Preliminary Study on Bidding Price Ratio Pattern of Public Works in Taiwan - a Case Study of Bridges, Elevated Highways, Tunnels and Subways

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Abstract. Commonly seen tender bid price information of the public works in Taiwan are the budget amount, floor price, awarding price and so on. The ratio of the awarding price to the floor price or budget price is the so-called bidding price ratio. This ratio is influenced by multifaceted factor interactions and is significant to decision making management in engineering projects. Low bidding price ratio may imply that the budget allocation by the tendering agency is inconsiderate or due to the improper market competition of low price bid rigging. High bidding price ratio in turn may indicate that the allocated budget is relatively low, bidder risks in increased contract execution uncertainty or even exclusive bidding scenario. Therefore, the correlation between the bidding price ratio and the aforementioned tender award information is the key issue of this study. This study gathered the tender information of the civil engineering projects in Taiwan within the past seven years. By performing statistical analysis and clustering the gathered data by bidding price ratio, this study investigated the influencing factors and regulations of bidding price ratio using data mining approach.

1. Introduction
Current tender procurement of the public works in Taiwan still typically adopted the lowest bidding price approach as the awarding decision basis. This approach may seem fair to certain extend but the market competition mechanism of Gresham’s law (bad money drives out good) may occur. The awarding decision of engineering project tenders is dependent on the established floor price as judgment principle, but the price gap between the floor price and the disclosed project budget, and the discounted rate between floor price and allocated budget are always the black boxes of the tendering agency. The bidding contractors can only speculate these values case by case. From the perspective of project execution resources, the aforementioned floor price/budget discounted rate would in fact weaken the project resources and profit of the contractors from the conducted works. Hence the contractors usually used the discounted market price after performing market survey prior to bidding, in order to increase the probability of obtaining the tender award. This scenario also drastically affect the contractor profit and construction quality in the future, which may easily lead to unreasonable appeals from the contractor to amend the construction design, so they could tie up the original unfavorable budget deficit conditions due to the low contracted unit prices. These situations would form a lose-lose situation for both the government agency and the contractor. In view of this, this study attempted to explore the influencing factors of bidding price ratio and their varying trend, in order to search for crucial information of budget allocation strategy by the tendering agency and bidding strategy for contractor. This study gathered the tender award data of public work projects from
year 2010 to 2016, including five major civil engineering works (as shown in Table 1), which has already covered over half of the domestic civil engineering project costs. This study conducted a preliminary case study on the engineering category of bridges, elevated highways, tunnels and subways.

Table 1. Bids information for Civil Engineering

| Category | Budget amount (hundred million) | Numbers of data |
|----------|---------------------------------|-----------------|
| 5162 Water pipe and drainage facilities | 1,258 | 8,959 |
| 5131 Expressway, street, road, railway, airport runway | 3,723 | 21,763 |
| 5132 Bridges, elevated highways, tunnels and subways | 4,459 | 2,482 |
| 5133 Waterway, harbor, dam, other water conservancy projects | 4,300 | 32,591 |
| 5134 Long-distance pipeline, communication and wiring | 1,158 | 194 |

From the planning and design up to the tender award of an engineering project, generally there would be information regarding budget amount, floor price, awarding price and so forth. The following bidding price ratio is derived from the project tender information:

1. Floor price / budget amount ratio: This ratio is almost being controlled by the tender awarding authorities, which could be used to estimate the budget allocation customary of each tender authorities.

2. Awarding price / budget amount ratio: The formation factor of this ratio is the most complicated case, which included the amount of bidding companies, project budget, floor price, degree of difficulty of project execution, project duration, project location and other conditions. All of which could affect the level of this ratio. This is suitable in investigating the perspective difference of the construction cost between the contractor and the tender authority, and is of significant reference importance to both parties. If the bidding contractor could fully understand the bidding price ratio pattern of similar works prior to the bidding, they could realize the market competitive degree and may not have to lower their bidding price to increase their probability of tender award. The tendering agency may also infer from this ratio whether the allocated budget and floor price are reasonable, in order to enhance the overall engineering environment.

3. Awarding price / floor price ratio: This ratio value is restricted by the Article 52 and 58 of the Government Procurement Act, regulating the awarding decision and limiting the floor price. The investigation of this ratio is relatively insignificant.

In summary, this study adopted the second ratio of awarding price-to-budget amount ratio for further analysis.

2. Source of Information
This case study selected the engineering projects of bridges, elevated highways, tunnels and subways, within the tender bidding duration of 7 years between year 2010 to 2016. This study mainly investigates the bidding price ratio clustering of awarding price-to-budget amount ratio, and its corresponding correlations to influencing factors. There are 2482 sets of raw data, which included several project types not discussed in this study, namely the integrated type multiple tender awarded cases, cases with bidding price ratio larger than 1 and cases with negative bidding price ratio.

There is 15 multiple tender award case in the raw dataset, the reason of excluding this tender award type from the case study is due to this tender project type usually belongs to several projects, and the raw data could not reflect the multiple original price fields. Cases with bidding price ratio larger than 1 indicated that the bidding price is higher than floor price, which are usually special cases where the contractors are not willing to undertake the project for award price below the floor price. The tendering agency can award the tender to the contractors with the award price above the floor price, according to the Government Procurement Act Article 58. There is 9 cases of this award type and their bidding price ratio are all smaller than 1.07. Negative price bidding ratio is the case where the contractors can acquire beneficial resources so they can reimburse some profits back to the tendering
agency. There is 3 cases of negative price bidding ratio, 1 case with the absence of budget information. This study eventually adopted 2445 data from the raw dataset, as shown in Table 2 below.

| Case type                      | Numbers of data | Adopt or not |
|-------------------------------|-----------------|--------------|
| General case                  | 2,445           | Yes          |
| Multiple tender case          | 15              | No           |
| Case with bidding price ratio > 1 | 18              | No           |
| Negative price bidding ratio case | 3              | No           |
| Lack of budget information    | 1               | No           |
| Total                         | 2,482           |              |

According to the aforementioned 2,445 data, by neglecting properties in other fields, Figure 1 shows the relationship between the bidding company amount and the tender/budget ratio. When the bidding companies was within 14 in total, the tender/budget ratio gradually decreased. However, when the amount of bidders laid between 15 to 20, the tender/budget ratio slightly increased. There was 1 data which the bidder amount is 21, the corresponding tender/budget ratio is only 0.18, and this is worth for further observation. Due to the multiple influencing factors of tender/budget ratio, trend estimation using only bidding company amount is insufficient, multiple properties analysis must be performed to provide a thorough understanding towards this issue.

![Figure 1. Relationship between bidding company amount and tender/budget ratio](image)

3. Research Methodology and Results

This study adopted the combination of both non-supervised learning and supervised learning during data mining. Non-supervised leaning is used to discretize continuous values, which mainly used the K-means approach among the data clustering methods. Supervised learning mainly used the decision tree approach with C5.0 method; this approach is a classification method and is used to validate the formation rules of the data clusters.

3.1. Data Clustering Result

Data clustering of the tender/budget ratio is conducted by K-means, the resulted values are between 0.1843 to 1.0 and the clustering amount is set within 3 to 10 clusters. K-means computations of each cluster are shown in Table 3. When the cluster number is larger than 6, the number of cluster 1 was lesser and less than 11 sets. After validation of the 11 data, their tender/budget price ratio was all lower than 0.4 with a mean of 0.2422, which is far lower than general project cases. These data can be
treated as outliers and removed from further analysis. Since the outliers could not be spotted for cluster amount of 3-5, the cluster amount is not recommended to be lower than 6. As the cluster amount is larger than 8, the data amount of the eighth cluster becomes smaller than 30, while statistical analysis normally require at least 30 data for statistical significance so the cluster amount is not recommended to be larger than 8. When the cluster amount is set as 7, its fifth cluster had only 38 data. Therefore, this study set the cluster amount to be 6 and by removing the outliers in first cluster, the actual cluster amount should be 5 clusters.

| Populations | Cluster amount | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Total |
|-------------|----------------|---|---|---|---|---|---|---|---|---|----|-------|
| 3           | 267            | 1397|781|   |   |   |   |   |   |   |   | 2,445 |
| 4           | 53             | 1259|427|706|   |   |   |   |   |   |   | 2,445 |
| 5           | 22             | 1142|458|640|183|   |   |   |   |   |   | 2,445 |
| 6           | 11             | 969 |282|488|94 |601|   |   |   |   |   | 2,445 |
| 7           | 7              | 869 |166|450|38 |589|326|   |   |   |   | 2,445 |
| 8           | 5              | 862 |160|452|48 |578|328|12 |   |   |   | 2,445 |
| 9           | 1              | 846 |169|431|19 |588|324|4  |63 |   |   | 2,445 |
| 10          | 1              | 718 |123|345|12 |392|226|4  |35 |589|   | 2,445 |

In case of 6 data clusters, the bidding price ratio range of each cluster is shown in Table 4. It is shown that the average ratio can be roughly categorized in to less than 0.3, approximately 1, 0.7, 0.8, 0.6, 0.9 and so on. Despite the first cluster, the standard deviations of other clusters are less than 0.06, indicating the clusters had a relatively concentrated distribution.

| Populations | Clusters | 1 | 2 | 3 | 4 | 5 | 6 | Total |
|-------------|----------|---|---|---|---|---|---|-------|
| Numbers of data | 11 | 969 | 282 | 488 | 94 | 601 | 2,445 |
| Average Ratio  | 0.2422 | 0.9733 | 0.6876 | 0.7906 | 0.5485 | 0.8903 | 0.8639 |
| Standard Deviation | 0.1160 | 0.022 | 0.033 | 0.029 | 0.058 | 0.027 | 0.1265 |

3.2 Categorization Results
Table 5 shows the contents of each property fields and some nomenclature is abbreviated for the ease of record. Table 6 shows the rule of the 2nd, 3rd, 4th, 5th, and 6th clusters. Since the data amount of the 1st data cluster is small and mostly outliers, they are neglected in this study. The 5th cluster has a bidding price ratio of lower than 60%, this can be clearly regarded as some contractor’s uses low price to obtain the tender. Inspecting the 2nd cluster, the bidding price ratios of this cluster is relatively higher and mostly are close to 1, indicating that the contractors within the clusters bid a very close price to the designated budget. There is a total of 969 data for this condition and there are mainly three rules for this cluster. The first rule can be interpreted as the bidding price ratio is high if the bidder amount is smaller than four for public works of the Ministry of Transportation and Communications in Chiayi County. The second rule is that if there is only one bidder, this represented the uniqueness of the engineering project, so the budget amount may be close to the awarding price. The third rule is the public works of the Ministry of Economic Affairs and the bidder amount is smaller than 4.

On the other hand, for the 3rd cluster, since 13 out of the 27 rules are related to the Ministry of Transportation and Communication, this can be viewed as even though this is public works of the same ministry, different bidder amount in different counties still have certain impact over rules. For instance, rule 1 with 5 bidders in Hualien County, rule 3 with 5~8 bidders in Miaoli County, rule 11 with over 11 bidders in Yulin County, rule 13 with 4 bidders in New Taipei City, rule 17 with more than 4 bidders in Taichung City, rule 18 with 4 bidders in Hualien County, rule 19 with 4 bidders in Nantou County, rule 20 with more than 1 bidder in Changhua County, rule 21 with more than 4 bidders in Taoyuan City, rule 23 with more than 4 bidders in Keelung City, rule 24 with 2~4 bidders in
Yilan County, rule 25 with more than 4 bidders in Tainan City and rule 26 with more than 4 bidders in New Taipei City.

After performing data clustering, the bidding price ratio properties of each data clusters are inspected. Figure 2 illustrates the bidding price ratio characteristics of each data clusters, where most of the ratio decreased as the number of bidders increased. The regional variation of each cluster can be provided to the tendering authorities or bidding contractors as their preliminary reference.

Table 5. Attributes of the decision tree

| Field Name                  | Attributes                                                                 |
|-----------------------------|---------------------------------------------------------------------------|
| Bidding agencies            | DOT, APC, MOI, MOST, MND, EDU, MOEA, COA, TPG, NPG, KLG, TYG, HCCG, HC HG, MLG, TCG, CHG, Yu LG, CYC, CYH, TNG, KHG, PTG, TTG, HLG, Yi LG, PHG, KMG, LJG, NTG |
| Bidding method              | OPB, PPB, LTB                                                              |
| Bidding company no          | N, [Positive Integer]                                                     |
| Site                        | TP, NTP, KL, TY, HCC, HCH, ML, TC, CH, Yu L, CYC, CYH, TN, KH, PT, TT, HL, Yi L, PH, KM, LJ, NT |
| Scale                       | SP, ThP, ThS, HP                                                           |

Table 6. Rules of decision trees

| Cluster No | Number of Rules | Number of data | Bidding Price Ratio | Rules set from the decision tree |
|------------|-----------------|----------------|---------------------|----------------------------------|
| 1          | -               | 11             | 0.2422              |                                  |
| 2          | 3               | 969            | 0.9733              | 1. if area = CYH, and bidding company no. <= 4, and unit = DOT  
2. if bidding company no. <= 1  
3. if bidding company no. <= 4, and unit = MOEA  
1. if area = HL, and bidding company no. > 4, and bidding company no. <= 5, and unit = DOT  
2. if bidding company no. > 4, and bidding company no. <= 7, and unit = CHG  
3. if area = ML, and bidding company no. > 4, and bidding company no. <= 8, and unit = DOT  
4. if unit = HCCG  
5. if area = TT, and bidding company no. > 5, and bidding company no. <= 7  
6. if area = CYC, and bidding company no. > 1  
7. if bidding company no. > 14, and unit = MOI  
8. if bidding company no. > 4, and unit = EDU  
9. if area = HCC, and bidding company no. > 4  
10. if bidding company no. > 1, and unit = MND  
11. if area = Yu L, and bidding company no. > 4, and unit = DOT  
12. if bidding company no. > 4, and bidding company no. <= 8, and unit = MLG  
| 3          | 27              | 282            | 0.6876              | 13. if area = NP, and bidding company no. > 3, and bidding company no. <= 4, and unit = DOT  
14. if bidding company no. > 8, and unit = NPG  
15. if area = NT, and bidding company no. > 5  
16. if bidding company no. > 4, and bidding company no. <= 5, and unit = TCG  
17. if area = TC, and bidding company no. > 4, and unit = DOT  
18. if area = HL, and bidding company no. > 3, and bidding company no. <= 4, and unit = DOT  
19. if area = NT, and bidding company no. > 3, and bidding company no. <= 4, and unit = DOT  
20. if area = CH, and bidding company no. > 1, and unit = DOT  
21. if area = TY, and bidding company no. > 4, and unit = DOT  
22. if bidding company no. > 2, and unit = TPG  
23. if area = KL, and bidding company no. > 4, and unit = DOT  
24. if area = Yi L, and bidding company no. > 1, and bidding company no. <= 4, and unit = DOT  
25. if area = TN, and bidding company no. > 4, and unit = DOT  |
| Cluster No | Number of Rules | Number of data | Bidding Price Ratio | Rules set from the decision tree |
|-----------|----------------|---------------|---------------------|----------------------------------|
| 4         | 4              | 488           | 0.7906              | 26. if area = NP, and bidding company no. > 4, and unit = DOT  
1. if bidding company no. > 4  
2. if bidding company no. > 2, and bidding company no. <= 4, and unit = TYG  
3. if bidding company no. > 1, and bidding company no. <= 2, and unit = DOT  
4. if bidding company no. > 1  
5. if area = TP, and bidding company no. > 4, and unit = DOT  
6. if area = TT, and bidding company no. > 7  
7. if area = ML, and bidding company no. > 8, and bidding company no. <= 14, and unit = DOT  
8. if bidding company no. > 8, and unit = MLG  
9. if bidding company no. > 1, and bidding company no. <= 4, and unit = KLG  
10. if unit = APC  
11. if bidding company no. > 4, and unit = PTG  
12. if area = KH, and bidding company no. > 4, and bidding company no. <= 5, and unit = DOT  
13. if area = PT, and bidding company no. > 1, and bidding company no. <= 3, and unit = DOT  
14. if bidding company no. > 1, and bidding company no. <= 2  
15. if bidding company no. > 1, and bidding company no. <= 4, and unit = KHG  
16. if area = TY, and bidding company no. > 1, and bidding company no. <= 3  
17. if area = NP, and bidding company no. > 1, and bidding company no. <= 3, and unit = DOT |
| 5         | 5              | 94            | 0.5485              | 26. if area = NP, and bidding company no. > 4, and unit = DOT  
1. if bidding company no. > 4  
2. if bidding company no. > 2, and bidding company no. <= 4, and unit = TYG  
3. if bidding company no. > 1, and bidding company no. <= 2, and unit = DOT  
4. if bidding company no. > 1  
5. if area = TP, and bidding company no. > 4, and unit = DOT  
6. if area = TT, and bidding company no. > 7  
7. if area = ML, and bidding company no. > 8, and bidding company no. <= 14, and unit = DOT  
8. if bidding company no. > 8, and unit = MLG  
9. if bidding company no. > 1, and bidding company no. <= 4, and unit = KLG  
10. if unit = APC  
11. if bidding company no. > 4, and unit = PTG  
12. if area = KH, and bidding company no. > 4, and bidding company no. <= 5, and unit = DOT  
13. if area = PT, and bidding company no. > 1, and bidding company no. <= 3, and unit = DOT  
14. if bidding company no. > 1, and bidding company no. <= 2  
15. if bidding company no. > 1, and bidding company no. <= 4, and unit = KHG  
16. if area = TY, and bidding company no. > 1, and bidding company no. <= 3  
17. if area = NP, and bidding company no. > 1, and bidding company no. <= 3, and unit = DOT |
| 6         | 17             | 601           | 0.8903              | 26. if area = NP, and bidding company no. > 4, and unit = DOT  
1. if bidding company no. > 4  
2. if bidding company no. > 2, and bidding company no. <= 4, and unit = TYG  
3. if bidding company no. > 1, and bidding company no. <= 2, and unit = DOT  
4. if bidding company no. > 1  
5. if area = TP, and bidding company no. > 4, and unit = DOT  
6. if area = TT, and bidding company no. > 7  
7. if area = ML, and bidding company no. > 8, and bidding company no. <= 14, and unit = DOT  
8. if bidding company no. > 8, and unit = MLG  
9. if bidding company no. > 1, and bidding company no. <= 4, and unit = KLG  
10. if unit = APC  
11. if bidding company no. > 4, and unit = PTG  
12. if area = KH, and bidding company no. > 4, and bidding company no. <= 5, and unit = DOT  
13. if area = PT, and bidding company no. > 1, and bidding company no. <= 3, and unit = DOT  
14. if bidding company no. > 1, and bidding company no. <= 2  
15. if bidding company no. > 1, and bidding company no. <= 4, and unit = KHG  
16. if area = TY, and bidding company no. > 1, and bidding company no. <= 3  
17. if area = NP, and bidding company no. > 1, and bidding company no. <= 3, and unit = DOT |
Figure 2. Relationship between bidding price ratio of each data clusters

4. Conclusions and Recommendations
This study adopted data mining approach to analyze the awarding information of 2482 bridges and tunneling construction works in recent years. After excluding certain outliers and unfavorable data, five tender award properties field of the selected dataset was included in analysis. K-means data clustering approach and C5.0 decision tree method was implemented in the subsequent statistical analysis. This study preliminarily investigated the trend variation of the bidding price ratio, the rules and the bidding price ratio variation of each data clusters. The observed clear data clustering rules can assist the bidding contractors in their primary evaluation of the tender projects. Further investigation in the rules of data clustering is recommended and the implied significance from the magnitude of the bidding price ratio is also suggested to be studied.

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