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Cost Variability Estimation at different levels of Project Definition

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Abstract— The project cost estimation is carried out according to the engineering study level, while performing better engineering definition, project cost estimation will be more accurate. Therefore, is important to ask the question about what is the accuracy range of the project estimation cost for each engineering level.
For this paper development, estimates of different development projects in the mining industry will be used, and cost variances will be analyzed as these projects progress at different levels of project definition. As a result, the accuracy ranges the cost estimate has, according to each engineering level will be obtained; which can be used as a reference for future projects, and trends are interpreted to reach a better cost management for similar projects.

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Introduction

For a project to be viable it is necessary that the idea of the project matures from the initial concept together with the designer, to reach a detail level of which the cost estimate is as accurate as possible to reduce the uncertainty in the project construction. The cost estimation in the project engineering stages should be a reliable source of investment provision for the project construction. In the project maturing process, studies are carried out for each engineering level, with the project owner's need to know the project cost estimation so it can be provisioned in its costs, and be a reliable baseline for monitoring and control of costs during the project life cycle. Consequently, to the extent that they develop a greater detail of the project engineering, a better accuracy of the cost estimation will be obtained.

In the current investigation, the authors will perform an evaluation of the cost estimates made regarding to actual costs incurred in the project. These cost estimates belongs to mining projects located in Peru and the costs incurred in these projects belongs to construction costs. The mining sector has a leading role in the Peruvian economy, so it is important to determine the accuracy range of cost estimates for this type of investment projects.

As part of the research, the authors will analyze and evaluate the accuracy ranges obtained at different project levels and will compare them with the expected accuracy ranges issued by the AACE® International through its Recommended Practice No. 18R-97 "Cost estimate classification system – as applied in engineering, procurement, and construction for the process industries" and in the Recommended Practice No. 47R-11 "Cost estimate classification system - as applied in the mining and mineral processing industries". Figure 1 shows the accuracy ranges recommended by the AACE® International for each class of project definition.

Through these results, the authors will obtain valuable conclusions for the cost estimates in projects of similar characteristics.

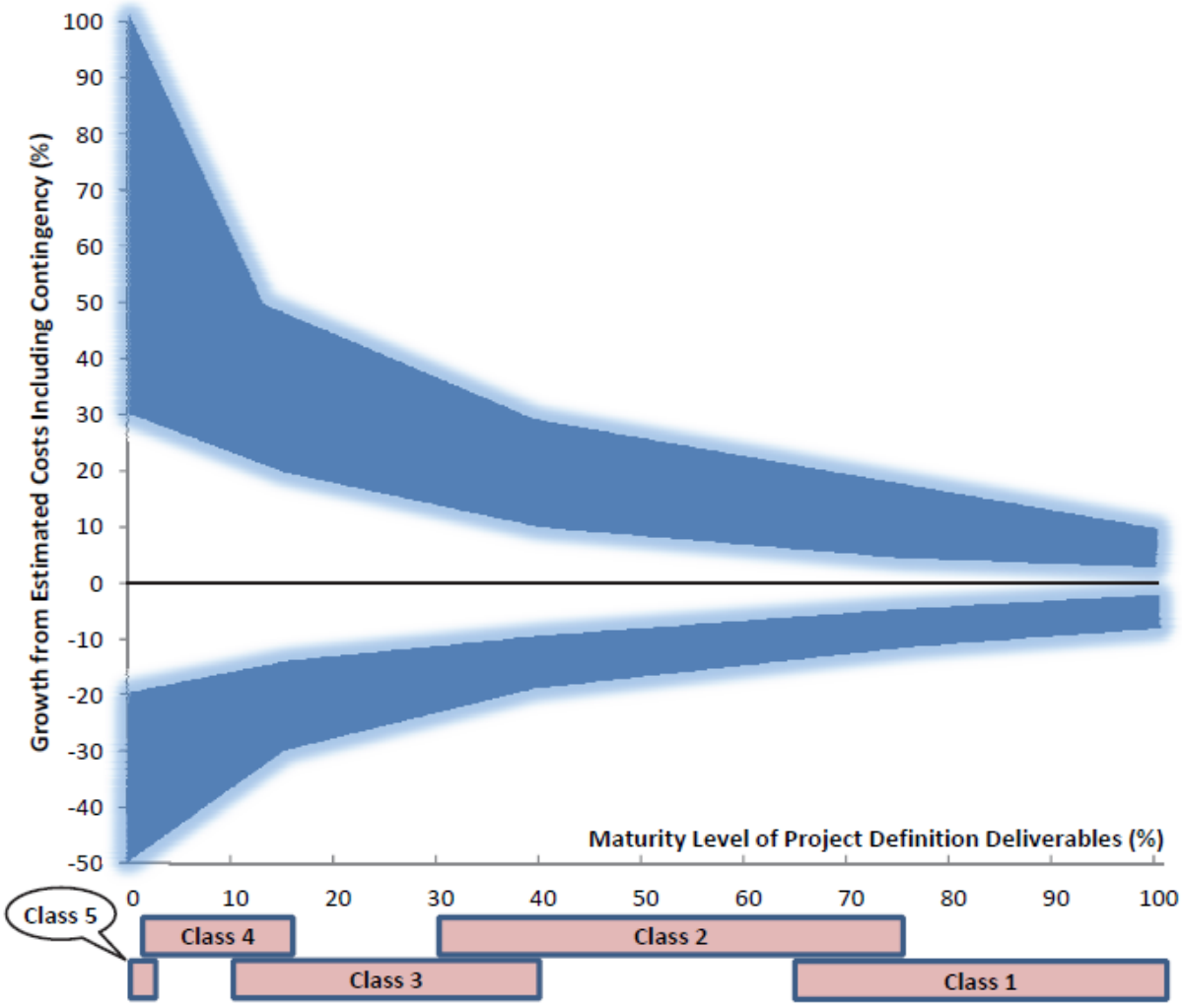

Figure 1 - Variability in accuracy ranges (RP 47R-11)

Data collection procedure

In order to obtain information on cost estimates of different projects, the authors have obtained costs of the different engineering stages of mining projects developed in consulting companies, based in Lima, Peru; moreover, the authors have obtained construction costs information from several projects already executed and / or are being executed by project owners. Consequently, the authors have compiled estimates costs and / or construction costs of 78 projects, dating from 2011 onwards. It is important to indicate that these costs estimations have been prepared in US dollars.

From the analyzed projects, there are 30 projects that have matured from Class 3 to Class 2, there are 31 projects that have matured from Class 2 to Class 1, and finally there are 31 projects that have matured from Class 3 to Class 1. Furthermore, 34 projects from the 78 have construction costs which represent 44% of total projects.

The project costs for each project maturity class and their evolution is shown in Table 1. The amounts of the cost estimates are expressed in thousands of US dollars.

Project number	Class 3 (K$)	Class 2 (K$)	Class 1 (K$)	Actual costs (K$)	Project number	Class 3 (K$)	Class 2 (K$)	Class 1 (K$)	Actual costs (K$)
1	9 721		2 551		**40**	19 552	16 062		
2	864		370		**41**	4 556	1 488		
3	1 751		2 091		**42**	3 508	7 145		
4		1 508	1 162		**43**		38 086	38 882	32 319
5	9 127	7 171	8 741		**44**	5 171	5 072	4 701	6 383
6	3 427	3 524			**45**	2 938		2 599	
7	4 685	3 847			**46**	953		755	
8	2 355	3 378	6 679		**47**	2 639	2 697	2 937	3 476
9	5 669	2 802			**48**	738		2 866	
10	2 000	988			**49**	852	775	886	943
11	3 686	5 720	6 439		**50**	4 154	3 537	3 776	4 053
12		2 884	5 957		**51**			7 843	6 353
13		541	668		**52**			9 568	12 347
14	39 427	21 561	24 650	21 496	**53**			4 028	4 966
15	11 575	9 264	8 907	6 431	**54**			1 489	1 317
16	602	463	524		**55**	10 841	10 408	11 128	
17	26 097	30 108	27 126		**56**	144		283	88
18	27 178	19 881	19 126		**57**	82		74	76
19	15 561	2 350	5 244		**58**	198		192	163
20		7 614	1 733		**59**	428		393	25
21		15 634	11 463		**60**			838	1 022
22		88 173	87 139		**61**	2 213		2 707	3 385
23		34 601	24 513		**62**	7 844		8 124	8 014
24		40 570	25 481		**63**	120		146	193
25		17 916	28 141		**64**	328			604
26		4 998	3 646		**65**			3 644	5 226
27	15 399	19 909			**66**	921			1 311
28	24 178		36 277		**67**	532		475	608
29	2 179	4 893	3 065		**68**	336			347
30	392	467			**69**			2 010	2 840
31	4 866	5 070			**70**	206			290
32	6 373	8 844			**71**	55			15
33	1 960	3 091			**72**	192			398
34	2 256	3 535			**73**	192			192
35		2 224	4 477		**74**	150			129
36	3 843	15 979			**75**	264			278

Project number	Class 3 (K$)	Class 2 (K$)	Class 1 (K$)	Actual costs (K$)	Project number	Class 3 (K$)	Class 2 (K$)	Class 1 (K$)	Actual costs (K$)
37	568	1 040	1 351		**76**		9 887	10 388	8 506
38		155	1 330		**77**			3 848	3 984
39		4 874	5 244		**78**			11 527	13 297

Table 1 – Cost estimates per classes in thousands US dollars (K$)

It was not possible to get construction costs in all cases because some projects have not been built yet, there are projects that will not be executed due to changes in the mine's operating strategy; and other projects that did not get construction costs because as a result of the confidentiality of costs for project owners. Table 2 shows the number of projects and the reason why the construction cost was not obtained.

Costs obtained?	Reason	Quantity of projects
Yes	--	34
No	Confidentiality of costs for project owners	8
No	The project will not be executed due to changes in mine operating strategies.	10
No	The project will be built in the future.	26
		78

Table 2 - Construction cost information (updated January 2017)

It should be noted that only 8 of the 78 projects have not been obtained construction costs for the owners' confidentiality to give the incurred cost information, which represents 10% of the total. On the other hand, 28 of the total projects have not been obtained because these projects will be built in the future. Table 3 shows the number of projects in the year when they were built for the case of the projects that were already built, and also it shows the most probable year that the project will be built for the case of projects to be built in the future, it should be also mentioned that in this table have not been considered the 10 projects that the owner has declined due to changes in the mine's operational strategy.

Construction status	Year of construction	Quantity of projects
Built	2011	7
	2012	10
	2013	10
	2014	6
	2015	3
	2016	6
To be built	2017	16
	2018	2
	2019	3
	2020	3
	2021	2
Total		**68**

Table 3 - Year of construction

Information analysis

Accuracy of cost estimates

When mining companies submit a tender of a construction of a project, usually, one of the evaluation criteria that has the highest score is the economic aspect, however, it is common that the cost of the winning proposal varies during the construction execution due to changes needed which impact on the cost. These changes can be additional or deductive from the initial construction cost that came up for different reasons, for example: events not foreseen in engineering, changes in the construction conditions, construction terms expansion, different climatological or topographic conditions, among others. For the cost estimators, these changes result from the uncertainty of upcoming events in construction, so they are quantified through contingency and management reserves; then, cost estimates in the different maturity stages of the project are made with the objective of considering all construction costs have been provisioned; however, these estimates tend to deviate from what the costs actually result. Therefore, the actual cost of construction is a good reference for calculating the accuracy of estimates made at different engineering stages.

In order to find the accuracy of each cost estimate was considered the Equation 1.

$$\text{Accuracy} = \frac{\text{CE} - \text{AC}}{\text{AC}}\% \qquad \text{(Equation 1)}$$

In the Equation 1, CE is the cost estimate and AC is the actual cost of the incurred costs during project execution. Therefore, when the accuracy is less than 0% then the cost estimate has been underestimated, when the accuracy is higher than 0% then the cost estimate has been overestimated.

Table 4 shows the accuracy levels that result from projects with construction costs.

Quantity of projects	Accuracy level (%)		
	Class 3	Class 2	Class 1
14	83%	0%	15%
15	80%	44%	39%
43		18%	20%
44	-19%	-21%	-26%
47	-24%	-22%	-15%
49	-10%	-18%	-6%
50	2%	-13%	-7%
51			23%
52			-23%
53			-19%
54			13%
56	64%		222%
57	7%		-3%
58	22%		18%
59	1621%		1481%
60			-18%
61	-35%		-20%
62	-2%		1%
63	-38%		-24%
64	-46%		
65			-30%
66	-30%		
67	-13%		-22%
68	-3%		
69			-29%
70	-29%		
71	278%		
72	-52%		
73	0%		
74	16%		
75	-5%		
76		16%	22%
77			-3%
78			-13%

Table 4 - Accuracy levels

To estimate the mean and the standard deviation in each class, the cost estimates was removed from the following projects which deviate from most of the data: project 56 (Class 1), project 59 (Class 3), project 59 (Class 1) and project 71 (Class 3). Table 5 and Figure 2 shows the mean and standard deviation of the accuracy for each class of cost estimate.

	Class 3	Class 2	Class 1
Mean	-1%	1%	-5%
Standard deviation	38%	24%	20%

Table 5 - Mean and standard deviation of accuracy

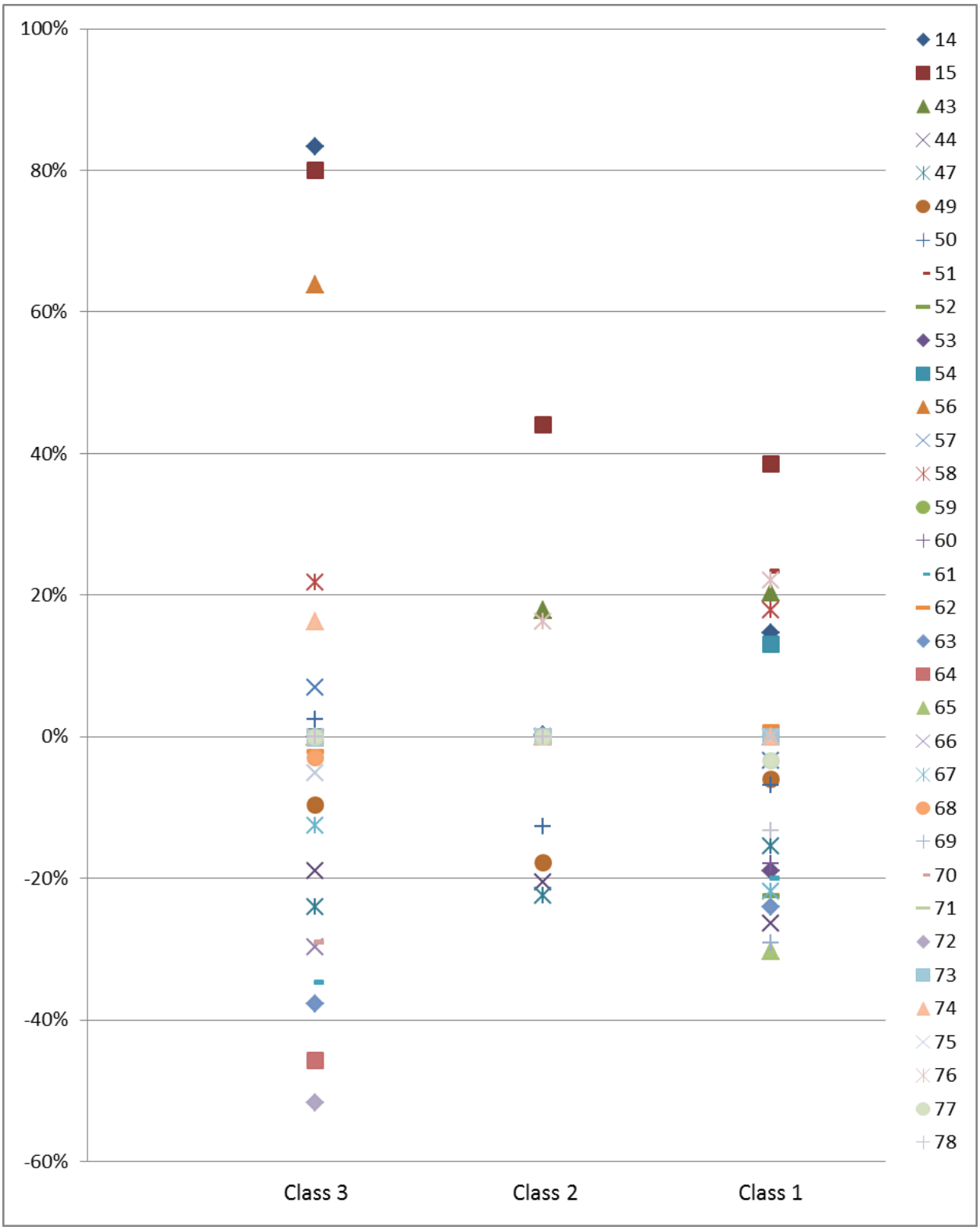

Figure 2 - Accuracy levels (%)

Table 4 shows that accuracy levels vary according to class types, accuracy levels for Class 3 range from -52% to 83%, as a result, the mean is -1%, therefore, it follows that the cost estimates were underestimated regarding to the actual costs. Furthermore, the standard deviation in Class 3 is 38%, higher than the other classes, and this can be understood because these estimates have a large dispersion of data due to these estimates are in an order of project definition between a 10% to 40%.

The accuracy levels for Class 2 ranged from -22% to 44% and the mean was 1%, that is to say, the cost estimates were overestimated. On the other hand, the standard deviation improves in relation to the Class 3 to a 24%, however, it is still a high dispersion. In this class no information was excluded.

In the case of Class 1, accuracy levels vary from -30% to 39% with a mean of -5%, which concludes that the cost estimates in this class were underestimated. Furthermore, the standard deviation improves to 20% regarding the other classes because these estimates have better accuracy.

From the results obtained, it can be concluded that the mean in Class 2 and 3 is close to 0%, however, the mean in Class 1 has a higher value and tends to be underestimated, and therefore, it is very important to know well the project to adequately quantify all costs including contingencies. The following are some of the consequences of working with underestimated estimates:

- The economic evaluation of a project gets better than it actually will be when it is executed.
- Feasibility can be given to a project that is not economically viable.
- Provision is made for minor project expenses that will generate negative balances in the project execution cash flow.

In order to understand the behavior of the accuracy levels obtained for each maturity class of the projects, the authors calculated the reliable intervals at 5% and 95% for each class in normal distribution. These reliable intervals are intended to give a trend of order of magnitude in which the data are found and compare with the recommendations provided by the AACE® International. The results are shown in Table 6.

	Class 3	**Class 2**	**Class 1**
Quantity of projects	21.00	8.00	23.00
Mean	-1.41%	-0.62%	-4.71%
Standard deviation	37.78%	23.67%	19.97%
Z 5%	-17.6%	-15.8%	-12.9%
Z 95%	+14.7%	+17.0%	+3.4%

Table 6 – Reliable intervals at 5% and 95%

From Table 6 can be seen that the results obtained in the projects are close to the expected range of accuracy specified by the AACE® International in the recommended practice 47R-11.

In the case of Class 3, the accuracy ranges proposed by the AACE® International are L: -10% to -20% and H: + 10% to + 30%, while in the research carried out at reliable intervals vary from -17.6% to 14.7%, therefore, the results are inside the expected ranges proposed by the AACE® International.

In the case of Class 2, the accuracy ranges proposed by AACE® International are L: -5% to -15% and H: + 5% to + 20%, on the other hand, the results of the confidence intervals vary from -15.8% to + 17%, which indicates that the results in the low range deviate by 0.8% from the minimum range proposed by the AACE® International, however the high range is within the recommendation.

In the case of Class 1, the accuracy ranges proposed by the AACE® International are L: -3% to -10% to H: + 3% to + 15%, while the results of the reliable intervals vary from -12.9% to + 3.4%, which indicates that the results in the low range deviate by 2.9% from the maximum range proposed by the AACE® International, however, the high range is within the recommendation.

Either for Class 2 as well as Class 1, the lowest values have a small difference from the low range proposed by the AACE® International, which again demonstrate that there is a tendency to make underestimated cost estimates what really obtain from construction costs.

Grouping of cost estimates by amounts

Another way to analyze cost estimates is by dividing them in groups according to actual construction costs. Table 7 shows the division of the Class 3 cost estimates in 3 groups: less amounts or equal to $ 1 million, ranging from $ 1 million to $ 5 million and amounts over the $ 5 million. This table shows that the mean accuracy fell from -7% of project amounts less than $ 1 million dollars to -22% in project amounts between $ 1 and 5 million dollars. On the contrary, the mean accuracy rise to 36% for projects higher than $ 10 million dollars, so there is an overestimation of costs in this range, however, the standard deviation of accuracy in this group is 54%, which means that these data are widely dispersed.

Grouping ranges – Class 3	Quantity of projects	Mean	Standard deviation
Less than or equal to 1 million dollars	13	-7%	31%
From $ 1 million to $ 5 million dollars	4	-22%	17%
Over 5 million dollars	4	36%	54%
Total	21	-1%	38%

Table 7 - Grouping of projects by amounts - Class 3

Table 8 shows the categorization of construction costs for projects Class 2, where it can be seen that the mean of the group estimation of cost estimates less than $ 1 million dollars and the group from $ 1 to 5 million dollars are equal, showing an underestimated cost in both cases. However, in the group of more than $ 5 million dollars the mean results 12%, that is to say, the costs were overestimated.

Grouping ranges - Class 2	Quantity of projects	Mean	Standard deviation
Less than or equal to 1 million dollars	1	-18%	--
From $ 1 million to $ 5 million dollars	2	-18%	7%
Over 5 million dollars	5	12%	24%
Total	8	1%	24%

Table 8 - Grouping of projects by amounts - Class 2

Table 9 shows the categorization of construction costs for projects Class 1, where the mean falls from -8% to -12% of the group of projects less than $ 1 million dollars in relation with the group of projects from $ 1 to 5 million dollars, however, the group of projects with amounts higher than $ 5 million dollars has a mean of 11%, that is to say, the costs are overestimated.

Grouping ranges - Class 1	Quantity of projects	Mean	Standard deviation
Less than or equal to 1 million dollars	5	-8%	17%
From $ 1 million to $ 5 million dollars	8	-12%	13%
Over 5 million dollars	8	11%	20%
Total	21	-5%	20%

Table 9 - Grouping of projects by amounts - Class 1

Finally, in this analysis there are two defined scenarios which are as follows: when the construction costs are less than $ 5 million dollars and when the construction costs are higher than $ 5 million dollars. Therefore, cost estimates tend to be underestimated in all classes analyzed when costs are less than $ 5 million; however, cost estimates tend to be overestimated when costs are higher than $ 5 million dollars.

Variation in the estimates of different classes

Another way to analyze the data is to interpret the variations that exist when a project varies from Class 3 to Class 2, from Class 2 to Class 1 and from Class 3 to Class 1. Table 10 shows the amounts in thousands dollars and variation percentages of the estimated amounts in the different class maturations.

Maturation of the project	Quantity of	Sum of costs –	Sum of costs –	Sum of costs –	Variation (K$)	Variation (%)

	projects	Class 3 (K$)	Class 2 (K$)	Class 1 (K$)		
From Class 3 to Class 2	30	240 498	221 299	--	-19 200	-7.98%
From Class 2 to Class 1	31	--	403 977	384 968	-19 008	-4.71%
From Class 3 to Class 1	31	214 717	--	193 788	-20 929	-9.75%

Table 10 - Variation between classes

In the list of projects there are 30 projects that matured from Class 3 to Class 2, from which results a variation of the cost estimates of -7.98%, this was due to the costs estimates in Class 2 (in contrast to cost estimates in Class 3) are detailed estimates where the prices of the installations and materials are estimated according to the purchase price for all the main equipment and materials. The estimate is based on lists of detailed quantities, labor cost and actual productivity according to labor union fees for trade agreements, rental costs of local contractors construction equipment, freight rates, and indirect costs estimated in more detail.

In addition, there are 31 projects that matured from Class 2 to Class 1 of which is a variation of the costs estimates of -4.71%. This variation is less if compared with the variation obtained when the cost estimates mature from Class 3 to Class 2, in other words, that while more detail is a project, the less variation with respect to the previous class. In addition, the variation between the Class 1 to Class 2 difference can be explained by the improvement in the support documents for the estimation of the costs as detailed plans by specialty, final design parameters, specifications, quantities to execute, construction schedules, etc. Besides, the variation is due to the fact that the estimates of the costs in the Class 1, unlike the Class 2, are detailed estimates of installation, products and packages based on the price of the award for all main equipment and materials, furthermore, it is use the real labor cost and productivity of the local workers, cost of real rental construction team which have worked in town, freight based on real data, the indirect costs are calculated based on actual data.

Finally, there are 31 projects that matured from Class 3 to Class 1, without going through Class 2. It should be noted that in small projects, it is usual to make cost estimates of Class 3 then move on to estimates of costs of Class 1, without developing engineering where you can develop a cost estimate of Class 2. This type of project gets a variation of 9.75% between the estimates of the costs of the Class 3 and Class 1. Therefore, it is shown that if the projects mature without going through all the classes, the variation of the cost will be higher due to the higher differences in the level of detail between classes.

It is verified from the analysis that the cost estimates will have smaller variations in relation to their previous classes when there is a higher level of detail in the project. Furthermore, if no engineering is performed in all maturation classes, there will be higher variations in cost estimates between classes. Also, the trend of cost estimates decreases as the project is maturing across the different classes, due to the greater detail in the elaboration of cost estimates and the lower uncertainties when the project matures to upper classes.

Causes of variation in the accuracy

According to the type of projects which have been carried out cost estimates for the current research, causes were found depending on whether the costs were underestimated or overestimated.

For the costs that were underestimated the following causes were found:

- Interferences not foreseen in the work area that were not detected in the engineering, therefore were not considered in the cost estimate.
- Lack of cost accuracy due to poor technical information. This cause is more frequent for the cost estimates of Class 3 and Class 2.
- Term extension in the project construction, the fact that construction costs increase.
- Stoppage of the project due to social problems in the region.
- Underestimation of amounts to be executed at site due to uncertainty of what is going to be executed, especially when there are mass earthworks.
- Poor client information for the development of the project engineering, which causes design inaccuracies and therefore also causes inaccuracies in the quantity estimate that feeds the cost estimate.

Likewise, the causes for which cost were overestimated, are as follows:

- Overestimation of amounts to be executed due to too high security factors that did not correspond to the reality of the project.
- Best practices in construction procedures that improve productivity and shorten construction times, therefore, the bidder proposal result lower.

Conclusion

In the current research the authors carried out the evaluation of the cost estimates of several projects and studied the variation that exists between different classes of maturity of projects definition. The authors found the accuracy levels of all projects located in their database.

According to the results of the accuracy mean for each project class, it is concluded that in Class 3 and Class 1 tend to be underestimated with values of -1% and -5% respectively, on the other hand, the mean in Class 2 is overestimated by 1%. However, Class 1 is the only one that has a significant tendency for underestimated costs, and this class often serves as the baseline of cost for the project construction. Therefore, it is important to carry out a thorough analysis including the uncertainties of the project in order to have better accuracy in cost estimates.

Analyzing the standard deviation, the authors conclude that the estimates are scattered in all classes analyzed, for Class 3 obtains a standard deviation of 38%, for Class 2 obtains 24% and in

Class 1 obtains 20%. However, it is shown that the dispersion decreasing if the level of detail and development of the project is higher.

The authors determined the reliable intervals at 5% and 95% according to the normal distribution due to the dispersion of project accuracy values. It was concluded that the results are within the ranges of accuracy recommended by the AACE® International even though they are dispersed, except for the lower ranges of Class 2 and Class 1 where the percentages are deviated by an additional percentage of 0.8% and 2.9% respectively for each class. In view of the foregoing, the cost estimates for this type of projects were underestimated slightly below the AACE® International recommendations.

In the current paper, the data were also analyzed according to the ranges of the real amounts of construction costs. Three ranges were established in based on construction costs: less than $1 million dollars, between $ 1 and 5 million dollars and higher than $ 5 million dollars. From this analysis, we find that the project costs less than $ 1 million dollars and those between $ 1 and 5 million dollars tend to be underestimated in all classes. On the other hand, the projects construction costs higher than $ 5 million tend to be overestimated.

The authors also analyzed the existing variations of the developing project process between one class to another, according to the following: from Class 3 to Class 2, from Class 2 to Class 1 and from Class 3 to Class 1. Data processing shows that when a project varies from Class 3 to Class 2, it will have a greater variation than when the project varies from Class 2 to Class 1. Furthermore, when a project varies from Class 3 to Class 1 there will be more variation than even when the project varies from Class 3 to Class 2, what is and understands that the projects development ignores the Class 2, there will be greatest variations in costs estimates.

It also verifies that the trend of the cost estimates, as the project is maturing, result as it is smaller than the project associated risks uncertainties reduction at the upper classes cost estimates.

References

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