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Quality-based performance comparison of design-build and design-bid-build project delivery methods for warehouses and self-storage facilities

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Abstract

Warehouses and Self-Storage facilities are essential for e-commerce operations, providing inventory, distribution, and delivery space. As per the Bureau of Labor Statistics, the number of warehousing and storage businesses in the United States increased from 15,152 in 2010 to 20,002 in 2021, showing continuous growth over the decade. Given the recent surge, there is a need to better understand the impact of these delivery methods on the quality metrics of these facilities. This study aims to contrast the measure of quantitative quality performance of design-build (DB) versus traditional design-bid-build (DBB) project delivery methods (PDM) for warehouses and self-storage facilities. This research conducted a literature review to document quality metrics to compare DBB and DB on project performance. ANOVA was conducted to compare the significant difference between the means to compare the performance between delivery methods and project outcomes across these critical areas. With these insights, owners can make informed strategic decisions about selecting the optimal PDM for future storage facility projects based on their unique quality and scope management objectives.

Keywords: Storage facilities, Design-Bid-Build, Design-Build, Project Performance, Quality Metrics, Warehouses, Self-Storage facilities.

1. INTRODUCTION

Warehouses and Self-Storage facilities form the core of modern e-commerce operations. Warehouses are facilities for cargo storage that hold a buffer function for optimizing inventory management among suppliers, producers, and customers[1]. Self-storage facilities allow individuals and companies to rent storage space for personal or company use over a specified period[2]. These facilities are essential for optimizing costs and bridging the gap between producers and consumers, providing the infrastructure for storing, managing, and efficiently distributing inventory and goods[3]. As the e-commerce sector expands, the demand for these storage facilities has increased, making their design and construction a critical aspect of business operations. Warehouses are crucial elements of the supply chain, and there has been a notable rise in the demand for warehousing operations[4]. The ability to evaluate and improve the performance of the construction of these projects has become more crucial. There has been extremely limited analysis isolated specifically to the construction of warehouses and self-storage facilities[5].

This problem can be addressed by measuring the performance of previously executed storage facility projects. Measuring project performance is critical to business success in a time of globalization and an increasingly competitive environment. The performance measurement revolution has spread to many industries, including construction[6]. In the Construction Industry, project performance evaluation is crucial in guiding organizations to success across various industries. The construction industry has shown less success in evaluating project performance, leading to lower productivity and performance than the manufacturing sector[7]. Performance management enables managers to accurately pinpoint and resolve issues, enhance communication, and maintain progress on schedule[8], leading to better project performance.

In construction, Project performance outcomes are greatly affected by the selection of PDM([9], [10]). DBB and DB represent the two most frequent or common construction PDMs, with the DBB involving separate contracts for design and building entities and the latter utilizing a combined single-point design and build contract[11]. There is a vast body of research comparing DBB and DB performance spanning costs, schedule, quality, owner satisfaction, and other metrics ([12], [13], [14], [15], [16], [17], [18]). Still, there is considerably less research on projects within storage facilities. The analysis conducted in prior studies mainly focused on comparing DB vs DBB based on cost and schedule performance but did not emphasize quality metrics. The objectives of the study are to (i) identify quality metrics and (ii) analyze the comparative performance of PDM for warehouses and self-storage projects, facilitating unique and specific insights tailored to an economically critical sector. The analysis can guide owners to match delivery methods to their objectives.

2. LITERATURE REVIEW

Metrics have been applied to assess performance outcomes for distinct phases in construction projects[19]. Khalef and El-Adaway[20] aimed to provide an improved understanding of DB and DBB methods for crucial risks that impact schedule and cost performance in airport projects. The results of this study showed that the traditional DBB method leads to higher risks for most factors when compared to the DB method. The work of Cha & Kim[21] aimed to define a quantitative performance measurement system and establish the evaluation criteria. Based on the performance assessment methodology, twenty-two (22) residential building projects were collected for comparative analysis and evaluated to determine whether the system applied to potential projects. This study identified various performance indicators for residential building projects and developed an approach for measuring these indicators. The framework developed by Sharma[22] in 2021 offered a structured approach for evaluating various types of capital facilities in the healthcare sector, leveraging healthcare facility metrics and project databases. This quantified process efficiency and assisted decision-making for ongoing and completed healthcare projects. Multiple studies have computed performance metrics to evaluate outcomes for various industry types. However, it is noteworthy that existing literature lacks investigation on metrics for facility types like warehouses and self-storage buildings. This gap underscores the need for a dedicated assessment of storage facilities, highlighting an opportunity for further exploration in this field.

The literature review revealed the importance of the selection of an appropriate project delivery method for project success. A significant body of existing literature compared commonly adopted DB and DBB methods; rigorous analysis was conducted to compare the performance of DBB and DB models utilizing metrics for cost, schedule, quality, and owner satisfaction [11]. A study[23] conducted in 2022 compared the commonly used methods of project delivery, Design-bid-build, CMAR, and design-build, and addressed their advantages and disadvantages in differing project scopes and sizes. A significant number of studies focused analysis specifically on infrastructure projects delivered through both methods ([9], [15]). Migliaccio[24] empirically assessed military housing construction delivered through DBB and DB approaches. Analysis of schedule and cost metric data across projects deduced that DB demonstrated statistically significant advantages in minimizing timeline extensions and preventing budget overruns compared to DBB. In 2014, a study [25] used a meta-analysis approach explaining patterns, trends, and potential research findings across key performance metrics for the project cost, schedule, and quality. In 2013, Asmar [26] provided the first quantitative benchmarks evaluating the integrated project delivery (IPD) method, which showed superior performance for metrics such as quality compliance, faster delivery, and no significant cost premiums compared to non-IPD methods. However, their focus on complex healthcare and research facilities does not isolate factors unique to storage facilities.

In contrast to the popular belief that the DB method is better for schedule and cost performance, results from previously conducted studies ([13], [14]) proved that DBB was a better approach subject to different scenarios. In a study conducted in 2013, Florida Department of Transportation (FDOT) databases were compared arithmetically and statistically for the performance of the two delivery systems for a finite period [13]. DBB projects performed significantly better in cost but not as favorably in terms of duration. The cost Performance of DB and DBB across different project types was compared by Moon[14] in 2020 using a t-test on 197 public projects in Seoul, South Korea. The findings showed that the cost performance of the DBB method has a mediation effect on architectural building projects rather than civil infrastructure projects. This implied that DB should not be considered superior to DBB despite the lower cost growth.

A study conducted by Park[15] employed discrete choice and linear regression models to evaluate the cost and schedule data. The results of the study strongly supported the schedule effectiveness of the DB method, which is attributable to managerial efficiency. The overall percent changes from the original contract amount to production cost were lower for DB projects when compared to DBB projects, with the differences being statistically insignificant. Comparison of actual and adjusted contract amounts, examining direct costs attributed to change orders, exhibited a weak advantage of DB over DBB. Another study[16] in 2017 used 77 building projects built by United States public universities' planning and construction divisions to compare DB and DBB projects by deploying statistical analysis to determine if metrics related to cost, schedule, and change orders significantly differed for the two approaches. Results showed that DB projects significantly outperformed DBB projects in schedule saving; moreover, the number of construction change orders was substantially lower in DB projects than in DBB projects. A broad analysis by Sullivan[17] in 2017 compiled findings from over 30 previous studies contrasting Construction Manager at risk, DBB, and DB approach across various project types. DB demonstrated a significant advantage in schedule performance with 10.7% average growth versus 18.4% for DBB. DB also exhibited lower average cost growth at 2.8% compared to 5.1%, though not statistically significant. However, there were no consistent differences found in quality outcomes.

Table 1 below summarizes the sources from which metrics were identified evaluating the performance of cost, schedule, and quality in projects. The literature review observed that past studies mainly focused on analyzing cost and schedule performance, with limited attention to quality performance analysis within construction projects. This study aims to bridge this gap by prioritizing the analysis of quality metrics, thereby improving the understanding of the contribution of the selection of project delivery methods for better project outcomes. The current study utilizes metrics identified during the literature review to compare DB and DBB methods.

Table 1. Summary of Identified Metrics from Literature Review

No.	Type of Metric	Metrics	Previous Study
1	Cost	Cost Growth, Unit Cost, Profit Percentage, Award Growth, Intensity	[5], [11], [12], [14], [15], [16], [17], [19], [22], [24], [25]
2	Schedule	Schedule Growth, Construction Speed, Delivery Speed	[5], [11], [12], [14], [15], [16], [17], [19], [22], [24], [25]
3	Quality	Number of Change orders, Number of RFIs(Request for Information), Number of Punchlist Items, RFI Response time, Punchlist Completion Time, Owner Satisfaction, Turnover Quality	[6], [11], [12], [14], [16], [17], [25]

3. METHODOLOGY

In this study, a quantitative empirical comparison is conducted using data from a single organization throughout the United States on storage facility projects built by DB and DBB. The methodology consisted of Identifying a list of Quality metrics (*Table 2*) through a literature review, developing questionnaires for data collection, and conducting statistical analyses.

A standardized questionnaire was developed for DB and DBB projects, enabling streamlined distribution among project managers. The questionnaire had general project information, including location and contact information, as well as project cost and schedule information. The data from the questionnaire was cleaned by removing the data that was not in the current interest of the study and made ready for analysis. Outliers that are more than three times IQR(Interquartile range) above the third quartile or below the first quartile were removed before statistically testing data for significance. The one-way analysis of variance (ANOVA) is used to test the significance of project performance in terms of quality between projects with project delivery type DB and DBB. This study's chosen significance level is $\alpha = 0.05$. A p-value greater than or equal to 0.05 indicates statistical insignificance; if the value falls within the range of 0.01 to 0.05, the difference in mean values is considered significant, while a p-value equal to or less than 0.01 signifies high significance. The flow chart in *Figure 1* illustrates the methodology adopted for this study.

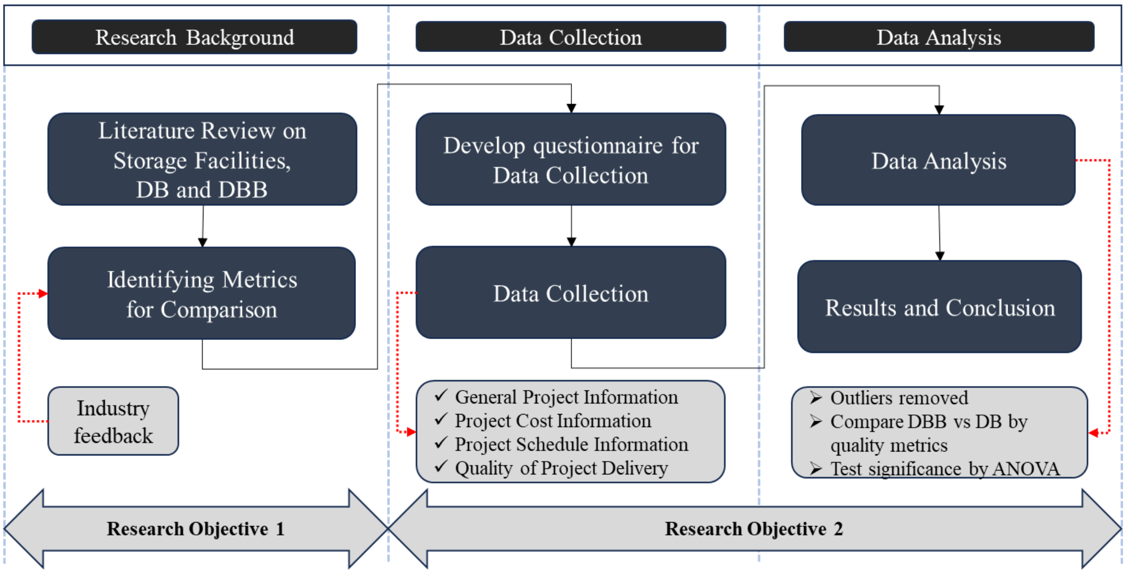

Figure 1. Flowchart illustrating the Methodology of the current study

4. RESULTS & DISCUSSION

4.1 Results of Objective 1 – (Identifying Metrics)

A list of quality metrics was identified through a literature review *(Section 2)*. The metrics identified are listed in *(Table 2)* with descriptions.

Table 2. List of Quality Metrics used for this study

No.	Metrics	Description
1	Number of Change orders	Total count of formal alterations made to the original scope of work outlined in a construction project contract.
2	Number of RFIs	A number of formal inquiries were initiated by project stakeholders seeking additional information or guidance on the project.
3	Number of Punchlist Items	Total Count of tasks, deficiencies, or incomplete work items identified during the final inspection phase of a construction project.
4	Punchlist Completion time (days)	Duration between the initial identification of punch list items and subsequent resolution or completion.

5	RFI Response time (days)	Duration taken by project stakeholders to respond to formal requests for information.
6	Owner Satisfaction	Owner satisfaction refers to the level of fulfillment or approval experienced by the owner upon project completion. (5 = Maximum satisfaction; 1 = not satisfactory)
7	Turnover Quality	Turnover quality refers to the standard of correctness and overall condition of a construction project at the point of handover. (5 = Maximum quality; 1 = Minimum quality)

4.2 Results of Objective 2 - (Data Analysis)

Data is collected through a questionnaire from 50 storage facility projects, out of which 25 are warehouses and 25 are self-storage projects; there are 38 projects with DB and 12 projects with DBB as their PDM. The questionnaire incorporated a predefined list of quality metrics *(Table 2)*, reflecting insights from the literature review of previous studies. While schedule and cost data were collected, the primary focus of the current study is the analysis of quality metrics. Throughout the data collection, the authors ensured to avoid any bias in the responses by providing a glossary of terms to the respondents and clarifying the questions, providing sufficient time for a survey response, and ensuring data confidentiality to the respondents.

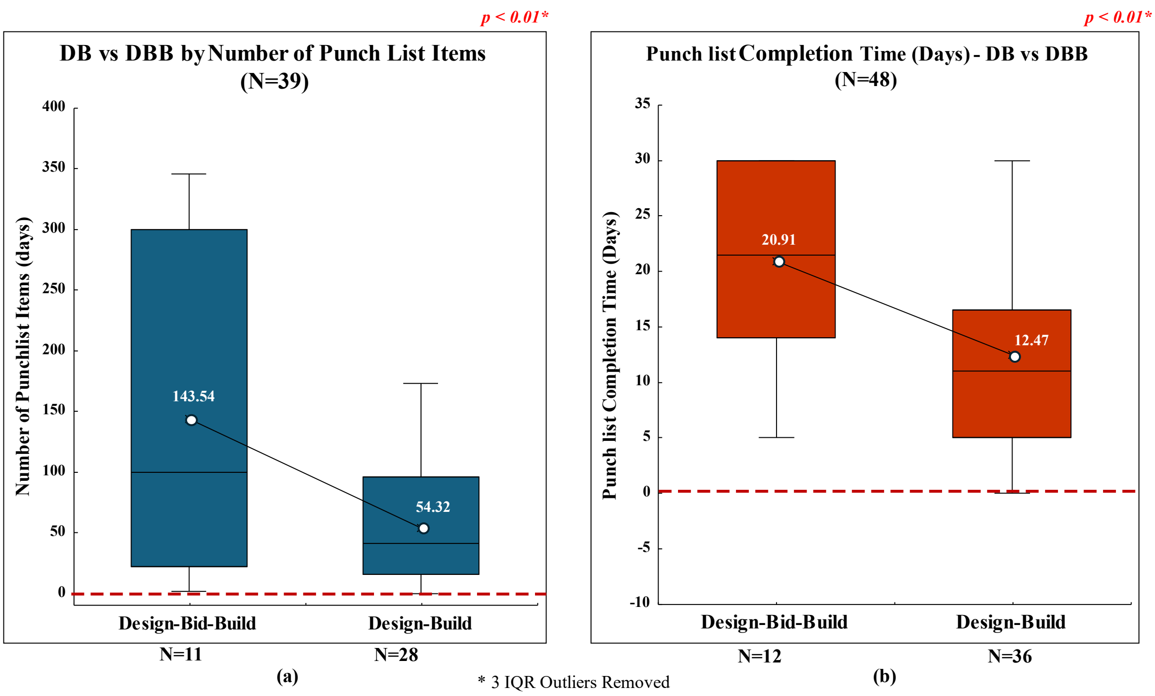

Figure 2. Comparison of DBB vs DB projects by Number of Punchlist Items and Punchlist completion time

In *Figure 2*, graph (a), it is crucial to note that for one (1) punch list item in DB project, there are 2.64 punch list items in DBB projects. Further, the higher spread of a number of punch list items in DBB projects vis-à-vis DB projects must prompt investigation of reasons for the same. In *Figure 2*, for graph (b), although the range of data distribution is similar for both DBB and DB projects, there is a significant difference in the means for punch list completion time (in days). It is evident that DB projects exhibit better control during the construction phase, resulting in significantly fewer post-construction corrections.

It is observed in Figure 3, graph (a), that the mean number of RFIs for DBB projects is approximately 287% greater than that for DB projects. Further, in Figure 3, graph (b), the mean of RFI response time for DBB projects is almost greater by 4.3 times that of DB projects. For both the comparisons in Figure 3, a significant p-value < 0.01 was observed, suggesting that DBB projects tend to have a substantially higher number of RFIs.

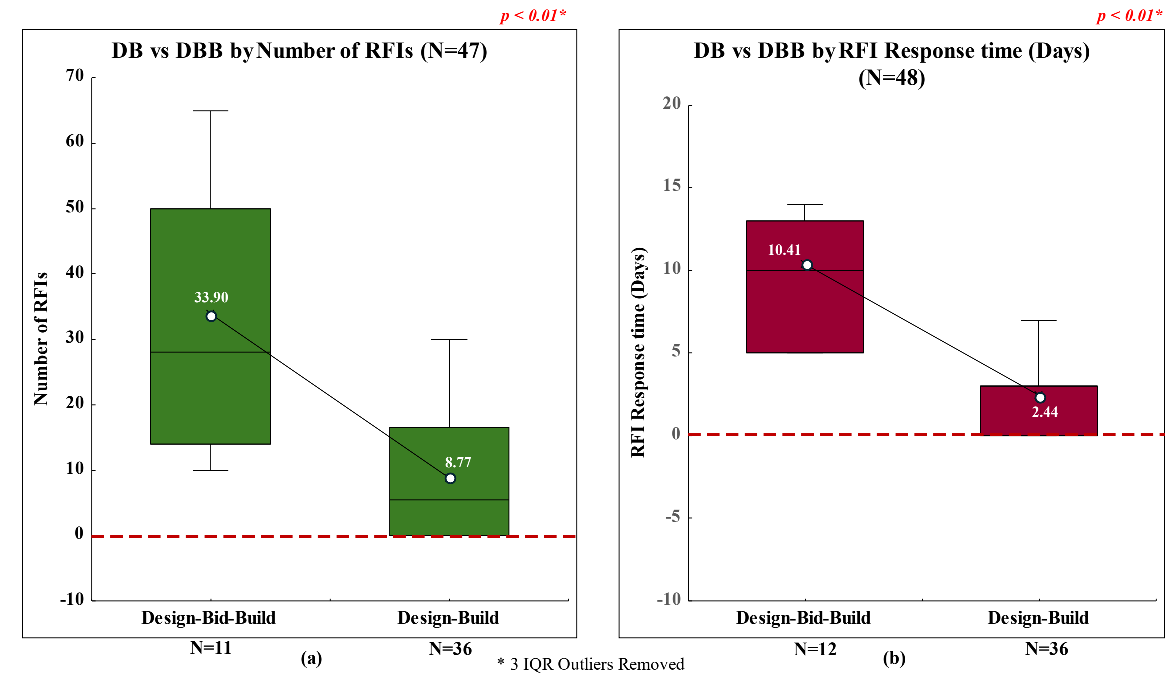

Figure 3. Comparison of DBB vs DB projects by Number of RFIs and RFI response time

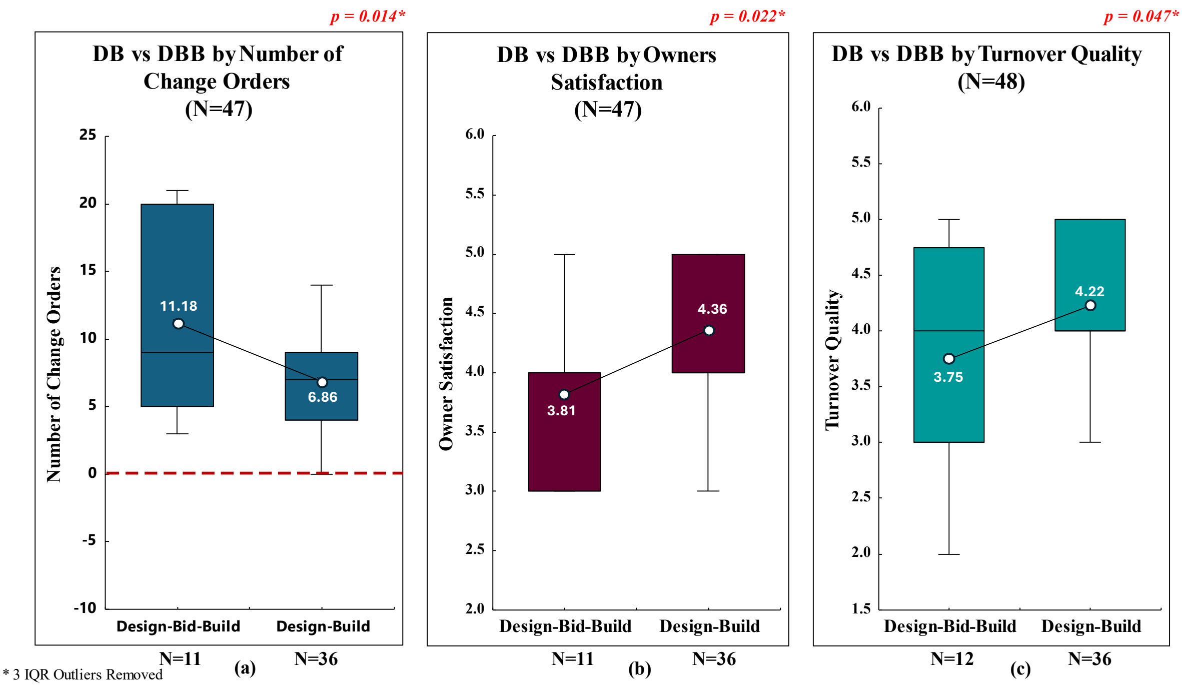

Figure 4. Comparison of DBB vs DB projects by Number of RFIs

The mean of the number of change orders in projects adopting the DBB method is 1.6 times greater than that of the DB approach with a significant p-value of 0.014 (*Figure 4, Graph a*). Fewer change orders for DB projects compared to DBB projects underscores the potential advantages of the collaborative approach of the DB method in minimizing project changes and enhancing efficiency. It is observed that owner satisfaction (*Figure 4, Graph b*) for projects that adopted the DB method is 14.4% more than that of the DBB method. Turnover quality (*Figure 4, Graph c*) is also a better performing metric for projects adopted DB method with 12.5% percentage difference higher that DBB method supported with significant difference in mean with p-values < 0.05.

A significant difference in mean values is observed in all the identified metrics (*Table 3*). p-value < 0.05 is observed across all the metrics.

Table 3. Summary of results after conducting ANOVA for the data, comparing DB & DBB

No.	Type of Metric	N Count*	p-value**	Current Study
1	Number of Change orders	47	0.014	Significant
2	Number of RFIs	47	< 0.01	Highly Significant
3	Number of Punchlist Items	39	< 0.01	Highly Significant
4	Punchlist Completion time	48	< 0.01	Highly Significant
5	RFI Response time	48	< 0.01	Highly Significant
6	Owner Satisfaction	47	0.022	Significant
7	Turnover Quality	48	0.047	Significant

* 3 times IQR outliers removed ** $\alpha = 0.05$

CONCLUSION

The current study examined 50 storage facility projects (25 warehouses and 25 self-storage facilities), identifying the best-suited project delivery method – DB versus DBB for performance. This was achieved by comparing project delivery methods utilizing quality metrics. On conducting ANOVA, for evaluating any significant variance in means of the data, the findings showed that the DB method performed significantly better than the DBB method in managing change orders and generating fewer RFIs. The DB method not only exhibited a lower number of punch list items but also demonstrated prompt resolution with a lower punch list completion time. Observations indicate higher levels of owner satisfaction and turnover quality in DB projects compared to DBB projects. The findings offer industry practitioners valuable insights and help them make informed decisions for selecting appropriate project delivery and enhancing efficiency in storage facility projects. Further, the scope and validity of the study can be increased by including data for other types of storage facilities like cold storage.

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