Inaccuracy in Pipeline-Compressor-Station Construction-Cost Estimation

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Summary

The intent of this paper is to investigate installed cost overruns of pipeline-compressor-station projects. A total of 220 pipeline-compressor-station projects constructed between 1992 and 2008 have been collected, including material, labor, and miscellaneous, land, and total installed costs; and compressor-station capacity; location; and year of completion. Statistical methods are applied to identify the distribution of cost overruns and overrun causes. Overall average overruns of pipeline-compressor-station material, labor, miscellaneous, land, and total costs are 3, 60, 2, −14, and 11%, respectively. Cost estimations of compressor-station-construction components are biased except for the material cost. In addition, the cost-estimation errors of underestimated compressor-station-construction components are generally larger than those of overestimated components. Results of the analysis show that compressor-station project size, capacity, location, and year of completion have different impacts on individual construction component cost overruns.

Introduction

Cost-estimating error is the tendency for actual costs to deviate from estimated cost. Bias is the tendency for that error to have a nonzero mean (Bertisen and Davis 2008). Project cost-estimation errors and bias are common and a global problem in cost estimating (Flyvbjerg et al. 2003). Project cost-estimation errors and bias have been mentioned and studied in numerous papers. Cost overruns of all Indiana department of transportation (INDOT) projects were 4.5%, while 55% of INDOT projects experienced cost overruns (Bordat et al. 2004). Jacoby (2001) found that 74 projects with a minimum cost of USD10 million had 25% cost overruns. Rui et al. (2011a, 2011b, 2012a, 2012b) investigated the cost overruns of 412 pipeline projects between 1992 and 2008, finding an average of 4.9% cost overrun for material, 22.4% for labor, −0.9% for miscellaneous, 9.1% for right of way (ROW), and 6.5% for total installed costs. In addition, literature reviewed also showed that cost overruns exist over time.

Although many studies have been conducted on project installed cost overruns, there are limited available references on pipeline-compressor-station installed cost overruns. With available pipeline-compressor-station data, this paper focuses on the cost-estimation errors of compressor-station-construction components—material, labor, miscellaneous, land, and total installed costs—and investigates and identifies the frequency of cost-overrun occurrences and the magnitude of cost overruns for pipeline-compressor projects. In addition, cost overruns in terms of compressor-station project size, capacity, location, and year of completion are investigated.

Data sources

In this study, the compressor stations are selected on the basis of data availability. Compressor-station cost data are collected from the Federal Energy Regulatory Commission (FERC) filing by gas-transmission companies, published in the *Oil & Gas Journal* annual data book (PennWell 2009). The compressor-station data set includes year of completion, capacity, location, and individual cost components. Compressor stations in the data set were distributed in all states in the contiguous US (i.e., excluding Alaska and Hawaii), and were completed between 1992 and 2008. The year of completion is defined by the time of filing the FERC report. For example, the year 1999 for the constructed projects means the FERC report was filed between 1 July 1999 and 30 June 2000. In this paper, the capacity is measured by the horsepower (hp) of the compressor station. All pipeline-compressor-station-construction component costs are reported in USD. The entire data set includes 220 compressor stations. “Cost” is defined as real accounted costs determined at the time of completion. In this paper, costs include material, labor, miscellaneous, land, and total installed capital costs. Miscellaneous cost is a composite of surveying, engineering, supervision, interest, administration, and overheads, contingencies, telecommunications equipment, freight, taxes, allowances for funds used during construction, and regulatory filing fees. The total installed cost of a project is the sum of material, labor, miscellaneous, and land costs (PennWell 2009).

Location information for US pipeline systems was provided in a state format, and refers to the 48 states in the contiguous US (i.e., excluding Alaska and Hawaii). The US Energy Information Administration (EIA) breaks the US natural-gas-pipeline network into six regions: northeast, southeast, midwest, southwest, central, and western. The map of regional definitions is shown in **Fig. 1.** These regional definitions are applied to analyze geographic differences. To make a comparative analysis, all costs are adjusted by the Chemical Engineering Plant Cost Index to 2008 USD (Marshall 2011).

Performance of Individual Compressor-Station-Construction Component Cost Estimation

This section will evaluate the performance of compressor-station-construction component cost estimation. Several methods may be used to study the difference between estimated and actual costs. In this study, the cost overrun is employed to measure cost performance. The formula for the cost overrun is

$$\text{cost overrun} = \frac{\text{actual cost} - \text{estimated cost}}{\text{estimated cost}} \times 100\%.$$

If the cost overrun is positive, the cost is underestimated, otherwise it is overestimated.

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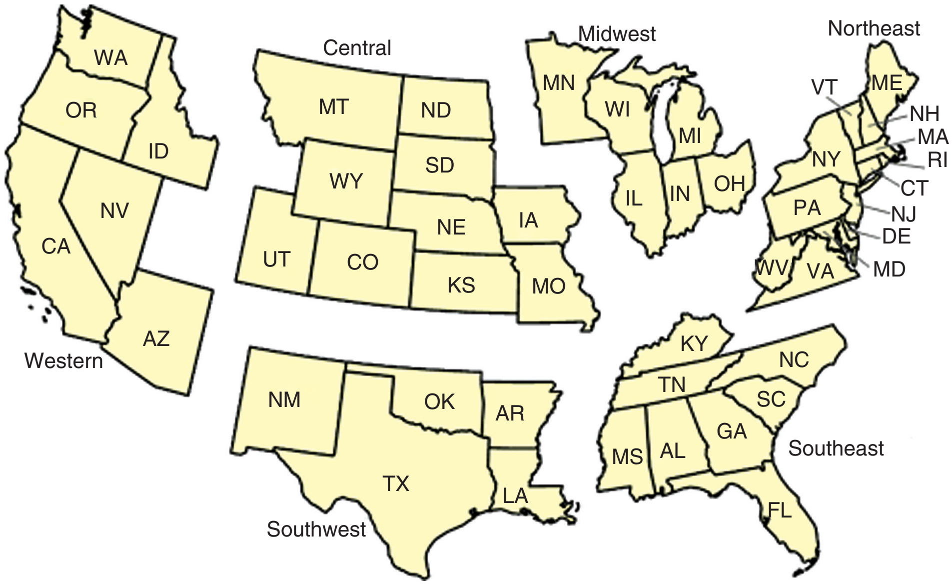

Fig. 1—US natural gas-pipeline-region map (EIA 2010). Note: Alaska and Hawaii are not included.

Histograms of Cost Overruns. Histograms of the cost overruns for compressor-station-construction components are shown through **Figs. 2 to 6.** If the cost error is small, the histogram would be narrowly concentrated at approximately zero. If underestimating cost is as common as overestimating cost, the histogram would be symmetrically distributed at approximately zero. It appears that the five figures exhibit nonsymmetric distributions, and none of them satisfied the previously mentioned assumptions. For material cost, 48.18% (106) of total compressor-station projects were underestimated and 51.36% (113) were overestimated. For labor cost, 72.81% (158) of compressor stations were underestimated and 27.19% (59) were overestimated. For miscellaneous cost, 35.32% (77) of compressor stations were underestimated and 64.68% (141) were overestimated. For land cost, 31.2% (29) of compressor stations were underestimated and 65.6% (61) were overestimated. For total cost, 57.27% (126) of compressor stations were underestimated and 42.73% (94) were overestimated. Furthermore, only one compressor-station project estimated for material costs accurately, and three compressor-station projects had accurate estimations for land costs.

In summary, more compressor stations were overestimated for material, miscellaneous, and land costs, while more compressor stations were underestimated for labor and total installed costs. In general, the percentage of overestimated compressor stations indicates that there are a fairly good number of compressor stations being completed with costs less than the estimated costs except for when it comes to labor costs. In addition, 81.3% of material cost overruns, 34.1% of labor cost overruns, 58.26% of miscellaneous cost overruns, 26.88% of land cost overruns, and 77.28% of total cost overruns are in a range from –40% to 40%. These numbers demonstrate that labor and land cost overruns are more severe than cost components, and are also indicated by their respective standard deviations (SDs) **(Table 1).**

Summary Statistics of Cost Overruns. Summary statistics of cost overruns of individual compressor-station-construction components are shown in Table 1. Skewness (S) is a quantitative method to measure the symmetry of the distribution. Symmetrical distribution has an S of zero. Positive S means that the right tail is "heavier" than the left tail. Negative S means that the left tail dominates

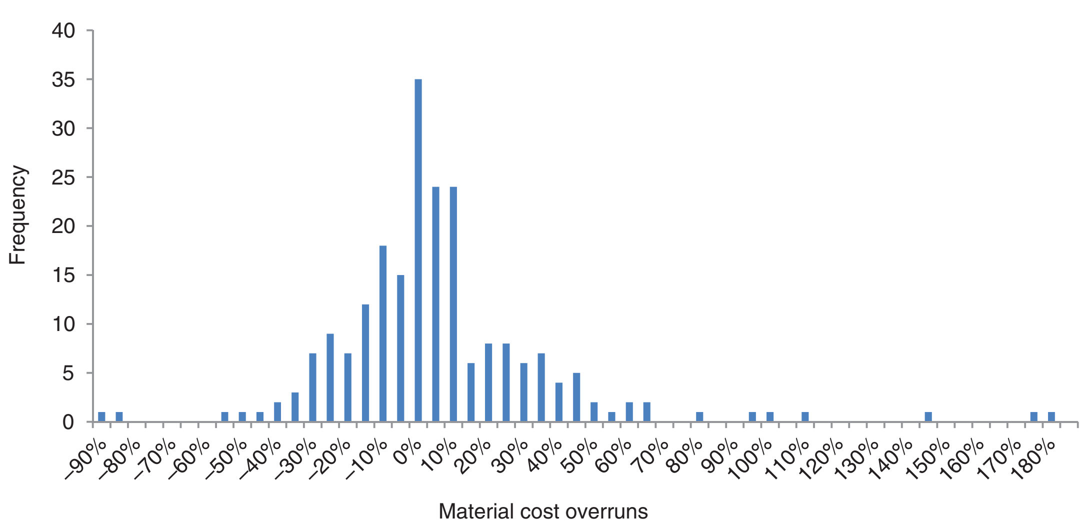

Fig. 2—Material cost overruns.

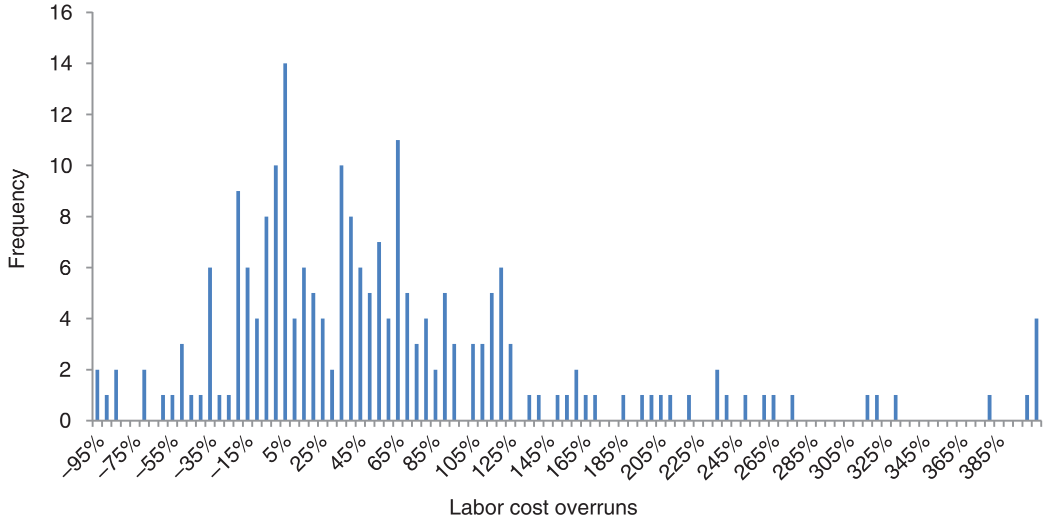

Fig. 3—Labor cost overruns.

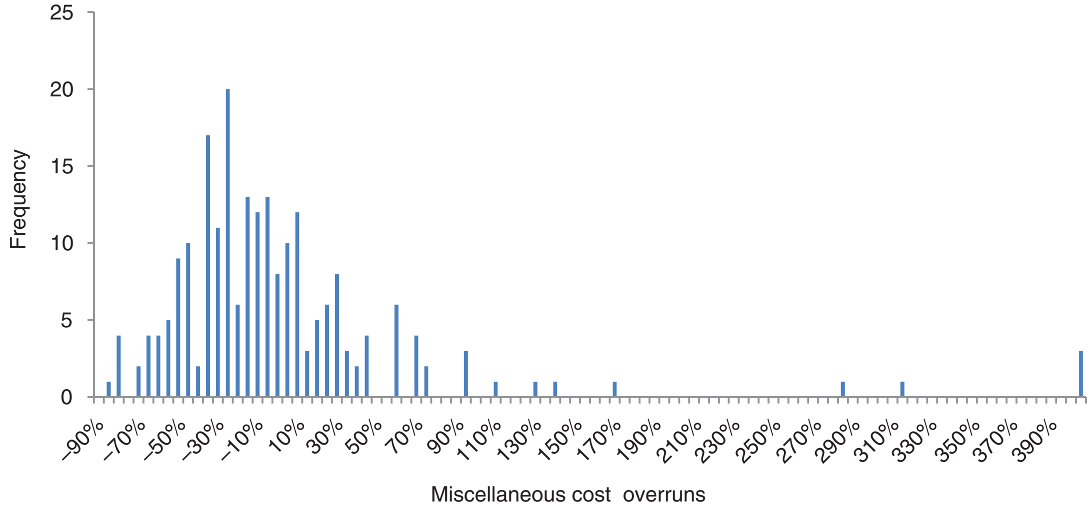

Fig. 4—Miscellaneous cost overruns.

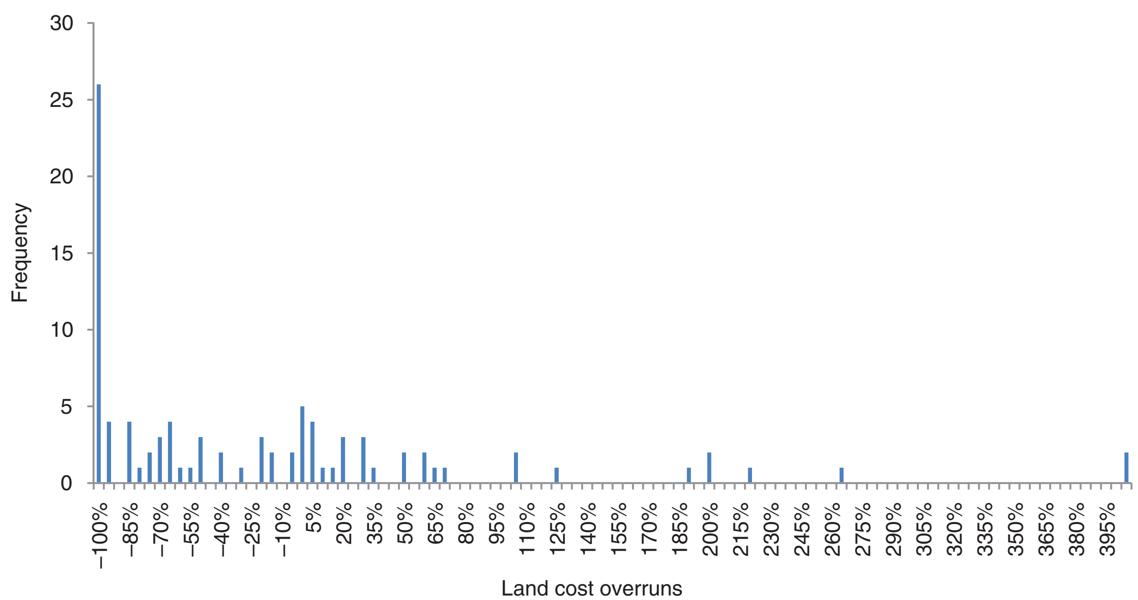

Fig. 5—Land cost overruns.

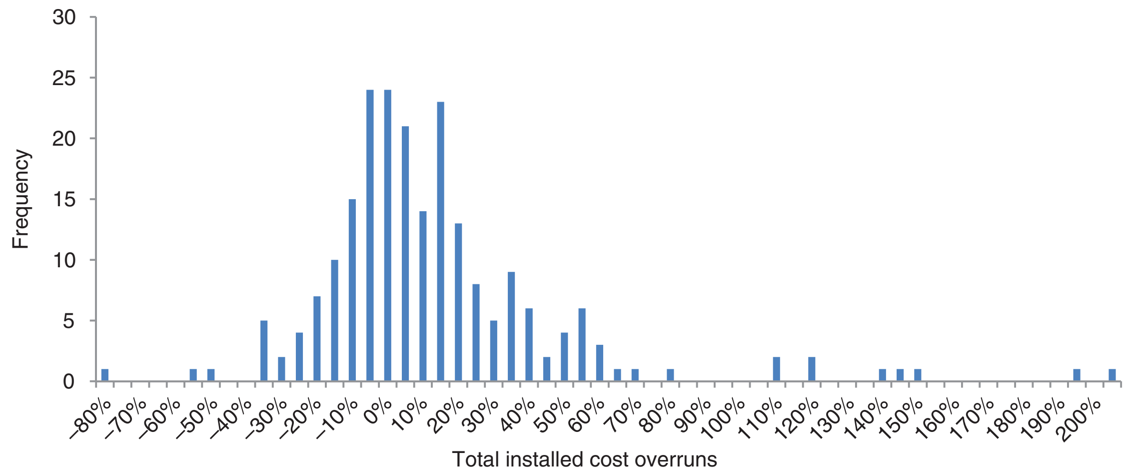

Fig. 6—Total installed cost overruns.

the distribution. Kurtosis (K) is a quantitative method to evaluate whether the shape of the data distribution fits the normal distribution. A normal distribution has a K of zero. K of a flatter distribution is negative and that of a more-peaked distribution is positive (Hill et al. 2008). Values of S and K in Table 1 show that none of the cost overruns of the five components has symmetrical normal distribution, which matches the implication from Figs. 2 through 6. Some transformation techniques (e.g., natural-log transformation) were applied to convert cost overruns to normal distribution, but those data transformations where unsuccessful. Therefore, the nonparametric statistical test is used in the following sections.

The values of minimum and maximum in Table 1 indicate that cost performance for some compressor stations is extremely bad. The miscellaneous cost has the largest maximum/minimum cost-overrun range of 896% of estimated cost, followed by the land cost of 886%, labor cost of 720%, total cost of 283%, and material cost of 273%. In addition, SD of individual cost components ranges from 33% of estimated cost to 104% of estimated cost. The large maximum/minimum cost-overrun range and SD indicate that the performance of compressor-station-construction cost estimating is unstable. Labor, miscellaneous, and land costs have large maximum/minimum cost-overrun ranges and SD, which indicates the difficulties of estimating these three construction component costs accurately. Material cost has the highest estimating accuracy. Total installed cost overrun has the second-smallest maximum/minimum range and SD because of its aggregation of individual cost components.

Average Cost Overruns. Average cost overrun is a key parameter for measuring the cost-estimation performance of individual construction cost components. The labor cost has the highest average cost overrun of 60% of estimated cost, followed by a total cost of 11%, material cost of 3%, miscellaneous cost of 2%, and land cost of –14%. The material, labor, miscellaneous, and total costs show positive average cost overruns, while the land cost demonstrates a negative average cost overrun. This result denotes that, on average, actual cost is larger than estimated cost for all compressor-station-construction cost components except the land cost.

Statistical Tests for Cost-Overrun Bias and Magnitude. It is an interesting finding that the average cost overruns of material and miscellaneous cost are positive, even though there are more compressor stations with overestimated material and miscellaneous costs. It appears that cost estimation of compressor-station-construction cost components is biased, and the underestimating error is generally greater than overestimating errors for some cost components. Two statistical tests are performed to validate this inference.

A binomial test is conducted to examine if cost-overestimating error is as common as cost-underestimating error. As shown in **Table 2,** the *p*-value of the binomial test rejects the null hypothesis that the overestimating error is as common as the underestimating error for labor, miscellaneous, land, and total installed costs ($p<0.05$), but fails to reject it for material cost estimation

TABLE 1—SUMMARY OF COST OVERRUNS OF COMPRESSOR-STATION-CONSTRUCTION COMPONENTS

	Material	Labor	Miscellaneous	Land	Total
Average	3%	60%	2%	–14%	11%
Standard error	2%	7%	6%	14%	2%
Standard deviation	33%	104%	94%	130%	36%
Kurtosis	8.05	6.67	41.69	17.33	8.01
Skewness	1.65	2.15	5.74	3.57	2.19
Range	273%	720%	896%	886%	283%
Minimum	–95%	–98%	–85%	–100%	–82%
Maximum	178%	625%	811%	786%	201%
Total number	220	217	218	93	220
Number of underestimated	106	158	77	29	126
Number of accurate	1	0	0	3	0
Number of overestimated	113	59	141	61	94

TABLE 2—STATISTICAL TESTS OF COST OVERRUNS OF COMPRESSOR-STATION-CONSTRUCTION COMPONENTS

	Material	Labor	Miscellaneous	Land	Total
Binomial test	0.735	0	0	0	0.045
Mann-Whitney test	0	0	0	0	0

($p>0.05$). Therefore, the cost estimations of compressor-station-construction components are biased except for material cost; miscellaneous and land costs bias toward overestimation, while labor and total costs bias toward underestimation.

Furthermore, the nonparametric Mann-Whitney test is employed to determine if the magnitude of cost-underestimating errors is the same as that of cost-overestimating errors. The *p*-value shown in Table 2 shows that the errors of underestimated compressor-station costs are significantly larger than those of overestimated compressor-station costs for all cost components ($p<5\%$).

After analyzing overall cost overruns of compressor-station projects, it is important to identify significant factors influencing compressor-station project cost overruns. The analyses of cost overruns in terms of compressor-station project size, capacity, location, and completion time are carried out in the following sections.

Cost Overruns in Terms of Compressor-Station Project Size

In this paper, the project size is measured by actual total cost. Compressor-station actual total installed costs range from USD 199,935 to 216,034,351, classified into groups of small, medium, and large. Ninety-two compressor stations with less than USD 12,000,000 are classified as small projects; 82 compressor stations between USD 12,000,000 and 24,000,000 are classified as medium projects; and 46 compressor stations with more than USD 24,000,000 are classified as large projects.

A descriptive statistical analysis of cost overruns in terms of project size is shown in **Table 3.** For all the cost components, there is no linear relationship between average cost overruns and project size. For the total installed cost, large projects have the highest cost overruns. A plausible explanation is that a large pipeline-compressor-station project, normally associated with a large pipeline project, can induce a demand that influences market price (e.g., labor salaries and material prices) and increases compressor-station-construction costs further. Expectation of increased pipeline- and compressor-station-construction costs can induce an increase in current unit construction costs (Rui et al. 2011b). Suppliers would raise prices with expectation for more demand. In addition, a large project limits the numbers of suppliers and contractors, reducing competition and increasing costs (Bordat et al. 2004; RGL Forensics et al. 2009). However, for the miscellaneous cost, large projects have the lowest cost overruns. It is possible that larger projects have better management systems coordinating different departments, increasing the efficiency of material usage and taking advantage of economies of scale.

To determine if there is a strong relationship between project size and cost overruns for different compressor-station-construction components, the nonparametric Kruskal-Wallis (KW) test is applied to test the null hypothesis that the project size has no effect on cost overruns of compressor-station-construction components. The KW test is chosen because the values of S and K show that the cost overrun of each group is not a normal distribution. Therefore, the KW test will be used when the data do not produce normal distributions.

For all cost components, results of the KW tests show that cost overruns for different project-size groups are not significantly different ($p>0.05$); therefore, it is concluded that project size does not significantly influence cost overruns for all cost components.

Cost Overruns in Terms of Compressor-Station Capacity

Cost overruns in terms of compressor-station capacity are tested in this section. The range of compressor-station capacity is between 80 and 217,000 hp, divided into three groups: small (0−5,000 hp), medium (5,000−10,000 hp), and large group (10,000−217,000 hp). Approximately 56.8% of compressor-station capacities in the data set are smaller than 8,000 hp, and only 2.73% have capacities larger than 40,000 hp. Compressor-station-construction cost component overruns for the three different capacity groups are shown in **Table 4.**

For material, labor, and total costs, cost overruns decrease with increasing capacity and are positive. For miscellaneous cost, the small-capacity group has the highest cost overruns, followed by the large-capacity and the medium-capacity groups. Average cost overruns of the large-capacity group and the mediu-capacity group

TABLE 3—AVERAGE COST OVERRUNS FOR DIFFERENT PROJECT-SIZE GROUPS

Components	Project Size	Average (%)	SD (%)	S	K	Min (%)	Max (%)	*N*=number
Material	Small	6	42	1.33	8.35	–95	178	92
	Medium	0	20	0.49	3.59	–49	62	82
	Large	5	33	1.94	8.76	–40	140	44
Labor	Small	66	126	2.00	7.96	–99	625	90
	Medium	43	74	1.46	6.48	–98	326	82
	Large	80	101	1.94	7.19	–50	454	43
Miscellaneous	Small	2	101	6.03	46.88	–85	811	91
	Medium	–1	71	3.74	21.28	–83	436	82
	Large	–8	41	1.05	4.15	–68	107	43
Land	Small	–30	68	1.16	4.40	–100	187	35
	Medium	–8	187	3.11	12.55	–100	786	33
	Large	2	111	1.14	3.16	–100	262	21
Total	Small	13	43	1.85	8.05	–82	201	92
	Medium	7	25	1.29	5.23	–37	105	82
	Large	16	38	2.61	12.41	–38	193	44

TABLE 4—AVERAGE COST OVERRUNs FOR DIFFERENT CAPACITY GROUPS

Components	Capacity	Average (%)	SD (%)	S	K	Min (%)	Max (%)	*N*
Material	Small	7	44	1.21	7.68	–95	178	80
	Medium	3	25	2.58	15.14	–49	140	62
	Large	0	25	1.02	5.04	–43	96	76
Labor	Small	77	135	1.66	6.43	–99	625	79
	Medium	58	84	2.73	11.79	–40	454	61
	Large	44	77	1.59	7.15	–98	380	75
Miscellaneous	Small	10	108	5.55	40.19	–85	811	79
	Medium	–8	54	3.06	15.54	–83	282	61
	Large	–7	64	4.50	31.41	–72	436	76
	Small	–35	71	1.21	4.24	–100	187	35
Land	Medium	–36	84	1.46	5.09	–100	220	20
	Large	19	188	2.67	10.28	–100	786	34
	Small	18	47	1.44	6.04	–82	201	80
Total	Medium	9	29	4.23	26.66	–22	193	62
	Large	6	26	1.30	5.97	–38	116	76

are negative, with difference of less than 1%. For the land cost, the large-capacity group has the highest cost overruns, followed by the small group and then the medium group. Average cost overrunss of the small-capacity and medium-capacity groups are negative, with a difference of approximately 1.4%.

In general, small-capacity groups have the highest average cost overruns for all the construction cost components except for the land cost. It appears that the small-capacity group is prone to cost overruns, and projects with large capacity may take more advantage of economies of scale to reduce cost overruns.

The nonparametric KW test is used to test the null hypothesis that the capacity has no effect on cost overruns of compressor-station-construction components. The results of the KW test show that overruns of component costs are not significantly different for different capacity groups at 95% confidence level (p>5%). Therefore, it is concluded that capacity does not influence construction component cost overruns significantly.

Cost Overruns in Terms of Different Regions

It has been shown that pipeline-compressor-station costs are significantly different by regions (Rui et al. 2012b). This section discusses whether compressor-station cost overruns are different in different regions.

Table 5 displays a noticeable difference of cost overrun between regions. For the material cost, the western region has the highest cost overruns of 23%, while the northeast region has the lowest cost overrun of −3%. The cost overrun of the southwest region is a perfect zero. According to a ±5% cost-overrun criterion, material cost estimating is performed well in all regions except the western region. Cost overrun for the labor ranges from 40% in the southeast region to 96% in the southwest region. No region performs well in labor cost estimating. For the miscellaneous costs, the northeast and central regions have positive cost overruns of 4 and 16%, respectively, while the other regions have negative cost overruns. Only the northeast region performs well in miscellaneous cost estimating. For the land cost, the largest cost-overrun difference, 101%, occurs between the western region at –66% and the southeast region at 35%. The land cost is overestimated higher in the western region. None of the regions perform well in land cost estimating. For the total installed cost, the cost-overrun difference is smallest because of the aggregation effect. The midwest and southeast regions perform well in total installed cost estimating.

The results of the KW tests show that the cost-overrun differences in different regions are significant for all construction cost components ($p<0.05$). Weather conditions, soil properties, population density, cost of living, terrain conditions, and distances from supplies are variables for different regions, making compressor-station project cost estimation more difficult (Rui et al. 2011a; Zhao 2000). More-detailed information for compressor stations is needed to explain cost-overrun differences between the different regions. Therefore, it is concluded that the cost overruns of all cost components show significant differences between regions, and compressor-station location matters for cost overruns in all cos-components.

Cost Overruns Over Time

Forty-seven megaprojects constructed between the mid-1960s and 1984 were reported with an average cost overrun of 88% (Merrow 1988). More than 1,000 World Bank projects between 1947 and 1987 had cost-estimating errors (Pohl and Mihaljek 1992). Fifty-five percent of all INDOT projects between 1996 and 2001 experienced cost overruns (Bordat et al. 2004). Cost overrun is constant for a period of more than 70 years between 1910 and 1998 for 208 transportation projects in 14 nations on five continents (Flyvbjerg et al. 2003). An analysis of 412 pipelines constructed between 1992 and 2008 shows that only the ROW cost overruns of pipeline projects decreases over time, but cost overruns of labor, material, miscellaneous, and total installed costs did not show any decrease over time (Rui et al. 2012b). All the literature shows that the cost-estimating errors persist over time in numerous different types of projects. But is there any improvement in pipeline-compressor-station cost estimation over time? This section attempts to discover whether the cost-estimating performance of compressor-station projects has improved over the years. Improved performance of cost estimating is normally expected with experience.

Average cost overruns of compressor-station-construction components between 1992 and 2008 are displayed in **Fig. 7.** Cost overruns of labor and land costs fluctuate widely; but cost overruns of material, miscellaneous, and total costs change more gradually, tending to decrease over time.

The length of the construction phase influences cost overruns; therefore, it is better to use the planning year as a time measurement (Flyvbjerg et al. 2003). But the data of the year of building and the construction period are not publicly available. Therefore, the year of completion is used as a measure of the time, which may cause bias. The nonparametric Nptrend test is conducted to see whether there is a changing trend in cost overruns over the years. All results of the Nptrend test show that cost overruns of compressor-station cost components decrease over time except for those of the labor costs ($p=0.51$ for labor cost). Therefore, on the

TABLE 5—AVERAGE COST OVERRUNS FOR DIFFERENT REGIONS								
Components	Regions	Average (%)	SD (%)	S	K	Min (%)	Max (%)	*N*
Material	Northeast	–3	32	0.81	9.18	–95	140	61
	Central	5	29	0.99	4.26	–55	94	46
	Midwest	–2	22	0.24	2.88	–39	43	17
	Southeast	1	24	–1.26	9.71	–95	61	32
	Southwest	0	21	0.12	2.05	–40	39	33
	Western	23	54	1.55	5.20	–59	178	29
Labor	Northeast	46	84	1.81	10.79	–98	454	59
	Central	49	90	1.28	3.95	–63	317	45
	Midwest	66	125	2.74	10.38	–40	505	17
	Southeast	40	90	1.19	3.74	–89	272	32
	Southwest	96	134	2.49	9.20	–9	625	33
	Western	85	119	1.34	4.44	–72	405	29
Miscellaneous	Northeast	4	78	3.60	19.11	–85	436	60
	Central	16	135	4.80	27.91	–72	811	46
	Midwest	–9	46	1.86	6.78	–56	137	17
	Southeast	–11	41	1.31	5.90	–84	129	32
	Southwest	–9	50	1.72	6.12	–71	165	32
	Western	–13	36	0.35	2.22	–68	58	29
Land	Northeast	9	172	2.04	6.59	–100	520	14
	Central	–6	163	4.25	21.26	–100	786	28
	Midwest	10	99	0.76	2.55	–100	200	14
	Southeast	35	61	–0.16	1.75	–40	104	4
	Southwest	–35	99	2.24	7.35	–100	262	13
	Western	–66	82	2.89	10.46	–100	220	16
Total	Northeast	11	35	2.06	13.97	–82	193	61
	Central	11	42	2.55	11.39	–54	201	46
	Midwest	5	25	1.35	5.79	–38	80	17
	Southeast	5	26	2.04	8.24	–30	105	32
	Southwest	10	31	2.19	7.72	–19	116	33
	Western	23	47	1.16	4.30	–60	148	29

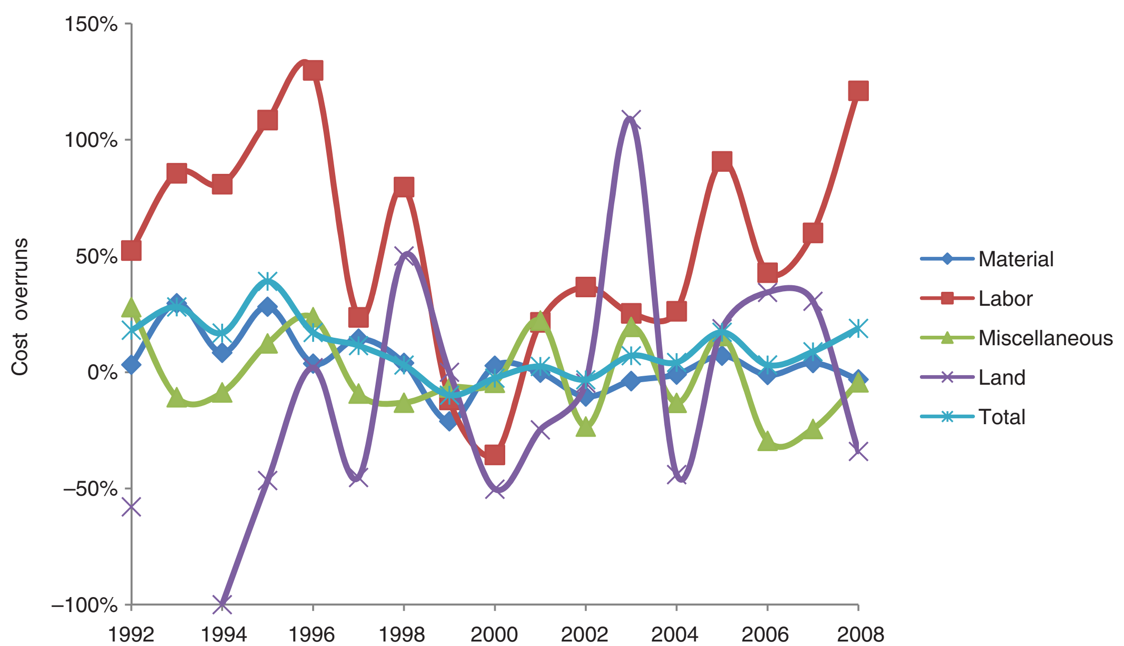

Fig. 7—Annual average cost overruns of cost components.

TABLE 6—PROPOSED GUIDELINES FOR COMPRESSOR-STATION COST ESTIMATION						
Category	Subcategory	Material	Labor	Miscellaneous	Land	Total
Project size	Small	C	A	D	D	B
	Medium	D	A	D	D	C
	Large	D	A	D	D	B
Capacity	Small	C	A	C	D	B
	Medium	D	A	D	D	C
	Large	D	A	D	B	C
Region	Northeast	D	A	D	C	B
	Central	C	A	B	D	B
	Midwest	D	A	D	B	C
	Southeast	D	A	D	A	C
	Southwest	D	A	D	D	C
	Western	A	A	D	D	A

Key: A=maximum attention; B=moderate attention; C=less attention; D=minimum attention.

basis of available data, it is concluded that cost estimating of compressor-station-construction cost components has improved over time except for labor cost.

Conclusions and Future Work

This paper statistically analyzes the estimating performance of individual pipeline-compressor-station construction component costs by using a data set containing 220 compressor-station projects. The trend and distribution of all 220 compressor-station-construction cost component estimation errors over the 1992–2008 period are analyzed. Overall, average cost overruns of the material, labor, miscellaneous, land, and total installed costs are 3, 60, 2, −14, and 11%, respectively. Labor costs have significantly larger cost overruns compared with other cost components. Statistical test results show that cost estimating for all cost components is biased except for the material cost. And the magnitude of the cost-underestimating error is generally larger than that of the overestimating error.

Results of statistical tests show that cost overruns of all construction cost components are not influenced significantly by project size and project capacity, at a 95% confidence level. However, the cost overruns of all construction cost components are significantly different in different regions, and all compressor-station-construction cost component estimation has improved over the 1992–2008 period except for that of the labor cost.

Weather, soil, terrain conditions, cost of living, population density, economies of scale, and distances from supplies are suggested as factors for accurate-cost-estimation difficulties.

On the basis of the analysis of historical pipeline-compressor-station cost estimating errors, this paper provides some proposed guidelines for compressor-station project cost estimators. It is considered that individual cost components should receive varying degrees of attention under different conditions in order to make cost estimation efficient and reliable. A four-level scale—maximum attention, moderate attention—less attention, and minimum attention, allows the estimators to consider the quantity of attention and effort that should be paid to individual component cost analysis, depending on project size, capacity, and location **(Table 6).**

To the best of the authors' knowledge, this paper is the first in-depth analysis of pipeline-compressor-station-construction component cost overruns. Suggested future work may include the following:

- Lack of good-quality data is a major difficulty for more-in-depth investigation for compressor-station cost overrun; therefore, collecting more-accurate detailed information on the compressor-station-construction period, ownership of projects, type of compressor and movers, and whether it is a green-field project is a major part of future work.
- Results of the analyses in this study should be applied to future compressor-station project cost estimations (e.g., compressor-station cost-overrun distribution and average cost overruns for different groups).
- A set of recommendations should be developed to help managers and engineers to estimate better compressor-station projects and minimize the cost-estimating errors.

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