Comparative Performance Analysis for Natural Gas and Oil Pipeline Operations

- Hank Brolick

Comparative performance analysis (CPA) is an effective tool which enables operating cost comparisons between pipeline systems of varying scales and complexities. CPA studies can calculate both expenditures and work hour requirements per unit EPC, and compare the outcomes for each pipeline system with results from groups of better-performing peers (i.e., first quartile or better half) and various physical peers (i.e., crude vs. products or line-diameter groups). This paper explains how the CPA principles were used to develop Equivalent Pipeline Capacity (EPC) divisor by Solomon Associates which is used to identify performance improvement activities to increase the efficiency of pipeline operations, given the system size and complexity constraints.

Defining the Study Envelope

There are several facets to defining the scope of a CPA to achieve results that can be reliably compared and used as a basis for serious performance improvement programs. CPAs should be designed to evaluate individual pipeline system business unit performance. If the performance of several pipeline systems is combined into company performance, you are simply averaging good and poor system performance, providing no reliable basis for performance improvement. Further, there is an economy-of-scale performance benefit for a contiguous pipeline system. On the other hand, if you combine the performance of two geographically separated pipeline systems, false economies of scale are indicated, and performance expectations for the separate systems may be in error.

Additionally, a CPA should compare systems with similar regulations and cost structures. Solomon’s NGTS Study compares main line transmission systems of all sizes. Natural gas pipelines with different cost structures—such as offshore pipelines, low-pressure distribution systems, and gathering systems—are excluded from the study. These facilities have different cost drivers, suggesting they should be evaluated in separate CPA studies.

Finally, to ensure data is reported on a consistent basis, Solomon provides input forms with line-by-line instructions, data input training seminars, and rigorous data validation for all CPAs.

Finding the Operating Cost Divisor

As one would expect, pipeline systems vary greatly in size and complexity. To further complicate matters, size can be measured in numerous ways. For instance, delivery capacity can be measured in volume (m$^3$) or volume-length (m$^3$-km), diameter-length (diameter inch-km), or possibly even operating megawatts (MW). To date, there has been no single operating cost divisor that provides a reliable metric for comparing pipelines of widely diverse scales and complexity. Therefore, Solomon developed EPC—a divisor that represents a substantial improvement over traditional alternatives used in the pipeline industry.
A standard method for measuring the robustness of a divisor is to compute the coefficient of determination ($r^2$), where $r$ is the Pearson correlation coefficient, between the actual and predicted expenditures. Table 1 shows $r^2$ values based on Solomon 2004 and 2006 study data using EPC and other divisors.

### Table 1. Coefficient of Determination ($r^2$) Values

<table>
<thead>
<tr>
<th>Divisor</th>
<th>Oil Pipelines</th>
<th>Natural Gas Pipelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utilized Capacity, volume-distance</td>
<td>0.64</td>
<td>0.41</td>
</tr>
<tr>
<td>Pipeline Length</td>
<td>0.69</td>
<td>0.64</td>
</tr>
<tr>
<td>Replacement Value</td>
<td>0.63</td>
<td>0.70</td>
</tr>
<tr>
<td>Diameter inch-km</td>
<td>0.72</td>
<td>0.75</td>
</tr>
<tr>
<td>EPC</td>
<td>&gt;0.90</td>
<td>&gt;0.90</td>
</tr>
</tbody>
</table>

These Pearson coefficients for EPC were developed from the diverse data set of 22 North America pipelines in the 2004 NGTS Study, as shown in Table 2.

### Table 2. System Diversity

<table>
<thead>
<tr>
<th>Divisor</th>
<th>Minimum</th>
<th>Range</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trillion cubic feet-miles</td>
<td>0.8</td>
<td>3,100</td>
<td></td>
</tr>
<tr>
<td>Total Length, mi</td>
<td>76</td>
<td>14,800</td>
<td></td>
</tr>
<tr>
<td>Diameter inch-miles</td>
<td>606</td>
<td>336,000</td>
<td></td>
</tr>
<tr>
<td>Average Diameter, inches</td>
<td>8</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Max operating power, MW</td>
<td>9</td>
<td>2,327</td>
<td></td>
</tr>
</tbody>
</table>

If you were to focus only on pipelines that were very similar in nature, the database for comparison would be very small. Since reliable comparisons require large samples of representative industry data, diversity is unavoidable, and EPC has been proven to provide reliable comparisons. Solomon’s first NGTS Study in 2004 included 27 systems. This year, Solomon anticipates significantly increased participation when the 2007 NGTS Study is offered worldwide.

The EPC process is performed by selecting cost drivers—primary characteristics that define your system—and comparing them to the controllable fixed operating costs that Solomon refers to as Manageable Non-Volume Related Expenditures (MNVE). These drivers, comprised of physical assets and size characteristics, are summarized as follows for natural gas pipelines:

- Pipeline, compressor stations, etc.
- Meter-regulator input/output stations
- Number and types of main line compressor drivers
- High-consequence area (HCA) effects
- Pipeline diameters and length
- Installed and operating power
- Number of shippers
- Utilized capacity (volume-distance)
- Pipeline terrain

Non-volume expenditures under management control (MNVE) are summarized as follows:

- Salaries and benefits, vehicles, equipment rentals, and contract services
- Maintenance capital and expense
- Operations, maintenance, general and administration
- Excludes ROW fees, property taxes, insurance, environmental fees
- Excludes energy and other volume-related costs

The correlation of potential primary characteristics compared to MNVE resulted in the following equation for EPC calculation using 2004 natural gas pipeline study data:

$$EPC = x_1(a) + x_2(b) + x_3(c) + x_4(d) + x_5(e) + x_6(f) + \ldots$$

Where:

- (a) Maximum operating power
- (b) Number of compressor units
- (c) ROW length/number of meter-regulator stations
- (d) Electric motor drive power
- (e) Number of shippers
- (f) Pipeline length in HCA
- … Other factors

Where: $x_1$ to $x_6$ are constants for each variable and (a) through (f) are the numbers of each variable for a specific pipeline system.

Note that in some cases the variables have an exponent other than one. The cost drivers selected to determine EPC for liquid pipeline systems are similar. An EPC value is calculated for each pipeline, and performance is compared using US dollars per EPC (US $/EPC).

### Using EPC in CPA

CPA studies can calculate both expenditures and work hour requirements per unit EPC, and compare the outcomes for each pipeline system with results from groups of better-performing peers (i.e., first quartile or better half) and various physical peers (i.e., crude vs. products or line-diameter groups). It is important to recognize that the methodology is designed to identify performance improvement activities to increase the efficiency of your operations, given the system size and complexity constraints. The typical industry performance metrics measure system competitiveness based on throughput cost, which can be measured in cost per cubic meter (US $/m^3) or cost per volume-distance (US $/m^3-km). Figure 1 illustrates study costs of US dollars MNVE per million cubic meter-kilometers (US $ MNVE/Mm3-km) for the 2006 North America liquid pipelines in the study.

In the curve shown in Figure 1, large pipeline systems, which benefit from economies of scale, populate the low-
cost, left side of the curve while small pipelines, which are unable to compete on a throughput basis, populate the right side of the curve. The performance ratio is 15:1 for 90% of the liquid pipelines. This metric does not provide a reliable basis for performance improvement programs.1

Figure 2 and Figure 3 depict typical industry curves using the EPC complexity divisor for liquid and natural gas pipelines. Both large and small pipeline systems are represented in all quartiles of the performance curve.

As expected, the 10–20% of the study population at the ends of each MNVE curve exhibit larger variations from the average. There are many reasons for these anomalies, such as incorrect cost reporting, a system recently acquired or sold, an abnormal year, or possibly just unusually good or poor performance. The mainstream performance is exhibited by 80–90% of the study population with gradual increases in cost per EPC for the study group. The ratios between the higher- and lower-cost performances in terms of cost per EPC are only 1.4:1 and 1.8:1 for most of the natural gas and liquid pipelines, respectively. The range represents opportunity gaps that can be quickly converted to potential savings by multiplying the cost per EPC gap by EPC for the specific pipeline system.

Also plotted on Figure 2 and Figure 3 are maintenance costs per EPC. The maintenance cost per EPC is a subset of each pipeline system's MNVE cost plotted directly above it on the MNVE curve. While maintenance cost varies from system to system, it is a major contributor to MNVE, and usually a major opportunity for performance improvement activities.

Does Age Matter?

One of the most frequently asked questions is “Does the data indicate a correlation between pipeline age and maintenance cost?” Figure 4 and Figure 5, on a maintenance cost-per-diameter inch-kilometer and cost-per-EPC basis, clearly indicate that there is no direct correlation between cost and age for the 42 pipelines shown.1

The same holds true for Solomon’s NGTS Study and, in general, for its other CPA studies. The message may be that a well-maintained system can sustain efficient op-
eral operations for the long term. Of course, maintenance catch-up for poorly maintained systems will always be an expensive proposition.

**Reliability**

Low-cost performance—without considering equipment operation reliability, supply to customers, and meeting environmental requirements—is only part of the picture. Collecting reliability data for pipelines can prove to be a challenge because the industry has made limited use of these metrics except for environmental performance. Solomon has found it very useful to identify which reliability factors might best serve an industry and, of course, it has found some commonality across the energy industry. The following have been identified as useful in other CPAs, and seem to be gaining acceptance by pipeline study participants:

- Unplanned delivery interruptions, hours, volumes, and number of events
- Leak and spill quantities, and number of events
- Safety, numbers of lost-time accidents, and frequency rates
- Major equipment unplanned downtime

Figure 6 illustrates an example of major equipment planned and unplanned downtime for natural gas pipeline compressor units. Overall better performers are expected to achieve both a high degree of reliability and good cost performance. In this case unplanned downtime is plotted as a subset of total downtime.

**Study Improvements**

Solomon’s 2006 LP&T Study will be completed by fourth quarter 2007. Invitations for the next NGTS Study will be sent out in September 2007, and the study performed in 2008. Each study has improvements in data collection and methodology. For instance, Solomon will be collecting more detail on compression and possibly adding underground natural gas storage as a study module. Also, there are clear indications that terrain influences both operating and maintenance costs. Pipeline access and maintenance work can be time-consuming and costly in rugged mountains; however, the same holds true for pipelines where a high percentage is located within city streets, which involves a completely different set of maintenance and operations challenges.

The study also covers pump and compression energy costs and consumption using other divisors. This is yet another area in which the methodology is constantly improving.

**Summary**

Performance improvement is an ongoing effort for many companies. A reliable comparative performance analysis of pipeline system cost data is an essential baseline to identify improvement opportunities. A complexity divisor such as EPC has been proven in practice to identify improvement areas more reliably than divisors focusing on competitiveness. Solomon conducts its pipeline industry studies every 2 to 3 years. Consecutive study participation provides the ability to compare trends to industry performance, adding another dimension to the quest for low-cost, reliable performance.

**The Author**

Hank Brolick, P.E. is Vice President Pipelines with HSB Solomon Associates LLC in the Dallas, Texas office. He has more than 30 years of corporate, project management, and engineering experience in the pipeline industry. Mr. Brolick was formerly President of Williams Technologies and Black Mesa Pipeline. He holds an MBA and a BS in Civil Engineering.

1 The y-axis scale units have been removed to protect client confidentiality rights.