

Copyright
by
Darden Lee Wall Jr.
2009

**The Report Committee for Darden Lee Wall Jr.
Certifies that this is the approved version of the following report:**

Parametric Estimating for Early Electric Substation Construction Cost

**APPROVED BY
SUPERVISING COMMITTEE:**

Supervisor:

Antony P. Ambler

Robert B. McCann

Parametric Estimating for Early Electric Substation Construction Cost

by

Darden Lee Wall Jr, P.E.; BSCE

Report

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Master of Science in Engineering

The University of Texas at Austin

December 2009

Abstract

Parametric Estimating for Early Electric Substation Construction Cost

Darden Lee Wall Jr, M.S.E.

The University of Texas at Austin, 2009

Supervisor: Antony P. Ambler

Developing accurate construction estimates is critical for electric utilities to make reliable financial plans for their future. Parametric estimating is just one of several techniques available to help estimate the cost of a construction project. Other estimating methods may have some advantages over parametric estimating in the latter stages of a project but parametric estimating is possibly the most accurate method in the very early stages of a project. This report delves into the analysis and development of a parametric equation for use primarily in the very early stages of a construction project. The result of this research is a functional equation that can be used for estimating future electric substation construction cost with a fair level of confidence.

Table of Contents

Text	1
Bibliography	40
Vita	41

The most challenging time for an estimator to develop an accurate cost estimate is in the initial stages of a project. This is challenging primarily because so little information is known or even available about a project at this stage of planning, which is before any of the design process has even started. Costs for electric substations are constantly changing with the wide variety of materials, specialized equipment and skilled workers needed for the successful completion of a substation on time and on budget. Management expects estimates to be reasonably accurate though whenever they are developed so the estimates can be included in the company budget. Accurate budgets are necessary so an appropriate amount of funds can be reserved for when the project expenses are actually incurred in the future. If a project is estimated to be less than the actual expenses then it can cause problems for a company because there may not be enough money available to pay for the project. If a project is estimated to be more than it actually cost then it can cause other problems too because the unspent money being reserved for this project could have been used on a different project so the opportunity to fund another investment might be lost. Estimates are also used for more than just establishing a budget for a project. If a project estimate indicates a cost that is more than what a company can afford then the project may need to be scaled back or delayed until the company can afford it. Estimates can also be used to analyze multiple projects and compare them against one another when there are not enough funds available for all desired projects. The project that gives the best rate of return, or possibly the quickest payback, will usually be chosen rather than just the cheapest project when more project opportunities are available than funds will allow.

Typically electric substation projects can take 2-3 years from the time management decides to pursue a project till the time bids are received from a contractor to build it. Actual expenses are typically realized about one year after the date from which the job is awarded to the winning contractor. This means that management needs fairly reliable estimates to ensure proper funding in the budget 3-4 years out into the future from when they are initially developed. Different companies have different standards but a typical target for budget numbers should be within a range of +/- 10% at the initial stage of a project. As projects mature and more information is known about them, then estimates are expected to be much more accurate. Here lies one primary area of miscommunication between estimators and management. An estimate is what a project should cost whereas a bid is what a project will cost. (Committee on Budget Estimating Techniques et al., 1990) In an ideal world where costs are predictable then there would be no problem developing an estimate that matches the bid amounts. The world we live in though is far from ideal and the difference in terminology needs to be understood by management so their expectations can be more flexible when comparing the original estimates to the bid amount. However, regardless of the terminology, an estimator's job is to develop an estimate that is as accurate as possible at the time it is developed.

One variable that can make project costs harder to predict accurately is commodity prices for materials like steel, copper, concrete and asphalt, which are all used extensively in construction of substations. Most of these prices can also be indirectly affected by the cost of other commodities such as crude oil. As crude oil prices rise, then

production and distribution costs for virtually all other commodities tend to rise as well and these extra costs are usually passed on to the consumer in the form of higher prices to the buyer. Trying to predict the price of a commodity more than a year into the future is nothing less than a guess for any estimator. Short term trends can help estimate some commodity price about 3 to 6 months out into the future but anything more than that is extremely difficult to judge accurately. For instance, if an estimator was basing an inflationary adjustment for the future cost of a project on the cost trend of the Producer Price Index (PPI) for crude oil (see figure 1) during December 2005 for a project that was scheduled to start 3 years out into the future. Then the cost trend would seem to indicate that the estimator should use a rather large adjustment because the price index trend line would be approaching around 300 from a current index of around 150.

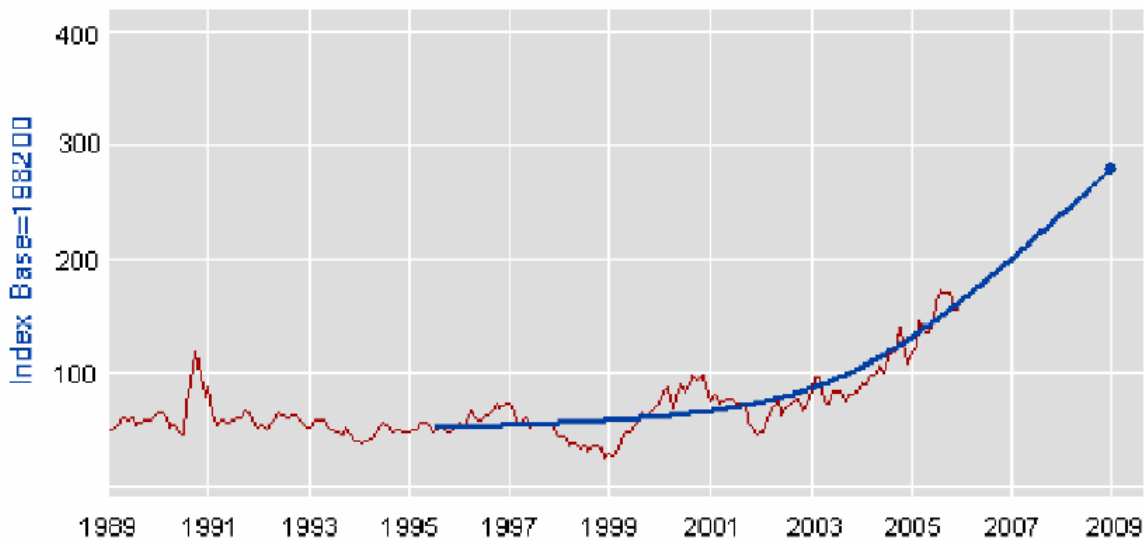


Figure 1

However, when viewing the actual PPI change for this commodity the PPI rose significantly more than expected, to a peak of approximately 400, just before it dropped

dramatically in the following 6 months after it peaked to approximately 100 at the time construction for this theoretical project was scheduled to start. (see figure 2)

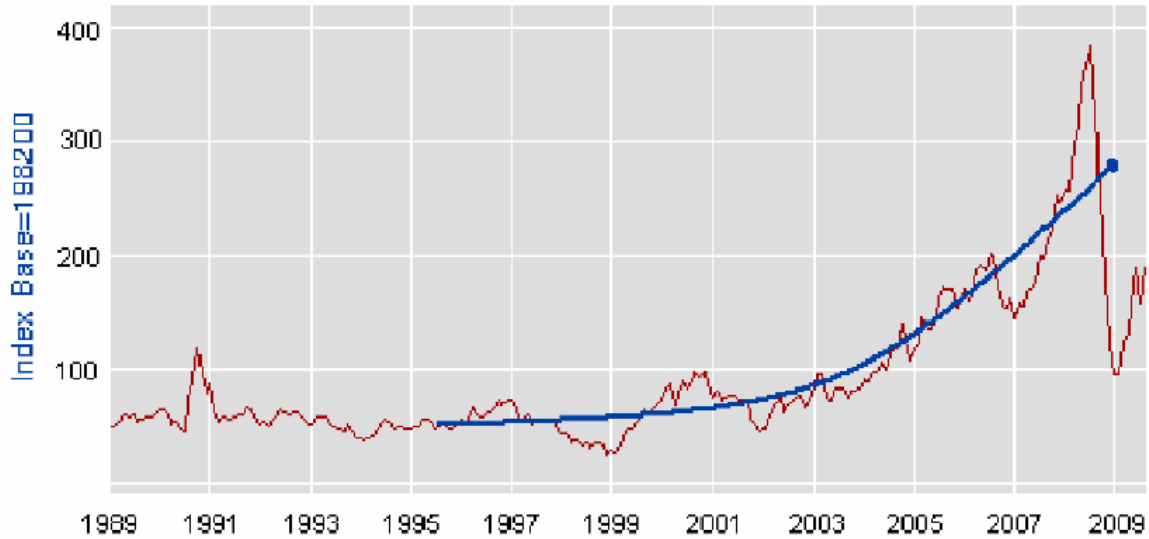


Figure 2

This example illustrates how some commodities can have very large price swings in a short period of time and the more volatile they are, the less reliable they are for an estimator's purpose. The PPI keeps track of many commodities individually as well as in groups of materials combined. One of these groups is for a category called 'Material and Components for Construction', which combines the PPI indexes from several of the most commonly used construction commodities. (see figure 3) This PPI index is more stable across time which makes it better for helping an estimator predict a project's cost out in the future.

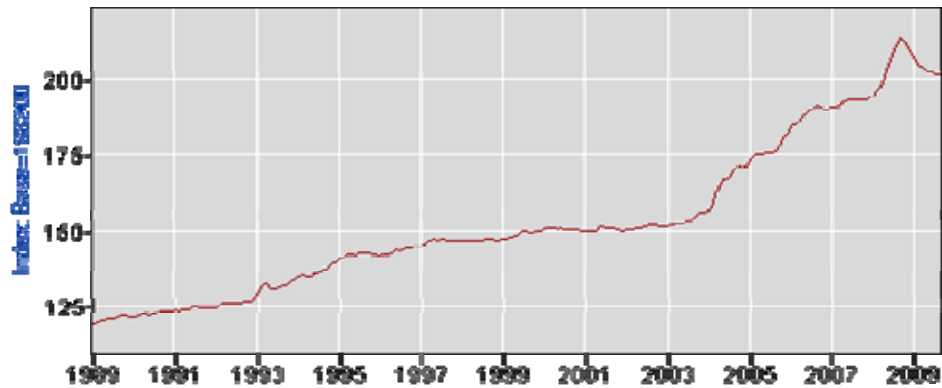


Figure 3

There are several methods or techniques, also called tools, that are available for estimators to use given the challenges and limited support they face when trying to predict future construction cost for a project. Some commonly used estimating techniques are:

- Unit Estimating
- Factoring Method Estimating
- Multi-Element Estimating
- Phased Estimating
- Benchmark Job Technique
- Probabilistic Estimating
- Parametric Estimating

The unit estimating method is probably the most common type of estimating technique used in the construction industry because it lends itself so well to the final deliverable. The desired end product is broken down into individual units for all items being constructed and a cost is allocated for each unit. Then all the individual unit prices

are added up to give a total sum for the project. Most of the unit prices include labor, materials and equipment costs although these items can also be broken out into separate expenses by themselves for each unit if the estimator so desires. The advantage to using this method is that it is fairly straightforward and there is a lot of public information available to help determine unit prices. Books like those published by the RS Means Co., Inc.TM have a vast array of detailed cost information for the most common construction items that an estimator might need for this method. The disadvantages for this method are that unit prices can vary widely even from one side of town to the other so the data may be unreliable unless it is available from a regular source. It also works best only when there is a complete set of plans to go by and the units provided, although numerous, don't necessarily apply to all construction items, especially for something as uncommon as an electric substation or transmission line. Another problem with this method is that it has a problem keeping up with the rising cost of materials and can become outdated quickly if it is not updated frequently. (Committee on Budget Estimating Techniques et al., 1990)

The factoring method of estimating is primarily for projects that have a substantial amount of cost tied up in only one or a few pieces of expensive equipment where the equipment cost make up a significant amount of the total project cost. The expensive equipment costs are added up and multiplied by one or more factors to determine the other cost associated with a project. All these amounts are then added up together for a total cost for that project. This method works reasonably well as long as there is an accurate database from which to derive the factors used in the calculation. (Committee

on Budget Estimating Techniques et al., 1990) This could be a viable method for estimating substation project cost because the cost associated with a single transformer is a significant part of the overall project cost. The problem with this method is that while a substation may have only one or two transformers installed that drive up cost significantly, they also have multiple items of smaller equipment such as switches and relays that are expensive in their own right and can sometimes collectively add up to drive costs on a project as much as the transformers. This method is also similar in nature to the apportioning method of estimating which is frequently used to verify, or cross check, a different project estimating technique by examining the funds allocated for a particular task and determining if that amount is sufficient for the required amount of work at hand. (Verzuh, 2005)

Multi-element estimating is a method that breaks projects up into classes or related categories. Prices are then estimated for each individual category and all the categories are added up to obtain the total project cost. This method is also similar to the unit pricing method except that the categories are not broken down into such small units as they are with the unit pricing method. The multi-element method relies more on breaking projects down into 12-16 standard building systems normally, such as foundations, structures, equipment and sitework just to name some of the systems. The main problems with this method are that it needs an accurate data set to derive the typical cost from and it doesn't account for a lot of the smaller details that can impact the cost of a project. These limitations make this method more suitable for order-of-magnitude

estimates only at the early stages of a project. (Committee on Budget Estimating Techniques et al., 1990)

Phased estimating is a technique that tries to take into account that estimates can be only as accurate as the information available is complete at the time when the estimate is made even though most estimates are required long before any major design decisions have been made. This technique allows an order-of-magnitude estimate to be made at the start of a project then the estimate goes through a series of revisions at different stages of a project. Each time the estimate is revised, more details become known and the confidence level in the estimate goes up. Later revisions also tend to be more accurate than the previous ones because as the project progresses through the stages, more information becomes available and fewer design decisions are left undecided. The phased estimating method typically revises the project estimate at the beginning of the design phase and again at the beginning of the construction phase. This method works well for balancing the needs of the owners and the estimators but at the cost of only being able to provide low confidence estimates during the early phases of construction. (Verzuh, 2005)

The benchmark job estimating method uses the idea that one particular task within a project can be estimated by itself and then the total work load is divided by the single task estimate. (Shtub, Bard, Globerson, 2005) This could work well for projects that involve the installations of something like multiple drilled piers. If it takes \$5,000 and 2 days to install one pier and there are a total of 30 piers to install, then the total project cost would be \$150,000 and take a total of 60 days. The primary problem with this

method is that it does not take into account economies of scale that can be achieved on some of the larger projects but not on the smaller ones. This method also works best when the benchmark job and the new job match each other. The more difference there is between the benchmark job and new jobs then the less accurate the estimates will be.

Probabilistic estimating is an estimating method where the potential cost for an item is determined and then a statistical analysis evaluation is applied to each item to determine the possible range of variation that this item may have and its potential impact on the overall project costs. This method is not as easy to use as the other methods and it typically requires the use of a computer to develop a histogram to show the probability of various estimate amounts. (Committee on Budget Estimating Techniques et al., 1990) The estimator might normally take this histogram and determine the expected cost of a project that would occur with an 80% chance or probability of being achieved. (Gallagher 1982) This method is basically a mathematical way to calculate the contingency factors that most estimators have used on a daily basis yet few have taken to this method because it is time consuming and complicated at first glance. It also requires that many assumptions be made for the analysis, which can introduce a degree of uncertainty into the process.

Parametric estimating is the technique of estimating a project in terms of a limited number of important features, otherwise known as variables, which represent the project as a whole. These variables are used to identify a standard or basic unit of work within a project. Then the basic unit of work can be multiplied across the project as a whole to determine the total cost for the project. Although a parametric model is not limited to

how many independent variables it may have in an equation, the emphasis is to include only the most relevant variables that affect the total price into an equation. These variables that affect the project costs the most are also referred to as the ‘cost drivers’ for a project. (Committee on Budget Estimating Techniques et al., 1990) Parametric estimating is similar to the factoring method mentioned above except that it doesn’t limit itself to just the most expensive piece or pieces of equipment and instead utilizes all of the major cost drivers regardless of their individual cost. This method can best be described with the following example about bomber aircraft. The development of bomber aircraft since World War II has progressed tremendously over the past several decades. Unfortunately so has the unit cost for each new aircraft type as shown below.

Bomber Aircraft:	Unit Cost:	Year of First Flight:
- B-17	\$188,000 ¹	1935 ³
- B-29	\$625,000 ¹	1942 ³
- B-47	\$1,900,000 ¹	1947 ³
- B-52	\$7,900,000 ¹	1952 ³
- B-58	\$25,000,000 ¹	1956 ⁴
- B-1	\$283,100,000 ²	1974 ³
- B-2	\$1,157,000,000 ²	1989 ³

1 – (Gallagher 1982)

2 – (<http://www.acc.af.mil/library/factsheets/index.asp>)

3 – (http://www.boeing.com/history/master_index.html)

4 – (<http://www.aviation-history.com/convair/b58.html>)

The cost for developing each new family of bomber progressively increases over the previous version development cost. There is no argument that each new family of bomber is better and more complex than the one before and therefore can reasonably be considered to be worth more. The primary problem lies with cost getting out of control if future prices follow the same trend into the future as they have followed in the past. If this trend continues on the same path then the price for the next new bomber after the B-2 could be estimated to cost somewhere around \$7,000,000,000 for each new aircraft.

While the cost for the B-2 may seem to be outrageous it should be noted that there were only 20 of these aircraft produced. The size of this production run hardly allowed any economies of scale that might have helped reduce the price for the B-2 when compared to an aircraft such as the B-17 that had 12,726 aircraft produced in various models.

(http://www.boeing.com/history/master_index.html) Parametric estimating works very well in situations like this even though the data shown above compares different aircraft, produced at different time periods and with different production sizes because the research and development process for bombers remains essentially the same. To determine an estimate, parametric estimating follows the historical trends such as increases in prices, complexity, armaments and also follows the trend for fewer total units of bomber aircraft ordered for each new family. This method then projects the basic aircraft research and development cost trends out into the future to give an estimator an idea of what the cost will be for any new bomber project.

Parametric estimating is particularly well suited for estimating projects like this and all sorts of other projects because of the use of independent variables and coefficients

associated with the individual project rather than relying on dependent variables such as commodity prices. This helps by requiring less information about the project up front and being relatively unfazed by the changing cost of materials. This is of particular concern when early construction cost estimates are determined for a Design/Build project. These projects are different in that a contractor is hired to design the project as well as build it. The Request for Quotation usually goes out with a site previously selected and only a general requirement about what is expected to be delivered and what quality standards the final product needs to meet or exceed. Only after a contractor is selected and the contract is signed will the design process start, so very little will be known about the project up to that point. This is a situation where parametric estimating really begins to shine.

Another example of parametric estimating that is more closely related to substation construction is a drilled pier foundation project. For example, a project might require 100 drilled piers, 30” in diameter, to be installed on a site that is assumed by the owner to have a 10’ thick layer of clay over rock. The design/build estimator is expected to give a bid for this work without knowing exactly what the subsurface conditions of the site are which puts a lot of the job risk on them. If they estimate too high then they might not get the job and if they estimate too low then they might lose money on this job. An estimator should have data collected on a few projects that were completed previously to look over for a historical basis of what the cost should be for this type of work. The previous jobs will be referred to as Job A, B and C in the example below. Suppose the jobs had the following attributes:

- Job A was for 50 piers that were all 36" in diameter and 30' deep in relatively soft clay for a total cost of \$392,500. This would break down into 7.85 cubic yards per pier at a cost of \$1,000 per cubic yard.
- Job B was for 20 piers that were all 24" diameter and 15' deep in rock for a cost of \$57,750. This would break down into 1.75 cubic yards per pier at a cost of \$1,650 per cubic yard.
- Job C was for 30 piers that were all 24" diameter and 30' deep in clay for a cost of \$126,000. This would break down into 3.5 cubic yards per pier at a cost of \$1,200 per cubic yard.

The average cost pier cubic yard can be plotted on a graph for each job. In this case these points will be plotted on a full log graph paper. (see figure 4) Draw a line between the two points for Job A and C because these two jobs were both in clay soil and match the closest. Then a line with the same slope can be drawn over point B. This would graphically indicate that a job requiring 100 piers will cost \$780 per cubic yard in clay and \$920 per cubic yard if the job was in rock. Since this job was based on the owner's statement that the site has approximately 10' of clay over rock, it is determined that cost should be estimated assuming 20' deep piers just in case if the owner is slightly wrong. Additionally, the 20' deep pier assumption lends itself well to averaging the cost per cubic yard because then half of the pier will be in rock and the other half in clay. The estimated price per cubic yard (T) to be used in this example should be \$850 as determined by averaging the points where the two lines drawn in cross the vertical line at P=100 in this example.

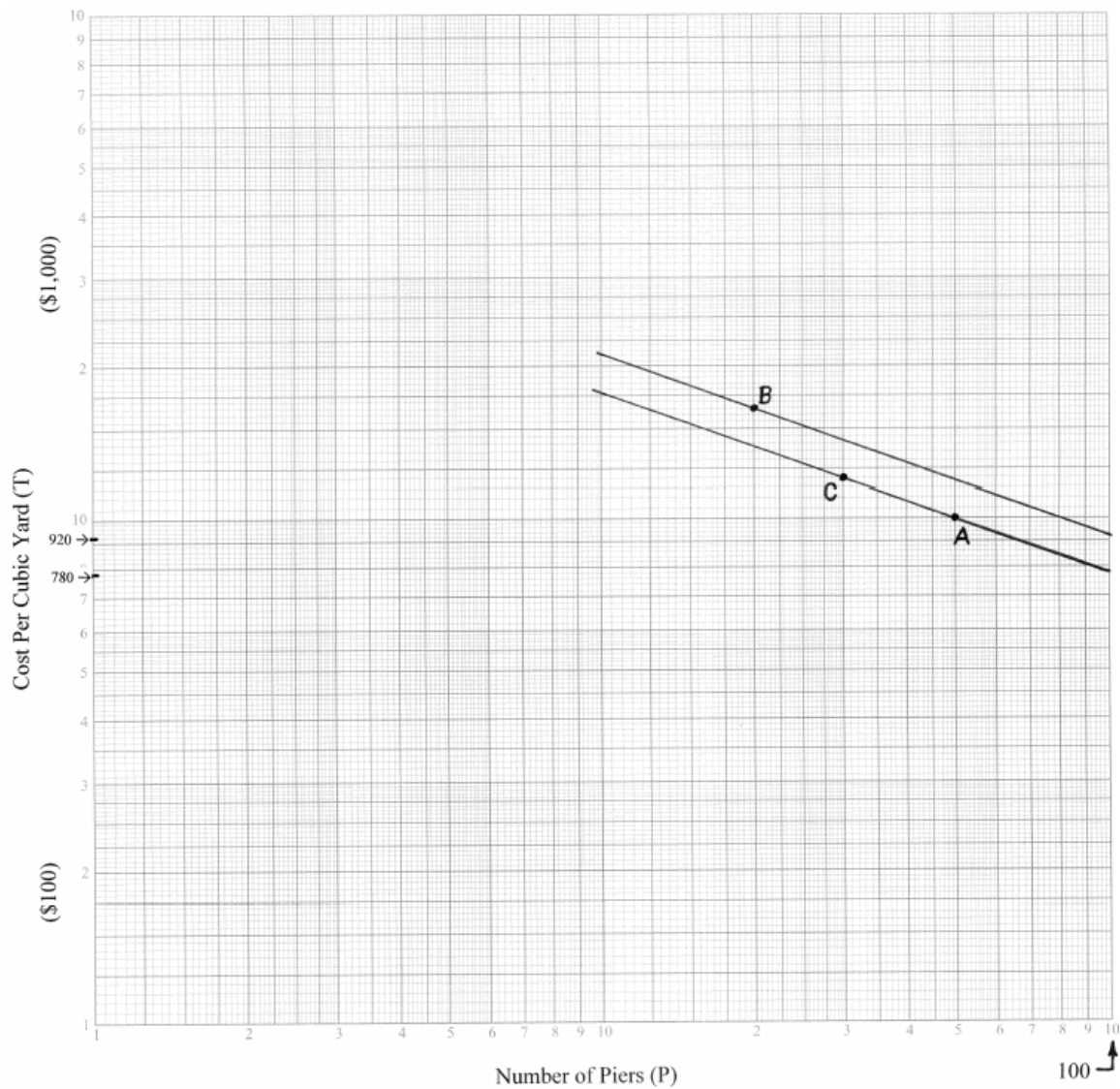


Figure 4

Since these are direct costs to the foundation contractor they will want to include their profit (10%) to the bid and maybe a factor for inflation (2%) if the work is to start one year in the future. They might also want to include a small percentage to account for any unknowns on the site (5%). Then the following parametric statement can be used:

$$\text{Pier Project Estimate} = 1.17 * 3.64 * T * P$$

In this example, the estimator should bid a value of \$361,998 for the total bid for this job where T equals the average cost of \$850 at number of piers P equals 100 (from figure 4), 3.64 is the total cubic yards of concrete in each 20' deep pier and the 1.17 is the cost of the job + profit + inflation factor + any uncertainty (1.00 + 0.10 + 0.02 + 0.05 = 1.17) from above. This graph can now be used for estimating any new jobs this company might have coming up that are of a similar nature which will save a lot of time in preparing the new bids.

Parametric estimating is not always this easy and the example shown above is a very simplified example of a parametric equation that used a graphical method rather than a true equation method due to the simplicity of using the graphs for this example. These equations can be much more complex and can also take the following form when an estimator sets them up for a regression analysis of a specific set of data. (Verzuh, 2005)

$$Y = b_0 + b_1X_1 + b_2X_2 + \dots + b_mX_m + u$$

Where, X= independent variables, b= coefficients,

m= number of independent variables, and u= normal distribution

(Shtub et al., 2005)

Relevant data from past projects is essential to initiate development of a parametric equation. The development data set doesn't have to match exactly the future projects it is intended to predict but the closer that the projects match then the more accurate the parametric equation will be. For this paper there are six previous substation projects that were analyzed. (see Figure 5) While these projects are somewhat different,

they are all substations that were built with the design/build process and are very close in equipment requirements. The most notable differences between these projects are the substation capacities and a variance in the number of transformers installed at each substation. There were also some special requirements at a few substations that required installation of uncommon items that need to be addressed through adjustments to help the data set match even more closely than it already does. The total expenses for special or unusual items must be taken into account because they can skewer the results of a parametric equation which would introduce unwanted errors into the estimating process. To accomplish this, all substations should be stripped down to their common basic cost in an attempt to minimize the variances between the different projects.

	Substation #1	Substation #2	Substation #3	Substation #4	Substation #5	Substation #6
Office, management supervision and other overhead costs:	\$ 801,243.00	\$ 1,288,978.00	\$ 123,000.00	\$ 166,641.00	\$ 383,148.00	\$ 270,000.00
Performance and Payment Bond costs:	n/a	n/a	n/a	\$ 124,266.00	\$ 179,845.00	\$ 110,000.00
Substation Engineering costs:	\$ 350,000.00	\$ 550,000.00	\$ 285,000.00	\$ 621,332.00	\$ 815,299.00	\$ 420,000.00
Site preparation, including compacted fill and fine grading:	\$ 660,192.00	\$ 2,585,128.00	\$ 626,000.00	\$ 2,310,234.00	\$ 939,386.00	\$ 1,170,000.00
Power duct banks and manholes:	n/a	n/a	n/a	\$ 559,289.00	\$ 593,585.00	\$ 1,200,000.00
Control cable trench and conduits:	n/a	n/a	n/a	\$ 157,843.00	\$ 167,522.00	\$ 735,000.00
Substation Wall:	n/a	n/a	n/a	n/a	n/a	\$ 900,000.00
Substation Foundations:	\$ 312,265.00	\$ 522,945.00	\$ 346,000.00	\$ 408,752.00	\$ 483,544.00	\$ 615,000.00
Control House:	\$ 71,005.00	\$ 72,640.00	\$ 77,500.00	\$ 57,272.00	\$ 60,784.00	\$ 75,000.00
Equipment inside Control House:	\$ 293,319.00	\$ 324,465.00	\$ 314,000.00	\$ 418,665.00	\$ 818,416.00	\$ 450,000.00
38KV circuit breakers:	\$ 215,424.00	\$ 287,135.00	\$ 288,500.00	\$ 209,400.00	\$ 910,545.00	n/a
138KV circuit breakers:	\$ 220,518.00	\$ 151,785.00	\$ 305,000.00	\$ -	\$ -	\$ -
138-13.8KV power transformer:	n/a	n/a	n/a	n/a	\$ 6,554.00	\$ -
138-36KV power transformer:	\$ 101,000.00	\$ 155,502.00	\$ 21,500.00	\$ 18,640.00	\$ -	n/a
138KV potential transformer:	\$ 42,816.00	\$ 44,476.00	\$ 25,900.00	\$ 40,669.00	\$ 83,469.00	\$ 68,000.00
138KV circuit switcher:	\$ 79,330.00	\$ 97,700.00	\$ 53,000.00	\$ -	n/a	\$ -
138KV disconnect switches:	\$ 138,074.00	\$ 133,992.00	\$ 99,500.00	\$ 112,828.00	\$ 164,005.00	\$ 115,000.00
Metal-Clad Switchgear:	n/a	n/a	n/a	n/a	n/a	\$ -
Incoming line dead-end structures:	\$ 144,593.00	\$ 211,963.00	\$ 178,000.00	\$ 186,425.00	\$ 232,803.00	\$ 375,000.00
Balance of steel structures:	\$ 262,640.00	\$ 258,927.00	\$ 234,500.00	\$ 442,757.00	\$ 417,615.00	\$ 285,000.00
Electric aluminum bus:	\$ 32,299.00	\$ 61,031.00	\$ 60,000.00	\$ 55,188.00	\$ 147,184.00	\$ 32,000.00
Electric bus insulators and bus fittings:	\$ 108,558.00	\$ 183,390.00	\$ 38,000.00	\$ 43,272.00	\$ 90,342.00	\$ 65,000.00
Asphaltic concrete for substation and access road:	*in site prep	\$ 211,500.00	\$ 145,000.00	\$ 175,474.00	\$ 235,777.00	\$ 210,000.00
Field installation cost of the substation:	\$ 1,187,249.00	\$ 1,160,007.00	\$ 680,000.00	\$ 1,119,014.00	\$ 1,055,673.00	\$ 903,000.00
Transmission Engineering cost:	n/a	*included below	*included below	\$ 16,945.00	\$ 137,881.00	\$ 40,000.00
Transmission foundation materials and installation:	n/a	*included below	*included below	\$ 33,891.00	\$ 71,938.00	\$ 186,000.00
Transmission structures and installation:	n/a	\$ 63,646.00	\$ 32,000.00	\$ 90,376.00	\$ 868,132.00	\$ 260,000.00
Transmission hardware, wire installation:	n/a	*included above	*included above	\$ 28,242.00	\$ 155,869.00	\$ 86,000.00
Change Orders (to date):	\$ 701,559.00	\$ 815,481.00	\$ 819,183.00	\$ 601,533.00		
Contractor construction cost (Bid Amount in total):	\$ 5,712,084.00	\$ 9,180,691.00	\$ 4,751,583.00	\$ 7,998,948.00	\$ 9,009,316.00	\$ 9,100,000.00
Other CPS Energy cost (to date):	\$ 2,718,707.00	\$ 3,213,910.00	\$ 1,551,333.00	\$ 1,992,566.00	\$ 2,118,572.00	\$ 6,650,894.00
TOTAL PROJECT COST:	\$ 8,430,791.00	\$ 12,394,601.00	\$ 6,302,916.00	\$ 9,991,514.00	\$ 11,127,888.00	\$ 15,750,894.00
Original Budget:	\$ 7,500,000.00	\$ 7,579,839.00	\$ 6,000,000.00	\$ 7,000,000.00	\$ 8,750,000.00	\$ 8,800,000.00
Amount over budget:	\$ (930,791.00)	\$ (4,814,762.00)	\$ (302,916.00)	\$ (2,991,514.00)	\$ (2,377,888.00)	\$ (6,950,894.00)
Percentage over budget:	12.4%	63.5%	5.0%	42.7%	27.2%	79.0%

Figure 5

Adjustments were identified for each substation that didn't match a basic or standard installation. The standard installation was defined as a substation without any special or unusual requirements and with two transformers being added to each substation at the time of the initial construction. Special or unusual requirements are defined as any relatively expensive item that was not consistently required by the majority of the substations in this data set. When analyzing the transmission cost data, it was determined that these costs fell into the special or unusual category because each substation had a wide variance in transmission requirements that caused a large difference in expenses for this item between the projects in the data set. The transmission costs are part of the overall project cost but are also normally estimated as a separate project and combined only for accounting purposes in determining the total design/build contract cost shown in the data set. These costs will be separated out because the parametric equation being developed is for substation cost only at this time. The right-of-way cost had a large variable that needed to be separated out because there wasn't anything consistent about it with a range of anywhere from nothing to over \$1,000,000.00 per acre depending on the project site location. In review of the data set there was a discrepancy noticed for the following costs items: Performance and Payment Bond, Power Duct Banks and Manholes, and for Control Cable Trench and Conduits. While these costs appear to be included in some substations but not in all, it must be noted that these items were included in all substations but that their costs were included in other categories of the data set. The reporting methods for the cost breakdown changed in the midpoint of the data set collection that make this appear as a discrepancy when it really is not. In

substation #6 there is one expense that clearly stands out as a special or unusual cost and that is for a retaining wall installation. This particular substation site had an existing retaining wall on it when it was purchased for the substation and the retaining wall was in deteriorating condition so it was in need of replacement. This retaining wall was not only a special requirement but it was also a very large expense that was only required due to the limitations of the site and had very little to do with the actual design or construction of the substation. Other substation projects had special items that were not separated out as individual expenses such as site-specific environmental requirements or non-standard entrances. These special items, while not individually distinguishable in the initial data set, will not be treated as a data set adjustment at this stage of the parametric equation development. Instead the adjustment for special items like site specific environmental requirements and non-standard entrances will be addressed later in the parametric equation formation as equation modifiers because these items are very likely to be a part of any substation, depending on the site selected.

Now that the major adjustments have been identified, implementing them is addressed by removing their values from the total value of their individual project cost. The adjustment for the number of transformers needs to be handled differently because it has to be either added or deducted from the total project cost depending on how they vary from the standard installation of two transformers per substation. While the cost for one additional transformer foundation and appurtenant materials might cost about \$150,000, the transformer itself might cost anywhere from \$900,000.00 to \$1,200,000.00 depending on it's capacity. Using the average of the transformer values then adding this number to

the cost of the foundation and appurtenant materials would give the following value for each transformer:

$$[(\$900,000.00+\$1,200,000.00)/2 + \$150,000.00] = \$1,200,000.00$$

This value can then be used to modify the basic parametric formula to account for the difference from a standard substation as an addition or subtraction to a project, whichever action brings the total number of transformers being added in the project to a total of two. Then the original data set is adjusted for the categories described above into a new data set (see figure 6) that is ready for analysis.

The selection of independent variables that can be analyzed for a parametric equation should be related to the project but are otherwise free to be just about any variable associated with the project. Variables such as the ultimate number of transformers to be added to a substation or the length of bus in each substation are just two examples of potentially parametric variables. The pounds of copper that is used in each substation could also be a parametric variable but since most copper use is related to substation grounding, which is also directly related to the size of the substation, then the cost per square foot for the substation is perhaps a better variable to explore. Substations are also built with a specific rating capacity that is measured in Mega-Volt-Amps (MVA) which seems like a very obvious variable to explore. The primary goal is to find a few variables within a project that have a pattern that can be quantified in the form of a mathematical equation or expression. The variables should be common enough in all the substations that make up the existing data set to allow a mathematical model to be developed that will consistently predict the cost of a new substation.

	Substation #1	Substation #2	Substation #3	Substation #4	Substation #5	Substation #6
Office, management supervision and other overhead costs:	\$ 801,243.00	\$ 1,288,978.00	\$ 123,000.00	\$ 166,641.00	\$ 383,148.00	\$ 270,000.00
Performance and Payment Bond costs:	n/a	n/a	n/a	\$ 124,266.00	\$ 179,845.00	\$ 110,000.00
Substation Engineering costs:	\$ 350,000.00	\$ 550,000.00	\$ 285,000.00	\$ 621,332.00	\$ 815,299.00	\$ 420,000.00
Site preparation, including compacted fill and fine grading:	\$ 660,192.00	\$ 2,585,128.00	\$ 626,000.00	\$ 2,310,234.00	\$ 939,386.00	\$ 1,710,000.00
Power duct banks and manholes:	n/a	n/a	n/a	\$ 559,289.00	\$ 593,585.00	\$ 1,200,000.00
Control cable trench and conduits:	n/a	n/a	n/a	\$ 157,843.00	\$ 167,522.00	\$ 735,000.00
Substation Wall:						
Substation Foundations:	\$ 312,265.00	\$ 522,945.00	\$ 346,000.00	\$ 408,752.00	\$ 483,544.00	\$ 615,000.00
Control House:	\$ 71,005.00	\$ 72,640.00	\$ 77,500.00	\$ 57,272.00	\$ 60,784.00	\$ 75,000.00
Equipment inside Control House:	\$ 293,319.00	\$ 324,465.00	\$ 314,000.00	\$ 418,665.00	\$ 818,416.00	\$ 450,000.00
38KV circuit breakers:	\$ 215,424.00	\$ 287,135.00	\$ 288,500.00	\$ 209,400.00	\$ 910,545.00	n/a
138KV circuit breakers:	\$ 220,518.00	\$ 151,765.00	\$ 305,000.00	\$ -	\$ -	\$ -
138-13.8KV power transformer:	n/a	n/a	n/a	n/a	\$ 6,554.00	\$ -
138-36KV power transformer:	\$ 101,000.00	\$ 155,502.00	\$ 21,500.00	\$ 18,640.00	\$ -	n/a
138KV potential transformer:	\$ 42,816.00	\$ 44,476.00	\$ 25,900.00	\$ 40,869.00	\$ 83,469.00	68000
138KV circuit switcher:	\$ 79,330.00	\$ 97,700.00	\$ 53,000.00	\$ -	n/a	\$ -
138KV disconnect switches:	\$ 138,074.00	\$ 133,992.00	\$ 99,500.00	\$ 112,828.00	\$ 164,005.00	\$ 115,000.00
Metal-Clad Switchgears:	n/a	n/a	n/a	n/a	n/a	\$ -
Incoming line dead-end structures:	\$ 144,593.00	\$ 211,963.00	\$ 178,000.00	\$ 186,425.00	\$ 232,803.00	\$ 375,000.00
Balance of steel structures:	\$ 252,640.00	\$ 258,927.00	\$ 234,500.00	\$ 442,757.00	\$ 417,615.00	\$ 285,000.00
Electric aluminum bus:	\$ 32,299.00	\$ 61,031.00	\$ 60,000.00	\$ 55,188.00	\$ 147,184.00	\$ 32,000.00
Electric bus insulators and bus fittings:	\$ 103,558.00	\$ 183,390.00	\$ 38,000.00	\$ 43,272.00	\$ 90,342.00	\$ 65,000.00
Asphaltic concrete for substation and access road:	*in site prep	\$ 211,500.00	\$ 145,000.00	\$ 175,474.00	\$ 235,777.00	\$ 210,000.00
Field installation cost of the substation:	\$ 1,167,249.00	\$ 1,160,007.00	\$ 680,000.00	\$ 1,119,914.00	\$ 1,055,673.00	\$ 903,000.00
Transmission Engineering cost:						
Transmission foundation materials and installation:						
Transmission structures and installation:						
Transmission hardware, wire installation:						
Change Orders (to date):	\$ 701,559.00	\$ 815,481.00	\$ 819,183.00	\$ 601,533.00	0	0
Contractor construction cost (Bid Amount w/o transmission cost):	\$ 5,712,084.00	\$ 9,117,045.00	\$ 4,719,583.00	\$ 7,829,494.00	\$ 7,785,496.00	\$ 7,638,000.00
Other CPS Energy cost (to date):	\$ 2,118,707.00	\$ 3,213,910.00	\$ 1,551,333.00	\$ 1,992,966.00	\$ 2,118,572.00	\$ 6,650,894.00
TOTAL SUBSTATION COST (to date)	\$ 8,430,791.00	\$ 12,330,955.00	\$ 6,270,916.00	\$ 9,822,060.00	\$ 9,904,068.00	\$ 14,288,894.00
Less ROW cost:	\$ 146,740.00	\$ -	\$ 104,519.00	\$ 1,051.00	\$ -	\$ 1,308,045.00
Adjustment to a 2 transformer standard format:	\$ -	\$ -	\$ 1,200,000.00	\$ 1,200,000.00	\$ 1,200,000.00	\$ -
Adjusted Substation total cost:	\$ 8,284,051.00	\$ 12,330,955.00	\$ 7,366,397.00	\$ 11,021,009.00	\$ 11,104,068.00	\$ 12,980,249.00

Figure 6

Using the number of transformers to be installed in a substation as a variable is similar to the factoring method. The factoring method of estimating is essentially the most simplistic form of parametric estimating that could be used to estimate substation construction cost by using only the number of transformers to be installed in a substation. The primary difference between the factoring method and a true parametric method is that parametric estimating uses a few or a reduced number of independent variables while the factoring method uses only one independent variable. This method can potentially work for estimating substation construction cost because the transformers are the single most expensive piece of equipment installed in a substation. The relationship among each project in the data set is not as clear though when plotting the data out on a graph to explore this idea. (See figure 7)

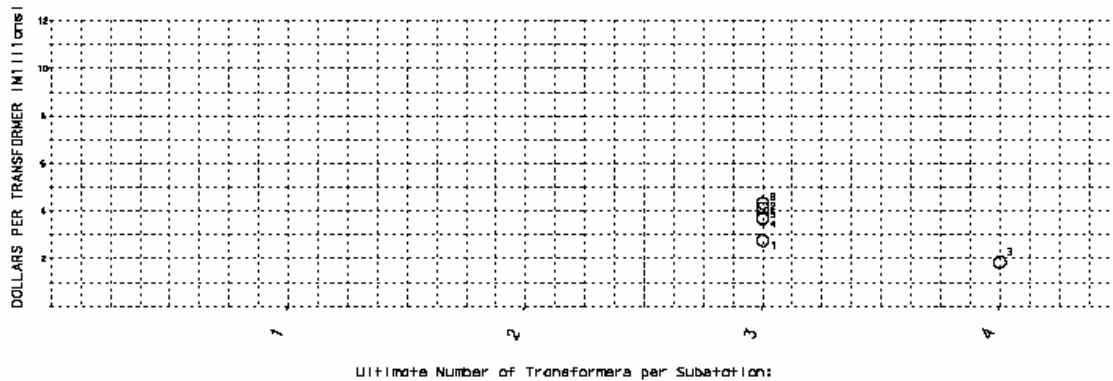


Figure 7

Virtually all substations that this parametric equation will be used for are designed to have an ultimate capacity of anywhere from a minimum of two to a maximum of four transformers, with three being the most common. Substations are rarely built with all transformers installed in the first place which can cause problems for estimating with this method. Another factor that can cause this method to be somewhat unreliable for this purpose is that the MVA capacity for each transformer can vary greatly with 40 MVA and 100 MVA transformers being the primary types used in the data set. Typically a 100 MVA transformer can cost as much as \$500,000.00 more than a 40 MVA. While the data results for this variable seem to show very little information, it does shed some light on some noteworthy aspects of this information. In comparing the data points on the graph in figure 7, the lowest value for a three-transformer substation is from substation number 1 which is the oldest substation that made up the data set. Rising construction cost due to inflation over time can probably justify most of the difference in cost shown for this particular substation. Then it is also interesting to point out that the highest cost per transformer occurred in substation number 6 which had three 40 MVA transformers

installed. The general trend in costs seems to indicate that smaller transformers cost more to install than larger transformers. This goes against initial impressions because the 40 MVA transformers are much cheaper than the 100 MVA transformers so one would think that they should cost less to install. Upon further examination though the 40 MVA transformers are typically used in congested areas where there isn't enough room to install a 100 MVA transformer. The congestion that warrants use of a 40 MVA transformer in a substation also causes additional construction cost for routing and installing the exit circuits from the substation. Congestion can even trap a substation that has not been built out to its full capacity when development around a substation literally blocks off any further routes for future exit circuits. This reasoning can help explain why construction costs are higher for the smaller capacity substations. The data points in figure 7 also tend to indicate that substation cost rise at a rate of approximately \$4,000,000 per transformer for an average three-transformer substation. While this value seems adequate to use for estimating purposes, the points do not show enough relationship to be used as a primary means of estimating. Perhaps though, it can be used as a secondary means for estimating substation construction cost or for cross checking a substation cost estimate derived by another means.

Analyzing the cost per square foot for the substation was a relatively natural way to evaluate this as an independent variable by just dividing the total substation cost by the square foot of fenced in area. By doing this the cost ranged from a low of \$51.59 per square foot to a high of \$241.02 per square foot. This information didn't seem to be very revealing until it was plotted out on a graph. (See figure 8) The initial graph indicated a

very good relationship between all the substations in the data set and a circular curve line can be drawn on the graph that closely matches all the points for the substation cost per square foot. Of all the points on this graph, the data point for substation number 5 was the furthest away from the line drawn on the graph. Part of this difference can be accounted for by realizing that this particular substation is not yet complete so additional costs from future change orders can still bring it closer to the line shown on this graph. Only time will tell how far off this line is from the actual data however any parametric equation should routinely be evaluated as new information becomes available and updated when the actual costs start deviating too far off of the original estimates.

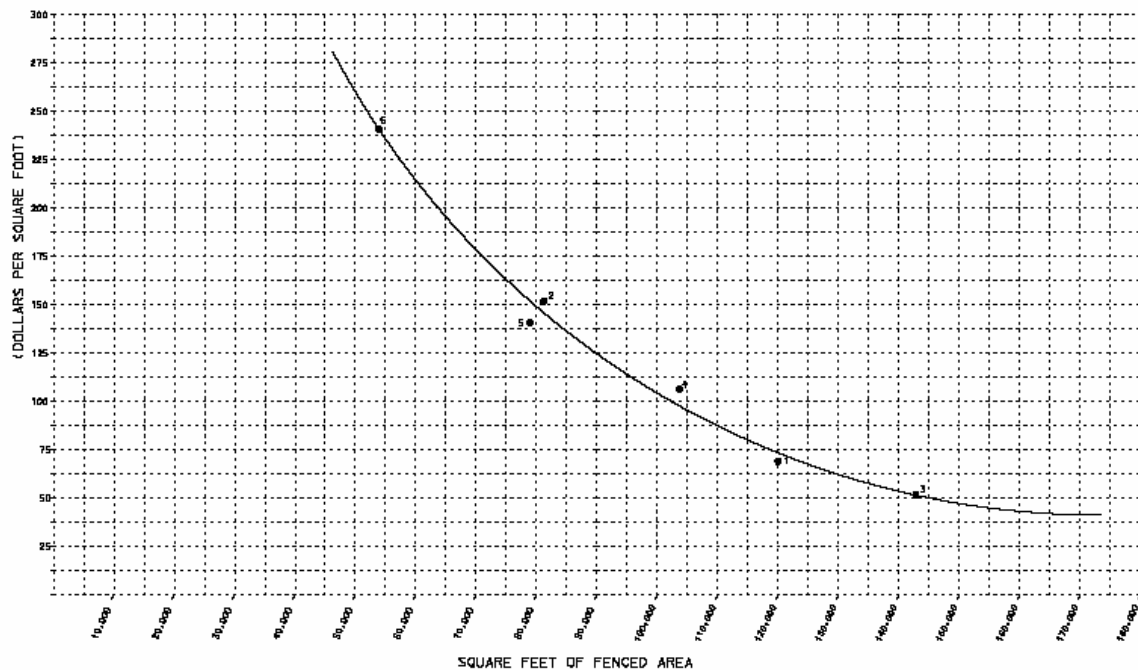


Figure 8

When trying to determine the equation for the circular curve it was discovered that the curved line was not circular at all but rather elliptical due to the difference

between the horizontal and vertical scales of the graph in figure 8. Placing the cost per square foot on a 1 to 1 scale graph with the square feet of fenced in area for each substation was not possible due to the extreme range of the substation size that made any such graph unreadable. For this reason the graph was left at the scale it was originally plotted at but analyzed like an ellipse. The equation for a basic ellipse is:

$$\frac{(x - h)^2}{(h - w)^2} + \frac{(y - k)^2}{(k - s)^2} = 1$$

This equation takes the following form when fitted to the cost per square foot data from the curve as shown in figure 9:

$$\left(\frac{x - 173,448}{143,835}\right)^2 + \left(\frac{y - 490.75}{449.48}\right)^2 = 1$$

Solving for this equation results in:

$$y = 490.75 - \sqrt{202,032.27 \left(1 - \frac{(x - 173,448)^2}{20,688,507,225}\right)}$$

$$(50,000 \leq x \leq 150,000)$$

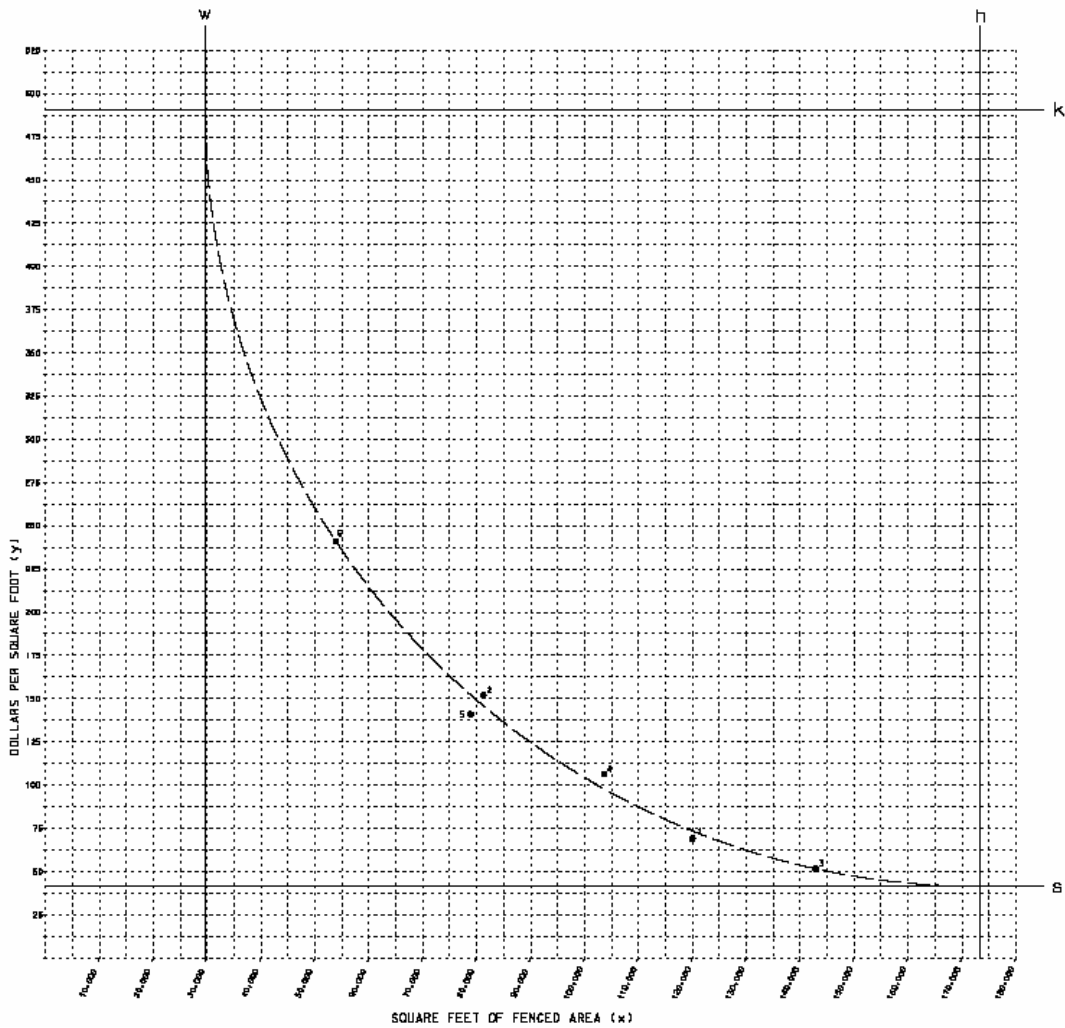


Figure 9

There are many things to consider when examining why this graph appears to model a substation's cost so accurately. Since one of the requirements for a parametric equation is for the data set that is being used to form the parametric equation to be similar in nature, it becomes understood that there should be a strong relationship in most aspects of the data set. One such aspect is the sitework. The sitework for all substations is virtually the same cost per square foot for any two substations of a given size. This would also pertain to any finished surfacing requirements in a substation. Some

economies of scale can be had for tasks like sitework because the mobilization cost is the same if a project requires 1,000 square yards of sitework or 10,000 square yards of sitework. As the total units of sitework on a project increase then the per unit cost for sitework will become cheaper, therefore the cost associated with this would naturally follow the curved line drawn on the graph in figure 8 for the substation cost per square foot. The foundations are another aspect of substation cost that generally increase in relation to the increased size of a substation but their relationship is not as clear because their costs are more dependant on the type of soil the substation is built on rather than the total units installed. Just like the sitework though, the foundation unit cost will generally go down as more units are included in a project because contractors will typically bring in more powerful equipment for larger jobs. The more powerful foundation equipment cost the contractors more in equipment rates, however those additional cost can be offset by savings they can realize in labor cost by getting the job done faster. These savings are only realized on large projects though and are dependant on other factors such as what other work a contractor may have scheduled at the same time so the foundation equipment is usually not chosen until just before the time when it is needed on site. Regardless of whether the potential savings with larger foundation jobs are realized or not, contractors will bid lower unit rates for foundation work as the jobs get larger, therefore the foundation costs should also follow the curved line drawn on the graph for a substation cost per square foot.

When analyzing the data for the possibility of a variable based on the cost per MVA for a substation, the total cost of each substation was divided by the ultimate MVA

capacity for that substation. This gave a range of cost from a low of \$18,415.99 per MVA to a high of \$108,168.74 per MVA. These costs were then plotted on a graphical scale just like the data was for the cost per square foot variable in figure 8 above. (See figure 10)

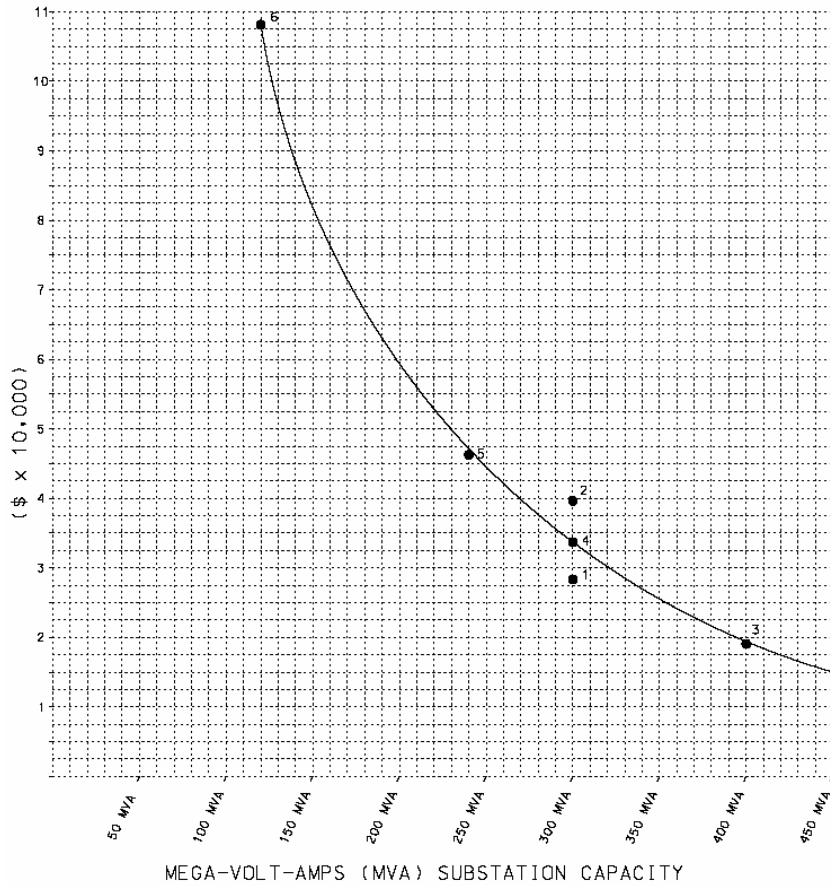


Figure 10

This data did not fit a circular curved line as well as the variable explored for figure 9 however it still shows some promising attributes to it. This curve was also a true elliptical curve just like the example above but looks like a circular curve due to the same problem of the scale of the graph being used. Using the basic ellipse equation, this equation takes the following form when fitted to the cost per MVA data graph:

$$\left(\frac{x - 579}{465}\right)^2 + \left(\frac{y - 126,710}{116,284}\right)^2 = 1$$

Solving for this equation results in:

$$y = 126,710 - \sqrt{13,521,968,656 \left(1 - \frac{(x - 579)^2}{216,225}\right)}$$

$$(100 \leq x \leq 450)$$

In analyzing the graph for the cost per MVA, the relationships are much harder to analyze because they are not as easy to identify. This equation also seems to have a large variance of about 20% when compared to the substation costs in the data set (see figure 10) While aspects such as the size of a substation do have some relationship to the MVA capacity there is no clear requirement for a specific square footage for each MVA that the substation is designed for. Then the unit cost per MVA also gets somewhat obscured by the fact that a substation can have a variety of different capacity transformers installed in them to make up their total capacity. For instance, a substation with a total capacity of 200 MVA can have either 2 – 100 MVA transformers or 1 – 100 MVA and 2 – 50 MVA transformers installed to make up that capacity. Mixing of transformers like this is actually quite common in some situations.

Upon analysis of this graph, costs from substations 3, 5 and 6 fall directly on the curve while cost from substations 2 and 4 fall above it, and substation 1 below it. An

interesting observation here is that substation #2 had three unique features incorporated into the design that were not separated out in the initial cost data. First this substation was being constructed on a difficult site located over the Edwards Aquifer Recharge area which required that special stormwater controls be constructed to ensure that pollution could not enter the aquifer from the substation. The special environmental controls alone added about \$150,000 in cost to this substation and were in addition to the normal stormwater controls and oil containment controls, required by the Environmental Protection Agency (EPA) Spill Prevention Control and Countermeasure (SPCC) regulations, which are required on all substations. Second, this substation site was being built into a solid rock hillside complicating the site and third, there was also a fairly long asphalt paved driveway installed to get to this substation which added to the overall cost for substation #2. Therefore the results being higher than the standard curve can be rationalized by the additional costs for the rocky site, additional environmental requirements and the extended driveway entrance. Then the data point for substation #4 being located slightly above the curve can be rationalized because this substation was also build on a rocky slope but it was not quite as difficult and it did not have any of the other special requirements that substation #2 had. Then the cost data point for substation #1 being lower than the curve can be rationalized by the fact that this substation was the oldest substation in the data set so an adjustment for inflation would be in order for this substation.

During further analysis of this graph and data for the substation cost per MVA, it appeared best to revise the curve from figure 10 above to account for the variances

between the graph line and the data points that fell off of this line. The first step is to identify the potential modifiers that would affect the data, such as the categories listed below:

- Producer Price Index (PPI), to take inflation into account for commodities such as basic construction materials used in construction of substations. There are many different PPI indexes that can reflect the increase in cost for a substation over a period of time. The PPI index for item SOP2200, “Materials and Components for Construction”, seems to suit this application very well. Over the past 20 years this index has risen approximately 80 points for an average annual increase of 2% per year. (see figure 3 above) As a comparison the parametric estimating technique using system parameters, also called the sleeve of experience, was used to estimate the increase in cost for a project over time. (see figure 11) This method indicated an approximate increase in cost of about 30% per year which seemed excessive so the initial PPI index growth rate of 2% per year will be used instead.
- Location, to take into account whether a substation is going to be built in a residential or rural area. The residential areas usually have a much higher overall cost due to more people being affected by the construction and by having to deal with higher property values for residential sites versus rural sites.

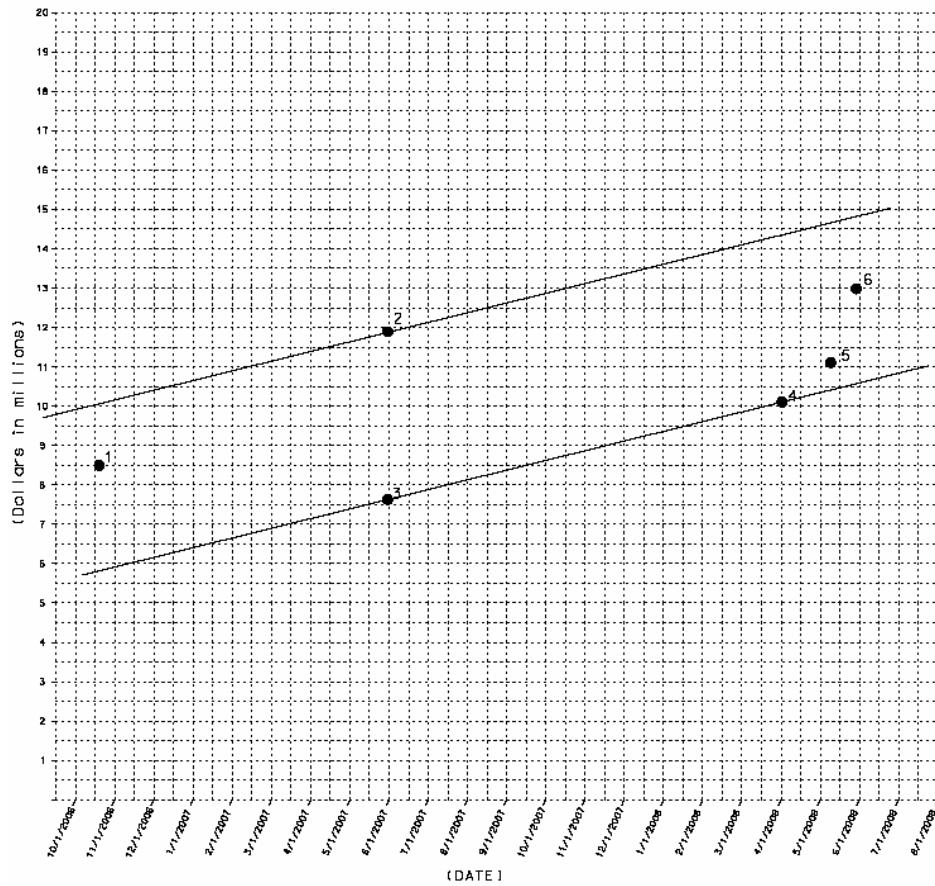


Figure 11

- Site Geology, to account for the different types of soil that the substation will be built on. This variable will be limited to either rock or clay since these are the only two types of soil encountered on the substations in the data set. The difference in cost between excavating hard or soft rock is also not enough to warrant any additional distinguishing modifier for either soft or hard rock so rock will generally include all types of rock.
- Site Difficulty, a factor that can be used to account for sites that have special requirements or restrictions. Examples of difficult sites could be a site that is

located on a steep slope or a site that has critical, existing underground utilities in the way of construction.

- Entrance Difficulty, to account for when a site requires more than a standard driveway entrance access. Most substation sites are selected with easy access however sometimes these sites are difficult to get to and require additional cut/fill or a long access road.
- Environmental considerations, to account for sites that have special environmental requirements. All sites will have a standard installation of environmental protections to comply with various state and federal regulations however some sites have special requirements that are above and beyond what a standard installation will provide. One of these special environmental requirements, in the central Texas area, is being located over the Edwards Aquifer Recharge Zone or Transition Zone. This area requires a special sediment trap as well as a secondary oil containment system to be installed on each site.

The goal for these modifiers is to allocate typical percentages for each modifier that would account for the differences between the data points and the graph line as close as possible. This iterative process can be time consuming by the fact that not all modifiers apply to each substation as can be seen in Table A below.

SUBSTATION #	1	2	3	4	5	6
CURRENT PPI FOR CONSTRUCTION MATERIALS (I)	•	•	•			
URBAN LOCATION (L)					•	•
SITE GEOLOGY (G)		•		•		
DIFFICULT SITE (D)		•				•
NON-STANDARD ENTRANCE (E)		•		•	•	
EXTRA ENVIRONMENTAL REQUIREMENTS (V)		•				

Table A

Examining each substation in the data set and comparing it to the graph for the cost per MVA yields clues for how much percentage should be applied to each modifier. Initial placement of the curve becomes somewhat arbitrary at this point so long as the curve matches the data points as close as possible after the modifier adjustments have been made to the numbers in the data set. Substations number 1 and 3 were chosen to start a base for the curve because they had the fewest applicable modifiers and the modifier for each of these two substations was the PPI. Since the PPI changes over time a base line for the parametric equation was established at 200, using 2008 PPI for Materials and Components for Construction information. The first reason for selecting 200 as a starting point was because half of the substation data was from projects that had pricing established in 2008 and the second reason was because 200 was the approximate value of the PPI in 2008 besides being a convenient number to use in an equation. Since substation number 1 had been built in 2006, a temporary point was established just above the point for substation number 1 in figure 12 that represented the cost for this project if it had been built in 2008 instead.

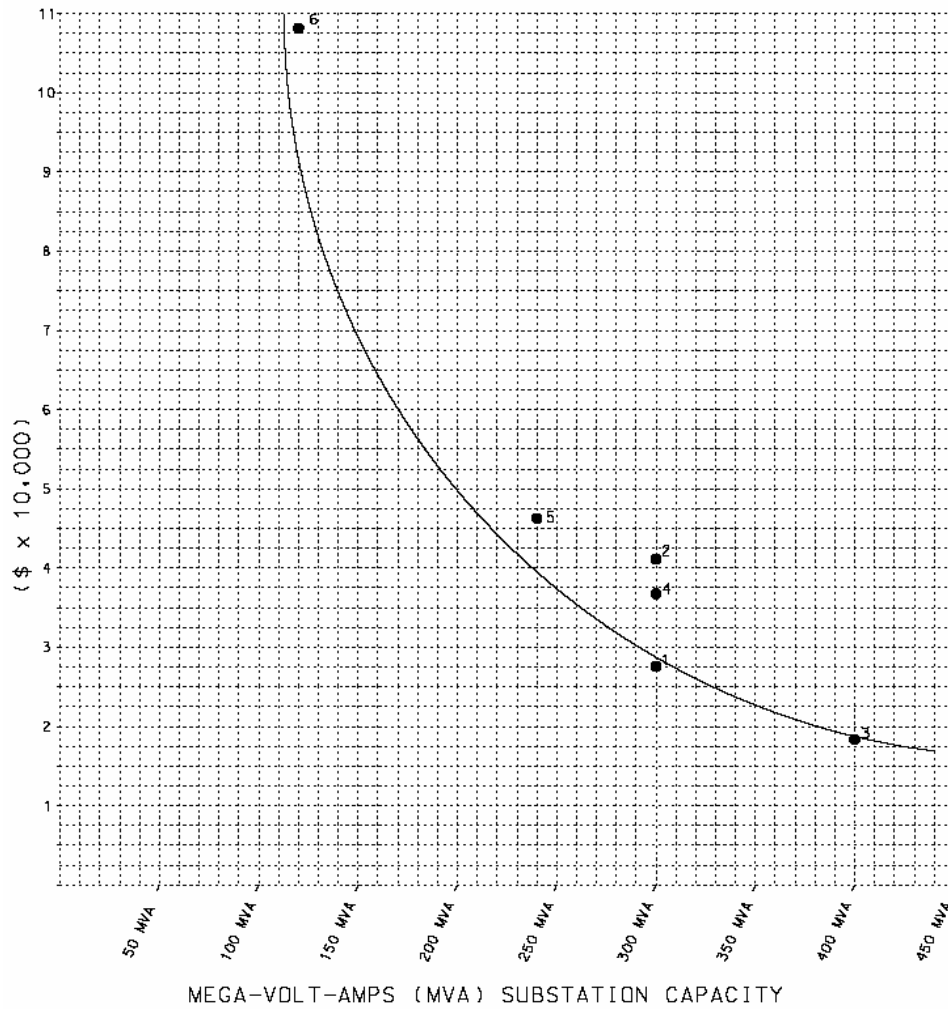


Figure 12

This point was annually adjusted to be 4% more than the point just below it which is 2 times the average annual percentage determined above for the PPI. The same process was done for substation 3 however the temporary point was established just 2% above substation 3 to represent the cost this substation would have been in 2008 since substation 3 was built only one year earlier in 2007. These two points give a starting point for the new graph however a third point is needed to properly establish a curve. To get the necessary information substations 5 or 6 will need to provide it. Substation 5 appears to

be more deterministic between these two substations with a residential location and a non-standard entrance cost modifier affecting this substation. When drawing the curve however, it must be drawn in a place that will seem realistic and appropriate for substations 5 and 6 as well as tie into substations 1 and 3. The results are shown below from figure 12 after a trial and error process which results in the following percentages for each modifier, as shown in Table B.

URBAN LOCATION (L)	8%
SITE GEOLOGY (G)	18%
DIFFICULT SITE (D)	10%
NON-STANDARD ENTRANCE (E)	10%
EXTRA ENVIRONMENTAL REQUIREMENTS (V)	7%

Table B

Then the resulting parametric equation for the graph in figure 12 becomes:

$$y = 109883 - \sqrt{8,789,062,500 \left(1 - \frac{(x - 488)^2}{140625} \right)}$$

$$(100 \leq x \leq 450)$$

When comparing all the methods shown above, using the cost per square foot as a basis for a parametric equation appears to be adequate however there are some concerns with that analysis. The primary concern with the analysis for figure 9 is that there doesn't seem to be any way to account for inflation or special items that affect the cost of

certain substations within the equation. Therefore the modified substation cost per MVA analysis will be used as a basis for a parametric equation. It provides a better basis for an equation because it generally follows a curved line well and, most importantly, it leaves room to account for the special circumstances identified in Table B above. Additionally, to be a functionally complete parametric equation, it will require factors to account for the following items:

- Number of Power Transformers, this is required to accommodate instances where the total number of transformers initially installed in a substation differs from the standard installation of 2 transformers that were used in the development of this equation. This factor should modify the value derived from the equation to reflect the actual number of transformers being installed in a project. This uses the value calculated earlier in this paper and is included into the overall parametric equation in the following form:

$[(N-2)*(\$1,200,000.00)]$;where N is the actual number of transformers being added to a project.

- Right-of-Way, given the large variability of this expense it is too important to ignore yet too variable to quantify therefore it should be included into the overall parametric equation but only as an estimated cost or as a simple budgeting number.

The PPI index modifier also needed to be adjusted some to adequately project inflationary cost out into the future. The 2% per year adjustment used above was adequate for looking back at the data set however this equation is being set up to project

cost 2 to 3 years forward into the future. Without having any idea what the PPI index might do in the future, this modifier was adjusted to reflect a 5% increase above the current PPI which represent the average increase in the PPI over the past 20 years for a period of 2.5 years. This value is then divided by 200, which is the approximate PPI value at 2008 to get the new PPI index adjustment that will account for inflation in the parametric equation.

To generate the final equation required taking the modified MVA equation for the elliptical curve as a basis for the cost per MVA, insert the modifying percentages and add the last two factors listed above along with the new PPI index adjustment. This yields the following final parametric equation for determining the future construction cost (C) for a substation:

$$C = \left[\left(109883 - \sqrt{8,789,062,500 \left(1 - \frac{(X - 488)^2}{140625} \right)} \right) * X + \left((N-2) * \$1,200,000 \right) + W \right] * \left(\frac{1.05 * I}{200} \right) * \left(1 + (L + G + D + E + V) \right)$$

(100 ≤ X ≤ 450)

Where X = the MVA rating for the Substation, N = Number of transformers to be installed, W = Right of Way Cost and I = Current PPI for Construction Materials. The following variables will be assigned a value of zero unless directly applicable to a project: L = Urban Location, G = Site Geology (Rock), D = Difficult Site, E = Non-Standard Entrance and V = Extra Environmental Requirements. When applicable, values will be assigned to these variables as indicated in Table B.

This equation has three primary variables for the cost of substation construction with approximately five secondary variables that take into account any special or extra items a substation might require above and beyond a standard substation project. The secondary variables or “adders” will only contribute to the overall substation cost when the special or extra items they are representing are applicable to that particular substation that is being estimated. This equation is developed specifically for substations between 100 MVA and 450 MVA and future estimating applications using this equation should be limited to substations within this range only. Any new projects estimated with this equation should also be added to the original database for this parametric equation and the equation shown above is recommended to be revised if two or more of the actual costs for new substations end up more than +/- 15% off from their estimates consecutively. While the final equation developed above is specifically for estimating electric substation cost, the techniques described within can be used for various other situations or projects as well.

Parametric estimating is just one of many different techniques that an estimator can use to calculate a project cost with some degree of accuracy. This method focuses on the cost drivers for a given project and represents them as variables in the parametric equation that can be used to calculate a substation cost across a wide variety of substation configurations and locations. While no estimating method is perfect, each has its own strengths and weaknesses that may make one technique more appropriate than another at different stages of the project or based upon the amount of the details known for a project at the time an estimate is determined. The parametric estimating technique works

especially well when estimates are desired and yet little or no design work has been completed up to that time.

Project managers and corporate managers should always be reminded that estimates are nothing more than an estimate and that estimates should be monitored and revised as design and construction progress on an occasional basis. As projects mature and more information becomes known about them, then other estimating techniques such as the unit cost estimating can potentially be more reliable and should be utilized when appropriate to revise an estimate for a project. Until then parametric estimating is one of the best methods available for estimating early construction cost for substations as well as other projects.

References

- Committee on budget Estimating Techniques, Building Research Board, Commission on Engineering and Technical Systems, National Research Council. (1990). *Improving the Accuracy of Early Cost Estimates for Federal Construction Projects V*. Washington: National Academy Press.
- U.S. Department of Labor, Bureau of Labor Statistics. (2008) *Producer Price Indexes*. <http://www.bls.gov/>
- Gallagher, P. (1982). *Parametric Estimating for Executives and Estimators*. New York: Van Nostrand Reinhold Company.
- Verzuh, E. (2005). *The Fast Forward MBA in Project Management* (2nd ed.) Hoboken: John Wiley & Sons, Inc.
- Shtub, A., Bard, J., Globerson, S. (2005). *Project Management Processes, Methodologies, and Economics* (2nd ed.) Upper Saddle River: Pearson Prentice Hall.

Vita

Darden L. Wall Jr. was born in San Antonio, Texas. He received a Bachelor of Science degree in Civil Engineering from The University of Texas at San Antonio in May, 1994. Since 1994 he has been employed by CPS Energy in San Antonio and is currently working as a Civil Engineer III in the Substation & Transmission department. He has been a licensed professional engineer since 2000 and in January, 2008, he entered the University of Texas at Austin.

Permanent email: kingair31@yahoo.com

This report was typed by Darden Lee Wall Jr., P.E.