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The reliability of the standard deviation bid method for awarding construction contracts

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Abstract

This study examines the complex test of observing to time, cost, and quality factors when executing construction projects in developing countries, which frequently becomes more difficult by awarding projects based on low bids. By compared to collusion implications and e-bidding benefits using the standard deviation bid and average bid methods, the study provides light on critical aspects. An examination of contracts in Nepal's Gandaki province between 2018 and 2022 yields interesting results. When there is no collusion, both bidding methods produce similar results. The average bid method, on the other hand, is subject to collusion, whereas the standard deviation bid method is not. To address the constraints associated with low bids, a cautious recommendation for the average bid method is made, along with vigilance against collusion. The standard deviation bid method, on the other hand, emerges as an effective obstacle to collusive behavior. To enhance the bid procedures, the study encourages for additional qualification criteria such as financial weighting and enhanced performance bonds. These amendments to Nepal's Public Procurement Act (PPA) and Public Procurement Regulation (PPR) of 2007 are intended to address issues raised by low bids. The importance of e-bidding practices is highlighted for digital transformation and corruption prevention. The study emphasizes the importance of putting in place mechanisms to detect collusion across bid selection methods. The research concludes with an invitation for experimental exploration of the Standard Deviation Bidding Method (SDBM), with an evaluation of its efficiency across time, cost, and quality domains. This investigation has the potential to reveal the best bid selection methodology for construction projects.

Key Words: Bidding, E-bidding, Collusion contracts, Low-bidding

1. Introduction

The dependability of the standard deviation bid method in awarding construction contracts pertains to the confidence in its efficacy and precision as a decision-making instrument [1]. This encompasses the method's

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capacity to consistently and accurately choose the optimal contractor, factoring in aspects like cost, time, quality, and risk [2]. Appraising its dependability involves gauging its uniformity and trustworthiness across diverse project scenarios, while acknowledging its constraints, predispositions, and stakeholders' faith in its outcomes [3]. The construction sector plays a substantial role in the global economy, contributing around $10 trillion to the overall Gross Domestic Product (GDP) [4]. In India, the construction industry stands as a vital pillar of the economy, poised for further growth due to economic advancement, industrialization, and urbanization [5]. In China, the expanding construction landscape introduces fresh challenges rooted in design and production risks. Evolving from state-owned enterprises (SOEs), Chinese construction firms are undergoing transformative shifts and structural reforms, transitioning from a model where the government bore risks, losses, and profits.

Nepal's development struggles continue, with infrastructure a central focus. Classified as a least developed nation, Nepal has low energy consumption and lacks substantial coal, natural gas, or oil reserves [6]. It holds vast hydropower potential, around 84,000 MW with 43,000 MW economically viable [7]. Nepal's construction industry's annual growth approximates 9%, employing 14% of the country's workforce, though 40% were non-Nepalese, mainly from India and Bangladesh [8]. Public sector construction procurement relies on the lowest bid system. Projects exceeding budget are pursued after competitive bidding. While price-centric open competitive bidding is favored for accountability, focusing solely on cost undermines time and quality factors
[9]. In China's changing business landscape, Chinese construction firms now face increased responsibility for risk management, departing from government support [10]. Meanwhile, Nepal's construction industry, nestled between India and China, grapples with resource allocation challenges. Central Bureau of Statistics data indicates Nepal's construction sector GDP rose from 145,183.18 NPR Million in 2019 to 153,253.39 NPR Million in 2020. Before the pandemic, the industry represented 7.7% of global employment, but it's expected to decline [11]. In the US, construction procurement isn't always based solely on the lowest bid. Government agencies weigh factors like technical expertise, experience, and performance. Consult the Federal Acquisition Regulation (FAR) guidelines for details [12], [13]. The UK promotes best value procurement, considering various factors beyond price. Public Contracts Regulations 2015 offer guidelines [14]. Australia also considers factors beyond the lowest price for construction procurement, like quality and technical expertise. Each state and territory have distinct procurement policies.

When driven solely by low bid prices, unqualified contractors often participate, some exploiting predatory bidding tactics to make up losses through change orders and claims. The lowest bid doesn't ensure "best value." True value stems from a compliant bidder meeting obligations, offering innovation, and providing low cost [9]. Bidding encompasses various factors including project specifics, technical complexity, socio-economic conditions, and competition. A contractor's bid influences the contract award cost, deviating from the engineer's estimate. Generally, most contracts are around 20 to 35 percent below estimates, excluding collusion. Notably, in places like Butwal and Shivapur, the number of bidders had a significant correlation (0.61) with the percentage below engineer's estimates, highlighting its role in low bidding [15]). The Low Bid Method is a price-based competitive closed bid system, widely used in traditional procurement when design documents are almost complete [16]. The contract is awarded by the Borrower during the bid validity period to a bidder meeting required capability and resource standards. The chosen bid should (i) substantially align with bidding documents and (ii) offer the lowest evaluated cost [17]. As contractors are not involved in design, the exact low-bid amount remains uncertain until design completion and bidding occur. Consequently, owners and architects must await completion of both design and bidding phases to ascertain budget compliance, even prior to change orders [18].

The term "best-value" holds diverse meanings in the industry. A comprehensive understanding implies incorporating price and other vital factors during evaluation for improved long-term performance and project value [19]. After assessing literature, meetings, and case studies, the definition of best-value procurement is distilled into four key concepts: parameters, evaluation criteria, rating systems, and award algorithms. The research concludes that a best-value procurement approach, easily adaptable to project specifics, is most effective within a traditional bidding system [20]. The average-bid method assigns the contract to the bidder whose price is nearest to the average of all bids submitted. Typically, the winner in this method is selected based on their bid's relation to the overall bid price average [21]. Different versions of the average bid method employ distinct procedures, including arithmetic or weighted averages, or excluding bids deviating significantly from the average. The winning bid may be based on proximity to the average or having a bid just below it. For instance, Taiwan uses the former, while Italy adopts the latter approach [22]. Legal provisions establish transparent, objective, and reliable public procurement procedures and decisions. Key aims include maximizing value from public spending, ensuring fairness, competition, accountability, and governance [17]. Nepal employs the Public Procurement Monitoring Office (PPMO) via an e-government portal for procurement activities, referred to as e-GP I/II.

Collusive bidding, also called bid rigging or cartel on bidding, involves contractors collaborating to manipulate competition, determine winners, and inflate prices. It occurs across projects of various scales [23]. Cross-level analyses show Jaccard coefficient's positive impact on market shares in collusion-prone cities. A monitoring system to track collusion tendencies is vital to thwart cartel growth [24].Collusion's covert nature has long hindered detection and deterrence in antitrust efforts. Factors enabling or hindering collusion are explored, along with feasible detection scenarios [25]. Detection methods employ bid price, winning bid price, ratios, and non-price attributes like capacity and experience [26].

This research aims to compare the effectiveness of the standard deviation bid method to the average bid method, focusing on the role of collusion. The standard deviation bid method gauges bid risk levels, where higher deviations signal greater uncertainty and risk. Examining bid price dispersion quantitatively helps assess contractor reliability. Incorporating statistical aspects bolsters objectivity, reducing reliance on subjective judgment [19]. Limited empirical evidence due to sample size, geographic scope, and specific contexts impedes generalization. Further research is vital for validation. Methodological issues in prior studies, like outdated data or inadequate techniques, hinder reliability. Exploring contractor perspectives and risk management strategies would enhance understanding.

Comparative analysis is needed to identify the most reliable method for awarding contracts, weighing the standard deviation bid method against other common approaches. Limitations are inherent when considering the standard deviation method. This method presumes bid prices follow a normal distribution, though construction bids are influenced by market conditions, contractor expertise, and project specifics. When bid prices deviate from the norm, accuracy may wane [26]. Reliability of the standard deviation method depends on sample size and representation. Limited contractor and project variety or small samples may yield less dependable results [27]. Bid collusion and strategic pricing can compromise the method. Collusion may skew bid prices, rendering the method less effective in identifying trustworthy bids [28]. Crucial context like contractor qualifications and experience isn't factored in by the standard deviation method. It should be used alongside other criteria for informed decisions [29]. Assuming a competitive bidding environment, the method might not hold in monopolistic or contractor-dominant markets [30].

Research Hypotheses:

The hypothesis for the alternative low bid award method is as follows: The bid nearest to the average of all bid values within the range of standard deviation (S.D) ± mean of all bids is selected for award. In case of two equally close values to the average, the lower bid is chosen for award.

2. Materials and Method

For this research, a survey method was applied as it proved effective in gathering the necessary data. Here utilized both qualitative and quantitative data. Quantitative data was used to assess the influence of the low bid on project time and cost, while qualitative data played a vital role in determining the frequency of procurement method and identifying their respective causes.

Primary data was collected to gain insights into the policies and procedures utilized for materials and equipment procurement, as well as to understand the challenges faced by personnel involved in the projects. The data also provided specific insights into the nature of issues arising from procurement delays. Research area was selected at Gandaki Province of Nepal as shown in map below.

Figure 1: Research Area, Map of Nepal, showing Gandaki Province.

Data from public construction sites over the past four fiscal years, focusing on bids exceeding Rs. 2 million, were categorized by procurement type. This encompassed general road construction, structural work like bridges, culverts, and road/bridge maintenance. Further analysis isolated road projects. Starting with road projects, the average of bids below the engineer's estimate was calculated. The low bid method was used for winner selection, especially for projects with high bidder numbers. Collusive bids were factored in for alternative methods, notably in projects with over 10 bidders within a fiscal year. In such cases, an additional project with half the bidders was introduced.

Three government entities were randomly chosen for sampling: the Department of Urban Development and Building (DUBC) in Kaski, Sundarbazar Municipality in Lamjung, and Bhimad Municipality in Tanahun. These organizations supplied road project procurement data for fiscal years 075/076, 076/077, 077/078, and 078/079.

$$\text{No. of Collusive bids} = \frac{\text{No.of applied bids}}{3} \text{------------------(1)}$$

Collusive Bid Amount = Engineer's Estimate * Avg. percentage below of four fical year--(2)
Average bidding method (ABM) and Standard deviation bidding method (SDBM) are compared before and after the collusion.

Collecting data for four fiscal years with bids over Rs. two million, categorization occurred based on procurement type. This encompassed general road construction, structural works (bridges, culverts), and road/bridge maintenance. Road projects were isolated for deeper analysis, and data was categorized for fiscal years 075/076 to 078/079. The percentage below the engineer's estimate was calculated as follows:

$$\%\mathbf{below} = \frac{\textbf{Engineer's Estimate} - \textbf{Award Amount}}{\textbf{Engineer's Estimate}} \;\; {}^*100\%\text{--(3)}$$

3. Tabulated of Data

Average Percentage below Engineers' Estimate

Practically, the percentage of bids awarded below the engineer's estimate rose from 22.11% in fiscal year 075/076 to 40.46% in 077/078, then decreased to 31.27% in 078/079. The four-year average was 32.11%. This approach adheres to the low bid method.

Before Collusion Analysis

Average Bid Method (ABM)

In this method, bid is awarded to the bid closest to the arithmetic mean of all the bids. As per Methodology we are selecting the bidder from the collected data according to average bid method.

Table: 1 Average percentage below for ABM

Average percentage below estimate for ABM fiscal year:075/076				
S.N	**PE's Estimate**	**Awarded Amount**	**Less/More**	**Percentage Below**
1	42476859.12	32209727.50	-10267131.63	24.17%
2	189091692.95	135234316.3	-53857376.70	28.48%
3	68688242.93	52053757.67	-16634485.26	24.22%
4	4307454.66	3599115.12	-708339.54	16.44%
5	7693065.86	7288859.879	-404205.98	5.25%
			Average	19.71%

Average percentage below estimate for ABM Fiscal year:076/077				
S.N	**PE's Estimate**	**Awarded Amount**	**Less/More**	**Percentage Below**
1	9615333.26	8697898.15	-917435.11	9.54%
2	6290248.37	4789026.84	-1501221.52	23.87%
3	19724314.72	14946568.68	-4777746.04	24.22%
4	7589976.91	5393423.30	-2196553.61	28.94%
5	8533284.31	5997551.10	-2535733.21	29.72%
6	4301440.33	3181652.00	-1119788.33	26.03%
			Average	23.72%

Average percentage below estimate for ABM Fiscal year:077/078				
S.N	**PE's Estimate**	**Awarded Amount**	**Less/More**	**Percentage Below**
1	7242283.57	4998383.96	-2243899.60	30.98%
2	9657279.11	6251359.11	-3405920.01	35.27%
3	14422551.70	11559248.51	-2863303.19	19.85%
4	19216081.17	13723503.66	-5492577.52	28.58%
5	19219008.83	12450884.66	-6768124.17	35.22%
6	14486724.58	10277333.05	-4209391.53	29.06%
7	14422328.81	10394362.22	-4027966.58	27.93%
			Average	29.56%

Average percentage below estimate for ABM Fiscal year:078/079				
S.N	**PE's Estimate**	**Awarded Amount**	**Less/More**	**Percentage**
1	4345600.45	2998759.69	-1346840.76	30.99%
2	4345633.45	2978412.43	-1367221.02	31.46%
3	4345054.96	3080170.97	-1264883.99	29.11%
4	4326664.19	3956089.43	-370574.76	8.56%
5	4316317.32	3155118.81	-1161198.51	26.90%
6	4326866.47	3504807.43	-822059.04	19.00%
7	4797735.88	3587592.44	-1210143.44	25.22%
8	12527529.45	9916185.30	-2611344.15	20.84%
9	45955208.52	36124727.09	-9830481.43	21.39%

10	4339510.83	4085644.48	-253866.35	5.85%
11	106758994.72	65609190.77	-41149803.95	38.54%
			Average	23.44%

From above table the average percentages below the engineer's estimate for fiscal years 075/076, 076/077, 077/078 and 078/079 is 19.71%, 23.72%, 29.56% and 23.44% respectively if the bid is awarded according to average bid method. Sample calculation process is shown in annex portion.

Standard Deviation Bid Method (SDBM) (Proposed Method)

Based on the objective research hypotheses was constructed and we are selecting the bidder from the collected data.

Table: 2 Average percentage below estimate for SDBM

Average percentage below estimate for SDBM fiscal year:075/076				
S.N	**PE's Estimate**	**Awarded Amount**	**Less/More**	**Percentage Below**
1	42476859.12	32209727.5	-10267131.63	24.17%
2	189091692.95	129993937.8	-59097755.15	31.25%
3	68688242.93	52053757.67	-16634485.26	24.22%
4	4307454.66	3599115.123	-708339.54	16.44%
5	7693065.86	7288859.879	-404205.98	5.25%
			Average	20.27%

Average percentage below estimate for SDBM Fiscal year:076/077				
S.N	**PE's Estimate**	**Awarded Amount**	**Less/More**	**Percentage Below**
1	9615333.26	8697898.15	-917435.11	9.54%
2	6290248.37	4195857.01	-2094391.35	33.30%
3	19724314.72	14872733.69	-4851581.03	24.60%
4	7589976.91	5393423.30	-2196553.61	28.94%
5	8533284.31	5965314.10	-2567970.21	30.09%
6	4301440.33	2774292.20	-1527148.13	35.50%
			Average	27.00%

Average percentage below estimate for SDBM Fiscal year:077/078				
S.N	**PE's Estimate**	**Awarded Amount**	**Less/More**	**Percentage Below**
1	7242283.57	4998383.96	-2243899.60	30.98%
2	9657279.11	5965207.85	-3692071.26	38.23%
3	14422551.70	11559248.51	-2863303.19	19.85%
4	19216081.17	13723503.66	-5492577.52	28.58%
5	19219008.83	12450884.66	-6768124.17	35.22%
6	14486724.58	10033434.08	-4453290.51	30.74%
7	14422328.81	10394362.22	-4027966.58	27.93%
			Average	30.22%

Average percentage below estimate for SDBM Fiscal year:078/079				
S.N	**PE's Estimate (Rs)**	**Awarded Amount (Rs)**	**Less/More (Rs)**	**Percentage**
1	4345600.45	2998759.69	-1346840.76	30.99%
2	4345633.45	2927134.16	-1418499.29	32.64%
3	4345054.96	3080170.97	-1264883.99	29.11%
4	4326664.19	3956089.43	-370574.76	8.56%

5	4316317.32	3222660.32	-1093657.00	25.34%
6	4326866.47	3504807.432	-822059.04	19.00%
7	4797735.88	3858090.484	-939645.39	19.59%
8	12527529.45	9727033.695	-2800495.75	22.35%
9	45955208.52	36124727.09	-9830481.43	21.39%
10	4339510.83	4136157.631	-203353.20	4.69%
11	106758994.72	72048651.77	-34710342.96	32.51%
			Average	22.38%

From above table 4.9 the average percentages below the engineer's estimate for fiscal years 075/076, 076/077, 077/078 and 078/079 are 20.27%, 27.00%, 30.22% and 22.38% respectively if the bid is awarded according to standard deviation bid method.

After Collusion Analysis

The above process is suitable for the low bidding method only. If the contract is awarded by Average method, then construction companies might make their dummy companies and submit the bids so that they can pull the average to their tender amount. So, imaginary tender amounts are added according to the methodology 3.7 and further calculation is done to compare two methods.

Table: 3 Bidder Selection after illegal bidding

Year/Code	075/076/ SN2	076/077 /SN4	077/078/SN5	077/078/SN2	078/079/ SN2
Bidding Amounts in (Rs)	60000000.00	2400000.00	6150000.00	3000000.00	1300000.00
	60000000.00	2400000.00	6150000.00	3000000.00	1300000.00
	124581455.60	2400000.00	6150000.00	5507077.06	1300000.00
	129993937.80	4210347.48	6150000.00	5645888.89	2580940.58
	130499927.20	4375672.30	10461978.44	5965207.85	2607070.70
	135234316.25	4777139.67	10992615.71	6038232.52	2705687.83
	156838884.12	5393423.30	11590769.34	6251359.11	2927134.16
		5406425.37	11764904.60	6717048.49	2978412.43
		5442791.40	11779396.85	6939871.33	3136046.30
		5570264.52	11945204.58		3220007.56
		5755551.29	12052755.15		3413407.06
		6222886.53	12450884.66		
			12992191.95		
			13017560.45		
			13706076.23		
			14443806.90		
			16134473.35		
AVG Method	135234316.25	4375672.30	10992615.71	5507077.06	2580940.58
% below	28.48%	42.35%	42.80%	42.97%	40.61%
SDM Method	129993937.80	5393423.30	12052755.15	6038232.52	2927134.16
%below	31.25%	28.94%	37.29%	37.66%	32.64%

Comparison of percentage below before and after collusion

The award amount before and after adding collusive imaginary data are calculated above for the five projects of four different fiscal years. Now the percentages below engineer's estimate of those projects are compared.

Table: 4 Comparison of percentage below before and after collusion

Year/ Code	AVG Method		SDM Method	
	Before Collusion	After Collusion	Before Collusion	After Collusion
075/076/ SN2	28.48%	28.48%	31.25%	31.25%
076/077/SN4	28.94%	42.35%	28.94%	28.94%
077/078/SN5	35.22%	42.80%	35.22%	37.29%
077/078/SN2	35.27%	42.97%	38.23%	37.66%
078/079/ SN2	31.46%	40.61%	32.64%	32.64%

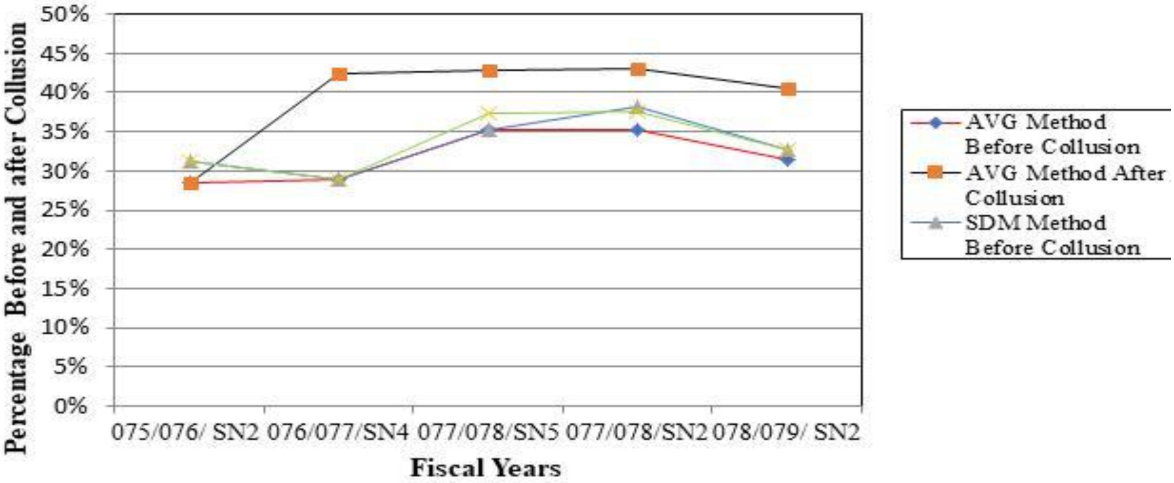

Figure: 2 Line chart comparison of percentage below before and after collusion

Based on the collected data, the average bid method and standard deviation bid method yielded similar results. This led to the conclusion that in the absence of collusive bids, there is no significant difference between these methods. However, when collusive bids were included following the methodology, the result of the average bid method after collusion differed. On the other hand, the results of the average bid method before collusion and the standard deviation bid method before and after collusion remained similar. This suggests that while certain collusion may not impact the standard deviation bid method, it does affect the average bid method.

Subsequently, the average percentage below the engineer's estimate was computed individually for four distinct fiscal years: 075/076, 076/077, 077/078, and 078/079. Additionally, the overall average was calculated. This analysis revealed the trend of the low bid award system.

$$\text{Average \% below} = \frac{\sum \text{\% below of one fiscal year}}{\text{Number of bids of that fiscal year}} \text{--------}(4)$$

The percentage below the engineer's estimate and its average were calculated for both the average bidding method and the standard deviation method (proposed method), following the process of the low bidding method described above.

In the average bidding method, the bid is awarded to the bid amount that is closest to the average of all the bids and is sustainably responsive. If two bids are equally close, the bid is awarded to the lowest one. In the standard deviation method, the bid is awarded to the bid amount that falls within the range of the standard deviation (S.D) ± mean of all bid amounts and is sustainably responsive. If two values are equally close to the average, the bid is awarded to the lowest one.

It's important to note that the bid was initially submitted for the low bid method, which may only be feasible for low bid selection. For other selection methods, there may be collusive biddings, so collusive bids are included in the analysis.

Before collusion, all three methods (average bidding method, standard deviation method, and low bid method) were compared. However, after collusion, only the average bidding method (ABM) and standard deviation method (SDM) were compared. This is because there is no need to compare the low bid method since the data was collected specifically from the low bid selection technique.

4. Result and Discussion

The research concludes with an invitation for experimental exploration of the Standard Deviation Bidding Method (SDBM), with an assessment of its efficiency across time, cost, and quality domains. This pursuit has the potential to reveal the best bid selection methodology for construction projects.

The initial search yield concentrates on the pricing facet within the bidding strategy. Though specific methodologies aren't detailed, this outcome evaluates extant approaches supporting bidding decisions, delving into their data requirements and practical limitations. It presents a simulation-based route for profit ratio determination. Yet, it omits a direct discourse on the reliability of the standard deviation bid method [31].

Secondly, the ensuing search outcome addresses the interplay between the engineer's estimate and the average bid, bound by standard deviation. It asserts that the engineer's estimate, coupled with a standard deviation, remains within a ±20% range of the average bid, with commensurate confidence. This implies that the standard deviation bid method, when appropriately employed, can furnish a reasonable estimate of the bidding spectrum surrounding the average bid. Nevertheless, it omits a comparative evaluation with other customary bidding methods and their respective reliability [32].

The third search result highlights the use of a weighted multiple criteria approach in more complex procurement situations. It suggests that in such cases, the evaluation process should consider criteria other than price and balance them to ensure the best value for money. While this search result doesn't directly discuss the reliability of the standard deviation bid method or compare it with other bidding methods, it provides insights into the importance of considering multiple criteria in the bidding process [33].

Overall, based on the search results provided, there is limited direct information regarding the reliability of the standard deviation bid method compared to other commonly used bidding methods in the construction industry. To thoroughly investigate the strengths and weaknesses of various bidding methods and propose novel approaches or modifications, it would be beneficial to explore additional sources such as academic papers, industry reports, or professional opinions from experts in the field. These sources may provide more detailed insights and comparisons of different bidding methods, their reliability, and suggestions for improvements in the bidding process.

It can still provide some general insights and suggestions regarding the impact of contextual factors on bid evaluations and propose strategies for adapting the bid method to different project scenarios.

Project characteristics can significantly influence bid reliability. Factors such as project size, complexity, location, scope, and timeline can affect the accuracy of the standard deviation bid method. For instance, large-scale projects with complex requirements may involve more uncertainties and risks, making bid evaluations more challenging. Evaluating historical bid data specific to similar project characteristics can provide valuable insights and benchmarks to enhance bid reliability [34].

Market conditions, the dynamics of the construction market can have a profound impact on bid evaluations. Factors such as market competitiveness, supply and demand fluctuations, economic conditions, and industry trends can influence bid outcomes. During periods of high competition, bids may become more aggressive, potentially affecting the reliability of the standard deviation bid method. By monitoring and analyzing market conditions, contractors can adapt their bidding strategies accordingly to improve bid reliability [35].

Stakeholder dynamics, involvement and interactions of various stakeholders, including clients, contractors, subcontractors, and regulatory bodies, can influence bid evaluations. Stakeholder dynamics, such as client preferences, risk allocation, contractual obligations, and project-specific requirements, can impact bid reliability. Understanding the priorities and expectations of different stakeholders and effectively communicating and managing these dynamics throughout the bidding process can enhance bid reliability [36].

While the specific analysis of case studies or real-world examples was not available from the provided search results, it is crucial to consider and analyze practical implications to understand the influence of contextual factors on bid reliability. Examining real-world examples and case studies can provide valuable insights into how these factors impact bid evaluations and offer lessons learned. By leveraging this knowledge, contractors can develop novel strategies for adapting the standard deviation bid method to different project scenarios [37].

To further investigate the impact of contextual factors and propose strategies for adapting the bid method, it may be beneficial to explore additional sources such as industry reports, academic papers, or expert opinions from professionals in the construction industry. These sources can provide detailed case studies, empirical research, and practical recommendations for adapting bidding methodologies to different project contexts [38].

While the specific limitations and challenges of the standard deviation bid method were not found in the search results, it is important to recognize that any bidding method, including the standard deviation approach, may have inherent limitations and potential areas for improvement. Here are some potential limitations and innovative solutions that can enhance the reliability of bid evaluations.

Insufficient consideration of project-specific factors, the standard deviation bid method may not fully account for project-specific factors that can significantly impact bid reliability. To address this limitation, it is essential to consider project characteristics, contract requirements, scope complexity, site conditions, and other project-specific factors when estimating bid reliability. Developing customized risk assessment frameworks or integrating project-specific factors into bid evaluation models can help improve the accuracy of bid assessments [39].

Incomplete data or inaccurate assumptions, the reliability of the standard deviation bid method heavily relies on accurate data and assumptions. However, incomplete or inaccurate data can undermine the accuracy of bid evaluations. Enhancing data collection processes, implementing quality control measures, and utilizing advanced data analytics techniques can help mitigate these challenges. Additionally, leveraging historical bid data, market intelligence, and industry benchmarks can provide valuable insights for more accurate bid assessments [40].

Limited consideration of non-price factors, the standard deviation bid method primarily focuses on price-related factors and may not adequately consider non-price factors that contribute to bid reliability. To address this limitation, integrating a weighted multiple criteria approach [33] can ensure a comprehensive evaluation that balances both price and non-price factors, such as technical competence, past performance, sustainability, and innovation. This approach can enhance bid assessments by considering a broader range of criteria.

Lack of predictive analytics, the standard deviation bid method relies on historical bid data to estimate bid reliability. However, it may not incorporate predictive analytics to anticipate future market conditions, industry trends, or project-specific risks. By incorporating advanced analytics techniques, such as predictive modeling and scenario analysis, contractors can better forecast market dynamics and project risks, leading to more reliable bid evaluations [41].

While the specific limitations and proposed improvements to the standard deviation bid method are not available from the provided search results, it is crucial to continuously explore innovative approaches, refine existing methodologies, and integrate advancements in data analysis and predictive techniques to enhance bid evaluation processes in the construction industry [42].

To delve deeper into the limitations and potential improvements of the standard deviation bid method, it may be beneficial to consult additional sources such as academic papers, industry reports, or expert opinions from professionals experienced in construction bidding. These sources can provide detailed insights into the challenges faced by the standard deviation method and offer innovative solutions to enhance its reliability and effectiveness.

It is concentrated on the data available from Department of Urban Development and Building, Kaski, Sundarbazar Municipality, Lamjung and Bhimad Municipality, Tanahun was the procurement data for road projects spanning four fiscal years: 075/076, 076/077, 077/078, and 078/079.

Bidding Trend

Average Percentage Below Engineers' Estimate

Following the established methodology, the average percentage below the engineer's estimate was calculated for each of the four fiscal years. Finally, the overall average was computed using the direct mean method. The bid award process adheres to the low bid method.

Table:5 Average percentage below estimate for fiscal year 075/076 calculation

		Average percentage below estimate		Fiscal year:075/076
S.N	PE's Estimate	Awarded Amount	Less/More	Percentage Below
1	42476859.12	32209727.50	-10267131.63	24.17%
2	189091692.95	124581455.60	-64510237.35	34.12%
3	68688242.93	52053757.67	-16634485.26	24.22%
4	4307454.66	3599115.12	-708339.54	16.44%
5	7693065.86	6799322.88	-893742.98	11.62%
			Average	22.11%

Based on the above table, it is evident that in fiscal year 075/076, projects on average went 22.11% below the engineer's estimate to be awarded. This indicates that contractors had to bid 22.11% lower than the engineer's estimate in order to receive the award. Out of the 5 projects, 3 projects exceeded the average bid amount, while 2 projects were below the average bid amount.

Table: 6 Average percentage below estimate for fiscal year 076/077 calculation

		Average percentage below estimate		Fiscal year:075/076
S.N	PE's Estimate	Awarded Amount	Less/More	Percentage Below
1	9615333.26	7300731.12	-2314602.14	24.07%
2	6290248.37	4178404.62	-2111843.75	33.57%
3	19724314.72	13995734.02	-5728580.70	29.04%
4	7589976.91	4210347.48	-3379629.43	44.53%
5	8533284.31	5079213.10	-3454071.21	40.48%
6	4301440.33	2758445.50	-1542994.83	35.87%
			Average	34.59%

Based on the above table, it is evident that in fiscal year 076/077, projects on average went 34.59% below the engineer's estimate to be awarded. This indicates that contractors had to bid 34.59% lower than the engineer's estimate in order to receive the award. Out of the 6 projects, 3 projects exceeded the average bid amount, while 2 projects were below the average bid amount.

Table: 7 Average percentage below estimate for fiscal year 077/078 calculation

Average percentage below estimate Fiscal year:077/078				
S.N	*PE's Estimate*	*Awarded Amount*	*Less/More*	*Percentage Below*
1	7242283.57	4682367.89	-2559915.68	35.35%
2	9657279.11	5507077.06	-4150202.05	42.97%
3	14422551.70	9118488.42	-5304063.28	36.78%
4	19216081.17	10803844.97	-8412236.21	43.78%
5	19219008.83	10461978.44	-8757030.39	45.56%
6	14486724.58	8850601.27	-5636123.32	38.91%
7	14422328.81	8676171.80	-5746157.01	39.84%
			Average	*40.46%*

Based on the abovementioned table, it is evident that in fiscal year 077/078, projects on average went 40.46% below the engineer's estimate to be awarded. This indicates that contractors had to bid 40.46% lower than the engineer's estimate in order to receive the award. Out of the seven projects, three projects exceeded the average bid amount, while four projects were below the average bid amount.

Table: 8 Average percentage below estimate for fiscal year 078/079 calculation

Average percentage below estimate Fiscal year:077/078				
S.N	*PE's Estimate*	*Awarded Amount*	*Less/More*	*Percentage Below*
1	4345600.45	2828464.51	-1517135.94	34.91%
2	4345633.45	2580940.58	-1764692.87	40.61%
3	4345054.96	2671960.39	-1673094.57	38.51%
4	4326664.19	3956089.43	-370574.76	8.56%
5	4316317.32	3155118.81	-1161198.51	26.90%
6	4326866.47	2905647.53	-1421218.94	32.85%
7	4797735.88	3307379.00	-1490356.88	31.06%
8	12527529.45	6365533.99	-6161995.46	49.19%
9	45955208.52	29253640.05	-16701568.47	36.34%
10	4339510.83	4057532.41	-281978.42	6.50%
11	106758994.72	65609190.77	-41149803.95	38.54%
			Average	*31.27%*

Based on the above table, it is evident that in fiscal year 078/079, projects on average went 31.27% below the engineer's estimate to be awarded. This indicates that contractors had to bid 31.27% lower than the engineer's estimate in order to receive the award. Out of the eleven projects, seven projects exceeded the average bid amount, while four projects were below the average bid amount.

Table: 9 Average percentage below estimate Summary

Average Percentage below estimate				
Fiscal Year	075/076	076/077	077/078	078/079
Percentage Below	22.11%	34.59%	40.46%	31.27%
Average	*32.11%*			

Based on above table it can be observed that the percentage below the estimate increased from fiscal year

075/076 to 077/078 (22.11% to 40.46%) and then decreased to 31.27% in fiscal year 078/079. The overall average of these four fiscal years is found to be 32.11%. Figure 4.1 depicts a line graph showing the initial increase followed by a decrease. The maximum below percentage recorded is 49.19% while the minimum below percentage is 6.05%, both occurring in fiscal year 078/079.

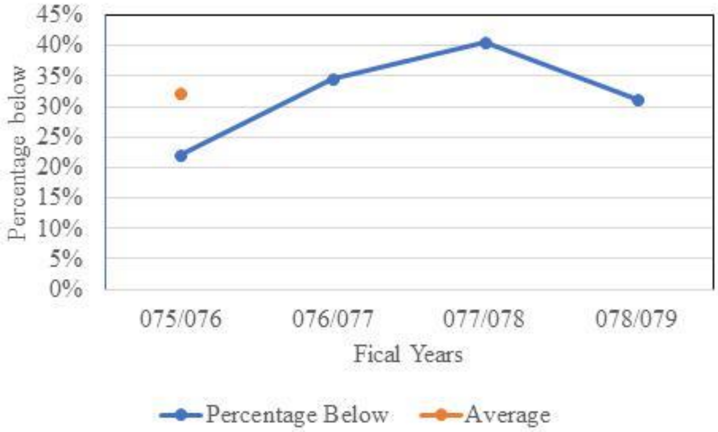

Figure: 3 Average percentage below estimate

Average Number of Bids per Project

The frequency of bids indicates the level of contractor interest and the availability of eligible contractors for those projects. To determine the average, separate averages were calculated for each fiscal year, as shown in Table 10

Table: 10 Average Number of Bidders

Average Number of Bidders				
Fiscal Year	075/076	076/077	077/078	078/079
Average Number of Bids	3	6	10	5
Average	*6.00*			

Based on Table 10, the number of bids per project increased from fiscal year 075/076 to 077/078 (3 to 10) and then decreased to 5 in fiscal year 078/079. The overall average across all four fiscal years is found to be 6. Figure 4.2 illustrates a line graph depicting the initial increase followed by a decrease. The maximum number of bidders in a single project was thirteen in fiscal year 077/078, while the minimum number of bidders was one in fiscal year 078/079.

Figure: 4 Average numbers of bidders

Bid Selection Alternatives

In Nepal, the prevalent bid selection method is the low bid method, and the trend analysis presented above is conducted based on this approach. However, as alternative options, we have analyzed the data using the following two methods:

- Average Bid Method (ABM)
- Standard Deviation Bid Method (SDBM) (Proposed Method)

Average Bid Method (ABM)

In the average bid method, the bid is awarded to the bidder whose bid amount is closest to the arithmetic mean of all the bids. As per the methodology, we are selecting the bidder from the collected data based on the average bid method.

Table: 11 Average percentage below for ABM

Average percentage below estimate for ABM fiscal year:075/076				
S.N	**PE's Estimate**	**Awarded Amount**	**Less/More**	**Percentage Below**
1	42476859.12	32209727.50	-10267131.63	24.17%
2	189091692.95	135234316.3	-53857376.70	28.48%
3	68688242.93	52053757.67	-16634485.26	24.22%
4	4307454.66	3599115.12	-708339.54	16.44%
5	7693065.86	7288859.879	-404205.98	5.25%
			Average	*19.71%*

Average percentage below estimate for ABM Fiscal year:076/077				
S.N	**PE's Estimate**	**Awarded Amount**	**Less/More**	**Percentage Below**
1	9615333.26	8697898.15	-917435.11	9.54%
2	6290248.37	4789026.84	-1501221.52	23.87%
3	19724314.72	14946568.68	-4777746.04	24.22%
4	7589976.91	5393423.30	-2196553.61	28.94%
5	8533284.31	5997551.10	-2535733.21	29.72%
6	4301440.33	3181652.00	-1119788.33	26.03%
			Average	*23.72%*

Average percentage below estimate for ABM Fiscal year:077/078				
S.N	**PE's Estimate**	**Awarded Amount**	**Less/More**	**Percentage Below**
1	7242283.57	4998383.96	-2243899.60	30.98%
2	9657279.11	6251359.11	-3405920.01	35.27%
3	14422551.70	11559248.51	-2863303.19	19.85%
4	19216081.17	13723503.66	-5492577.52	28.58%
5	19219008.83	12450884.66	-6768124.17	35.22%
6	14486724.58	10277333.05	-4209391.53	29.06%
7	14422328.81	10394362.22	-4027966.58	27.93%
			Average	*29.56%*

Average percentage below estimate for ABM Fiscal year:078/079				
S.N	**PE's Estimate**	**Awarded Amount**	**Less/More**	**Percentage**
1	4345600.45	2998759.69	-1346840.76	30.99%
2	4345633.45	2978412.43	-1367221.02	31.46%
3	4345054.96	3080170.97	-1264883.99	29.11%
4	4326664.19	3956089.43	-370574.76	8.56%
5	4316317.32	3155118.81	-1161198.51	26.90%
6	4326866.47	3504807.43	-822059.04	19.00%
7	4797735.88	3587592.44	-1210143.44	25.22%
8	12527529.45	9916185.30	-2611344.15	20.84%
9	45955208.52	36124727.09	-9830481.43	21.39%
10	4339510.83	4085644.48	-253866.35	5.85%
11	106758994.72	65609190.77	-41149803.95	38.54%
			Average	*23.44%*

Based on 11, the average percentages below the engineer's estimate for fiscal years 075/076, 076/077, 077/078, and 078/079 are 19.71%, 23.72%, 29.56%, and 23.44%, respectively, when the bid is awarded according to the average bid method. The calculation process is detailed in the annex section.

Standard Deviation Bid Method (SDBM) (Proposed Method)

In accordance with research objective and the construction of hypothesis the bidder selection process was performed based on the collected data. Table 11 displays the average percentage below the estimate for the

Standard Deviation Bid Method (SDBM).

Table:12 Average percentage below estimate for SDBM

Average percentage below estimate for SDBM fiscal year:075/076				
S.N	**PE's Estimate**	**Awarded Amount**	**Less/More**	**Percentage Below**
1	42476859.12	32209727.5	-10267131.63	24.17%
2	189091692.95	129993937.8	-59097755.15	31.25%
3	68688242.93	52053757.67	-16634485.26	24.22%
4	4307454.66	3599115.123	-708339.54	16.44%
5	7693065.86	7288859.879	-404205.98	5.25%
			Average	*20.27%*

Average percentage below estimate for SDBM Fiscal year:076/077				
S.N	**PE's Estimate**	**Awarded Amount**	**Less/More**	**Percentage Below**
1	9615333.26	8697898.15	-917435.11	9.54%
2	6290248.37	4195857.01	-2094391.35	33.30%
3	19724314.72	14872733.69	-4851581.03	24.60%
4	7589976.91	5393423.30	-2196553.61	28.94%
5	8533284.31	5965314.10	-2567970.21	30.09%
6	4301440.33	2774292.20	-1527148.13	35.50%
			Average	*27.00%*

Average percentage below estimate for SDBM Fiscal year:077/078				
S.N	**PE's Estimate**	**Awarded Amount**	**Less/More**	**Percentage Below**
1	7242283.57	4998383.96	-2243899.60	30.98%
2	9657279.11	5965207.85	-3692071.26	38.23%
3	14422551.70	11559248.51	-2863303.19	19.85%
4	19216081.17	13723503.66	-5492577.52	28.58%
5	19219008.83	12450884.66	-6768124.17	35.22%
6	14486724.58	10033434.08	-4453290.51	30.74%
7	14422328.81	10394362.22	-4027966.58	27.93%
			Average	*30.22%*

Based on Table 12, the average percentages below the engineer's estimate for fiscal years 075/076, 076/077, 077/078, and 078/079 are 20.27%, 27.00%, 30.22%, and 31.27%, respectively, when the bid is awarded according to the standard deviation bid method. The calculation process is detailed in the annex section.

In line with objective, we are comparing three methods: low bid method, average bid method, and standard deviation method. The summarized data is presented in the figure below.

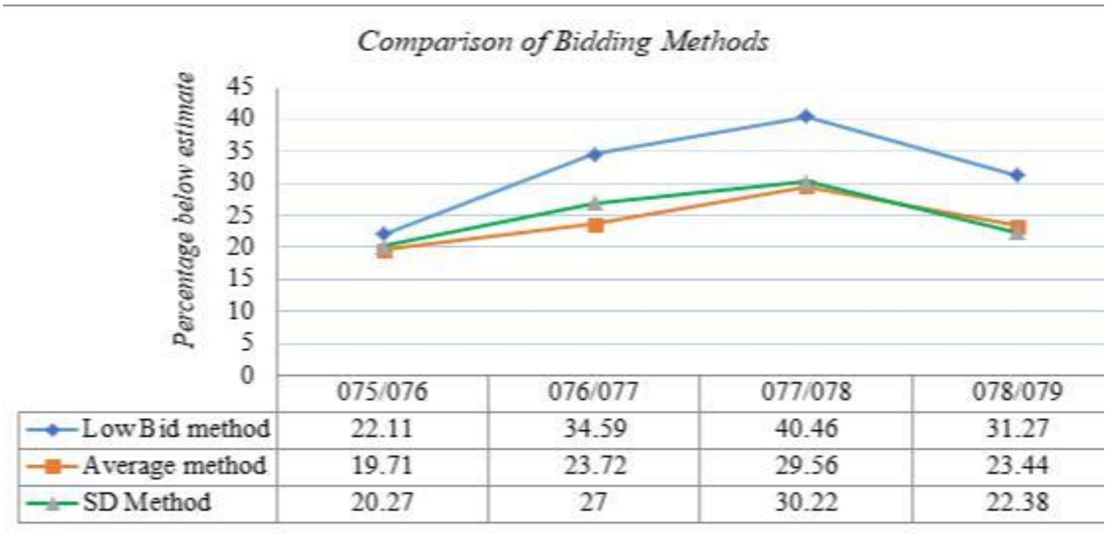

Figure: 5 Comparison of bidding methods

Based on Figure 4, it can be observed that the data for fiscal year 075/076 is closer to all three methods. However, for the other fiscal years, the data for average bid method (ABM) and standard deviation method (SDM) are similar, whereas the low bid method differs. The average percentage below the estimate for the low bid method, average bid method, and standard deviation method are 32.11, 24.11, and 24.97, respectively. This indicates that the bid awarded amount is relatively similar for ABM and SDM, while the awarded bid for the low bid method is lower than both alternatives.

Alternative Comparison after Collusion

The aforementioned process is applicable specifically to the low bidding method. However, in the case of awarding contracts through the average method, construction companies may create dummy companies and submit bids to manipulate the average towards their desired tender amount. As per methodology, hypothetical tender amounts are included, followed by additional calculations to compare the two methods.

Table: 13 Bidder Selection after illegal bidding

Year/Code	075/076/ SN2	076/077 /SN4	077/078/SN5	077/078/SN2	078/079/ SN2
Bidding Amounts (Rs.)	60000000.00	2400000.00	6150000.00	3000000.00	1300000.00
	60000000.00	2400000.00	6150000.00	3000000.00	1300000.00
	124581455.60	2400000.00	6150000.00	5507077.06	1300000.00
	129993937.80	4210347.48	6150000.00	5645888.89	2580940.58
	130499927.20	4375672.30	10461978.44	5965207.85	2607070.70
	135234316.25	4777139.67	10992615.71	6038232.52	2705687.83
	156838884.12	5393423.30	11590769.34	6251359.11	2927134.16
		5406425.37	11764904.60	6717048.49	2978412.43
		5442791.40	11779396.85	6939871.33	3136046.30
		5570264.52	11945204.58		3220007.56
		5755551.29	12052755.15		3413407.06
		6222886.53	12450884.66		
			12992191.95		
			13017560.45		
			13706076.23		
			14443806.90		
			16134473.35		
AVG Method	*135234316.25*	*4375672.30*	*10992615.71*	*5507077.06*	*2580940.58*
% below	*28.48%*	*42.35%*	*42.80%*	*42.97%*	*40.61%*
SDM Method	*129993937.80*	*5393423.30*	*12052755.15*	*6038232.52*	*2927134.16*
%below	*31.25%*	*28.94%*	*37.29%*	*37.66%*	*32.64%*

Comparison of Percentage Below Before and After Collusion

Table 14 Comparison of percentage below before and after collusion

Year/ Code	**AVG Method**		*SDM Method*	
	Before Collusion	**After Collusion**	**Before Collusion**	**After Collusion**
075/076/ SN2	28.48%	28.48%	31.25%	31.25%
076/077/SN4	28.94%	42.35%	28.94%	28.94%
077/078/SN5	35.22%	42.80%	35.22%	37.29%
077/078/SN2	35.27%	42.97%	38.23%	37.66%
078/079/ SN2	31.46%	40.61%	32.64%	32.64%

Figure: 6 Line chart comparison of percentage below before and after collusion

The comparison of percentages given above based figure, the engineer's estimate is conducted for the award amounts of the five projects across four different fiscal years, both before and after the inclusion of collusive imaginary data.

Conclusion

It is concluded that the results of the average bid method and standard deviation bid method are similar to each other for the collected data only. It is also concluded that in the absence of collusive bids, there is no significant difference between these methods. However, if collusive bids are introduced, the result of the average bid method is affected, while the other three results (average bid method before collusion and standard deviation bid method before and after collusion) remain similar. Therefore, it is determined that certain collusion does not affect the standard deviation bid method, but it does affect the average bid method.

Based on the key findings and conclusion mentioned above, the average bid method is considered suitable for overcoming the limitations of the low bid method. The main drawback of the average bid method is collusive bids, while the standard deviation bid method is found to be more effective than the average bid method in mitigating collusion. It is recommended to reject collusive bids if identified. However, the standard deviation bid method also has its own limitation, as it may not eliminate all types of collusive bids. Therefore, prequalification is deemed almost necessary.

It is recommended to introduce additional qualification criteria through amendments to the PPA (2007) and PPR (2007). These criteria involve assigning monetary weight and an extra performance bond based on the percentage below the engineer's estimate. Emphasizing the e-bidding process for bid selection is also important as it brings advantages and drives digitalization, leading to a reduction in corruption and financial leakages. Furthermore, implementing criteria to detect collusive bidding is crucial for all bid selection methods. To determine the optimal bid selection method, it is advised to conduct experimental research on the Standard Deviation Bidding Method (SDBM) over a fiscal year, comparing its key factors of time, cost, and quality.

Conflict of interest

No conflict of interest.

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