest that these billing discrepancies are more pronounced at specific stages of the project lifecycle. Conversely, the two-tail test results, which address the question of any difference in billing patterns, also show significant results during the same months. This reinforces the notion that the billing patterns between the two groups differ substantially during certain project phases. The T statistics from the analysis reveal distinct billing trends between Group 1 and Group 2. Negative T values in the initial months (months 3 to 6) with corresponding one-tail p-values below 0.05 indicate that Specialty Contractors (Group 2) billed more significantly during these early stages compared to General Contractors (Group 1). This suggests that the specialized nature of their work likely leads to earlier billing milestones. A stark reversal is observed in month 11, where a positive T statistic with a low p-value points to Group 1 billing a higher percentage, possibly due to reaching substantial completion phases. In months with T statistics near zero and non-significant p-values (months 8 and 12), there appears to be no statistical difference in the billing percentages, indicating a potential alignment of billing practices towards the end of the project cycle. These variations in T values underscore the dynamic billing landscape within the construction industry, reflecting the different project phases and contractor roles.

The billing discrepancies between the General Contractors and Specialty Contractors underscore the multifaceted nature of construction project management. The early lead by Specialty Contractors could be attributed to their engagement in critical tasks that permit earlier billing, whereas the steady catch-up by General Contractors mirrors their extensive involvement over the project's full duration. Contractual terms, payment schedules, project milestones, and cash flow strategies all play a part in shaping these billing patterns.

Understanding these dynamics is crucial for explaining the financial operations within the construction industry. It provides stakeholders with insights into effective cash flow management, risk mitigation, and the strategic planning necessary to align project milestones with financial objectives. The observed billing patterns and their eventual convergence also offer assurance of a mature and predictable financial framework within the construction sector, which is vital for its sustained growth and stability.

Conclusion

In conclusion, the research conducted provides a comprehensive overview of the billing practices and financial achievements in the construction industry, segmented into General Contractors, Heavy Civil, and Excavation Contractors (Group 1), and Specialty Contractors (Group 2). The data, eloquently visualized through a line chart, demonstrated a systematic and steady increase in the average percentage billed across the project duration, with notable billing discrepancies between the two groups.

Group 1's progression, though initially slower, displayed a strong finish, indicative of the nature of large-scale and phased projects that these contractors typically manage. In contrast, Group 2 showed a swifter billing initiation and maintained a narrow lead throughout the year, reflecting the specialized, compartmentalized nature of their work and possibly more aggressive billing terms. The synchronization of billing percentages in the latter months of the project timeline suggests a convergence in project completion strategies, despite the initial disparities. This alignment is a positive indication of the industry's ability to standardize project completion and financial closure, irrespective of the contractor group or project type. Moreover, the peak in earned value observed in the 4th month marks a significant financial milestone, potentially indicative of industry-wide billing practices or project lifecycle patterns.

Discussion and Limitations

Given the abundant data at hand, there was a resolute endeavor to conceptualize a predictive model. Crafting such a model is pivotal for contractors. Armed with this model, contractors can foresee project outcomes with greater precision. This prescient capability stands to revolutionize their upcoming projects, endowing them with refined financial predictions, enhanced risk management strategies, and judicious resource allocation. The exploration of these billing patterns provides valuable insights for construction project management, particularly in the realms of financial forecasting, cash flow management, and strategic planning. It highlights the importance of understanding the billing cycles and earned value trends which are critical for aligning financial operations with project milestones. While the current research has delved into a 12-month project cycle, it paves the way for future investigations into longer project durations. There is potential to expand this research to projects that extend beyond the typical annual cycle, to understand if the billing patterns observed herein persist, taper, or if new trends emerge over a protracted timeline. Such longitudinal studies could greatly enhance the predictive capabilities for financial planning in the construction industry, ensuring stakeholders are better equipped to manage the financial aspects of construction projects with greater precision and insight.

Considering the previous literature that informed this study, and the results established by this study, we recognized that we are only at the cusp of what can be further researched. Earned value analysis, provides an effective communication tool within the construction project team – including the owner, the construction manager, and the trade partners (to name a few key stakeholders). And this study provided insight into the potentiality that standardized EVA curves might be established with a relatively high level of accuracy. Yet, further research must continue to improve the accuracy and predictability of the EVA curve. For example, future studies should consider longer or shorter durations. Additionally, further stratification of the data may reveal specific nuances in the EVA curve. All of these considerations can and should be integrated into future research on the subject.

Regardless of the current limitations, this study presented the first step towards establishing a generalizable EVA curve – which, if used appropriately, enhances the predictive capabilities of schedule and cost performance monitoring on a construction project.

References

Abuelnasr, M., Etman, E. E., & Sanad, H. (n.d.). *Optimizing Cash Flow of Construction Projects through Material Procurement Plans Master of Science View project Critical Chain Management View project*. https://www.researchgate.net/publication/354654529

Ball, R., & Nikolaev, V. V. (2022). On earnings and cash flows as predictors of future cash flows. *Journal of Accounting and Economics*, *73*(1). https://doi.org/10.1016/j.jacceco.2021.101430

Bhosekar, S. K., & Vyas, G. (2012). Cost Controlling Using Earned Value Analysis in Construction Industries. *International Journal of Engineering and Innovative Technology (IJEIT)*, *1*(4). https://www.researchgate.net/publication/265285339

Gilchrist, S., & Himmelberg, C. P. (n.d.). *Monetary ECONOMICS Evidence on the role of cash flow for investment*.

Kerkhove, L. P., & Vanhoucke, M. (2017a). Extensions of earned value management: Using the earned incentive metric to improve signal quality. *International Journal of Project Management*, *35*(2), 148–168. https://doi.org/10.1016/j.ijproman.2016.10.014

Kim, E. H., Wells, W. G., & Duffey, M. R. (2003). A model for effective implementation of Earned Value Management methodology. *International Journal of Project Management*, *21*(5), 375–382. https://doi.org/10.1016/S0263-7863(02)00049-2

Narbaev, T., & De Marco, A. (2014b). An Earned Schedule-based regression model to improve cost estimate at completion. *International Journal of Project Management*, *32*(6), 1007–1018. https://doi.org/10.1016/j.ijproman.2013.12.005

Nour, M., Ibrahim Nour, A., Noor, M. I., Nour, A., Musa, S., zorqan, S., & Info, A. (2012a). The Role of Cash Flow in Explaining the Change in Company Liquidity. *Journal of Advanced Social Research*, *2*(4), 231–243. https://www.researchgate.net/publication/257066312
https://www.researchgate.net/publication/257066312

Proaño-Narváez, M., Flores-Vázquez, C., Vásquez Quiroz, P., & Avila-Calle, M. (2022). Earned Value Method (EVM) for Construction Projects: Current Application and Future Projections. *Buildings*, *12*(3). https://doi.org/10.3390/buildings12030301

Song, J., Martens, A., & Vanhoucke, M. (2022). Using Earned Value Management and Schedule Risk Analysis with resource constraints for project control. *European Journal of Operational Research*, *297*(2), 451–466. https://doi.org/10.1016/j.ejor.2021.05.036

Zayed, T., John, S., Liu, Y., & Li, S. (2009). *Cash flow analysis of construction projects Oil and Gas Project View project Investigating into OHS of Repair, Maintenance, Alteration, and Additional (RMAA) Works View project CASH FLOW ANALYSIS OF CONSTRUCTION PROJECTS*. https://www.researchgate.net/publication/266289526

Zayed, T., & Liu, Y. (2014). Cash flow modeling for Construction projects. *Engineering, Construction and Architectural Management*, *21*(2), 170–189. https://doi.org/10.1108/ECAM-08-2012-0082

Zohoori, B., Verbraeck, A., Bagherpour, M., & Khakdaman, M. (2019). Monitoring production time and cost performance by combining earned value analysis and adaptive fuzzy control. *Computers and Industrial Engineering*, *127*, 805–821. https://doi.org/10.1016/j.cie.2018.11.019