Using Pareto Principle plus statistic methodology in establishing a cost estimating model

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Abstract

Previous experience and research indicated that the Pareto Principle (80/20 Principle) has been widely used in many industries to achieve more with less. The study described in this paper concurs that this principle can be applied to improve the estimating accuracy and efficiency, especially in design development stage of projects. In fact, establishing an effective cost estimating model to improve accuracy and efficiency in design development stage has been a subject, which has attracted many research attentions over several decades. For over almost 40 years, research studies indicate that using the 80/20 Principle is one of the approaches. However, most of these studies were built by assumption, theoretical analysis or questionnaire survey. The objective of this research is to explore a logical and systematic method to establish a cost estimating model based on the Pareto Principle. This paper includes extensive literatures review on cost estimating accuracy and efficiency in the construction industry that points out the current gap of knowledge area and understanding of the topical. These reviews assist in developing the direction for the research and explore the potential methodology of using the Pareto Principle in the new cost estimating model. The findings of this paper suggest that combining the Pareto Principle with statistical analysis could be used as the technique to improve the accuracy and efficiency of current estimating methods in design development stage.

Keywords: Pareto Principle, Cost Estimating Model, Cost Estimating Testing

1. Background

The study described in this paper is intended to explore a logical and systematic method to establish a cost estimating model using the Pareto Principle (80/20 Principle), which was proposed, by many academics (Yu, Lai and Lee, 2006), to be used in the early cost estimating stages of projects to improve the cost estimating accuracy and efficiency.

Previous experience and research indicated that the 80/20 Principle has been widely used in many industries to achieve more with less (Korch, 1998). The research described in this paper considers that the Pareto Principle can also be applied to the Quantity Surveying field

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to establish cost estimating models through a logical and systematic method. This study has faith in the established cost estimating model in assisting the quantity surveyor to improve the understanding and skills of conducting the cost estimating in the early budgeting and cost planning stages of projects, such as the concept and sketch design stages. Most importantly, it is also believed that the proposed cost model will enhance the efficiency and accuracy of the cost estimate. The possible future study is listed in the conclusion. The objective of the research described in this paper is to prove that the Pareto Principle could be used to set up a logical and systematic method in establishing and testing an elemental cost estimating model in the early pre-tender stages.

2. Literature Review

In the mid 1960s, Stone (1966) suggested the building industry is one of the most important activities in any economy. It can account for 8% to 10% of national employment. The importance of the construction industry in a national economy has been established by scholarly work in the field of economics. Smith (1998) concluded that the construction industry consistently contributes 7% to 10% to the GNP (Gross National Product). Ashworth (2004) agreed with this, and he suggested that the construction industry is an important industry worldwide, even in poor countries. He described how governments regard the construction industry as an economic regulator, an important tool in government's management of the economy. In Australia, according to ABS (2012), during 2010-2011, construction is the 3rd GDP contributor with 7.7% share after Finance and Insurance Services with 9.7% and Manufacturing in 8.1%. At August 2012, there was nearly one million people employed, representing 8.5% of the total workforce (ABS, 2012a). Therefore, it is essential to continuously investigate and regulate the building economy.

2.1 Building Economics

Before going into the specific field of the cost estimate accuracy, it is worth introducing the more general areas, such as "building economy", "cost planning of buildings", "building economy" and "estimating and cost control". In the 1950s and 1960s, a booming population caused a dramatic increase in demand for construction work in the world; especially an increased demand for housing. Building projects became larger and more complex. Therefore, there was a need to officially establish "building economics" as a research subject. Many researchers have studied building economics since then. Ashworth (2004) listed the building economics texts from 1950s to 2000s, which includes more than thirteen studies. Nisbet (1961) concluded that cost plays its part throughout every stage of the whole design and building process. Cartlidge (1973) agreed with this assertion and advised that throughout the design development, cost had a continuous influence on a building project. Cost planning plays a very important role in decision-marking in the building industry. For a small building owner, building investment might be once in a lifetime decision. For a larger building owner, cost planning would affect his future investment policy. Ferry, Brandon and Ferry (1999) suggested that the developer or investor is likely to be affected the most by cost planning. They analysed the impact of cost from the developer's viewpoint and identified cost planning has a role in profit development, social or public sector user development, private user development and mixed development.

2.2 Cost Estimating Accuracy in the Building Economics

Due to the important role highlighted above that cost planning plays in the construction industry, many research studies suggested that cost estimating accuracy has always been one of the important topics in the building economic and the cost planning. Ferry Brandon and Ferry (1999) described how the government recognised that unrealistic cost rules can lead to bad design. Therefore, the government would put enormous efforts to allow money saved in one direction, which could be spent in another. Most importantly, tantamount efforts were also put in to work out complex cost criteria to achieve accuracy. In 1973, Trimble and Jupp developed cost models using regression techniques for various facets of building work. In 1981, Bennett stated that the key activity in the quantity surveying profession's cost planning service is cost estimating. The main task is to improve the estimating accuracy. Morrison (1984) examined the accuracy of cost estimates prepared by quantity surveyors in the design stage of construction projects. He suggested that the most likely area for improvement lies in developing methods of using large cost databases. Skitmore (1985) strongly agreed the importance of the availability and adequacy of the essential cost information in the accuracy of cost estimation.

2.3 Using Pareto Principle in the Construction Industry

Therefore, it is viable to adopt a logical and systematic method based on the Pareto Principle and establishes a cost estimating model to improve the cost estimating accuracy and efficiency. This 80/20 Principle was identified by an Italian economist – Vilfredo Pareto in 1906. He found that a minority of the people held most income and wealth. He also discovered that a consistent mathematical relationship exists between the proportion of people and the amount of income or wealth that this group has (Koch, 1998). Today, this Principle has become a golden rule in the management field to help millions of managers separate the "vital few" from the "useful many" in their activities (Reh, 2002). The reason that the 80/20 Principle is so valuable is, because this principle asserts the pattern of imbalance exists everywhere, in everything. The imbalance relationship may be 65/35, 75/25, 80/20, 95/5 or any set of numbers in between.

From 1980s, the 80/20 Principle was widely adopted in the construction industry. Ashworth and Skitmore (1982) and Thompson (1981) suggested that 20% of the items of a bill or quantity contained 80% of the value. Shereef (1981) developed an alliterative estimating, which predicted an accuracy of +/- 5% without pricing more than 30% of items in the bill of quantity. Bennett (1981), POH and Harner (1995) and Morrison (1984) agreed that the majority of the cost lies in a small number of 'cost significant' items. Shaket et. al. (1986) established a cost significant model, which can be used both to estimate and control construction projects. This model contains only 10% to 20% of the items in a conventional bill of quantities.

2.4 Improving Cost Estimating Accuracy by the Pareto Principle

Further to the various research studies described above, there also have been many studies investigating the possibility of using the Pareto Principle to improve the cost estimating accuracy. Curran (1989) studied to link the Pareto Principle with cost estimating accuracy and efficiency together. He found that in almost all project estimates the uncertainty is concentrated in a select number of critical items. Curran further suggested that relatively small items are often critical while very large ones may not be critical at all. Further to his study above, Curran (1989) developed the Range Cost Estimating, which can significantly reduce the risk of overestimating or underestimating associated with cost estimation. Range estimating is a risk analysis technology that combines Monte Carlo sampling, a focus on the few critical items, and heuristics (rules of thumb) to rank critical risks and opportunities. This approach is often used to establish the range of the total project estimate (Humphreys, 2008). Furthermore, Humphreys (2008) use Curran's research and Monte Carlo analysis techniques to determine probabilities and contingency in a reliable manner.

Later on, Raftery (1994) suggested that 80% of the project cost might be accounted for by measuring the largest 20% of the units of finished work. However, he indicated that this ratio is just a rule of thumb. Whether 80% of the project cost is covered by 20% of the items measured in the bill of quantities depends on which method of measurement was used. Horner and Zakieh (1996) agreed and indicated that it is possible to aggregate cost significant items into cost significant work packages, which represent a consistent and high (close to 80%) proportion of the total value of any project in the same category. Therefore, the total value of a project can be determined by pricing the relevant cost-significant work packages (Asif and Horner, 1989). In 1998, Koch simply stated that the Pareto Optimum Criterion suggests 80% of the overall project cost determined by 20% of the cost items. Therefore, instead of estimating the quantities of all cost items, only the top 20% most significant cost items' quantities were estimated and their related unit prices were sought. With the Pareto Optimum Criterion, almost 80% of estimation cost and time can be saved; not only does it reduce the cost but also expedites the estimation process.

Yu, Lai and Lee (2006) used the 80/20 Principle to create a web-based intelligent cost estimate (WICE) system, which fulfils the need for real-time response to construction cost estimating and to increase the estimate accuracy. The author recognised there are two construction cost elements - quantity of the cost item and unit price of the cost item. They used the 80/20 Principle to accommodate the changes of unit price and indicated that 80% of the overall project cost is determined by 20% of the cost items. Therefore, WICE only estimates the top 20% most important cost items and their related unit prices. This does not only reduce the cost, but also expedites the process of estimation,

As shown, over some 40 years, the 80/20 Principle has been used to develop the cost estimate models in order to improve the cost accuracy and efficiency in the construction industry. Academics suggested that the cost estimating accuracy topic has attracted more and more attention from the construction industry participants and academics. However, comparisons with other research topics of the construction industry, the number of study carried out to test, examine and review the reliability and effectiveness of the cost estimating model is still limited. Therefore, in one aspect, the study described in this paper proposed to use the 80/20 Principle to set up a logical and systematic method in establishing an elemental cost estimating model to improve the accuracy and efficiency of cost estimating. In another aspect, this study also tests and validates the reliability and effectiveness of the established cost estimating model including the theory.

3. Methodology

The literature review above revealed the history and development of cost estimating modelling and the cost estimating accuracy. The Pareto Principle has been identified as one of the most constructive theories, which could be used to establish cost estimate models. The application should include two phases. Phase 1 is about the establishment of the cost estimating model based on the Pareto Principle. This includes applying 80/20 Principle and using statistical methodology to analyse cost data and test the statistical analysis results. This follows by Phase 2 which is interpreting and validating the statistical analysis methodology in order to test and validate the theory and cost estimating model established in precedent phase.

3.1 Phase 1: Proposed Analytical Method

This study mainly uses the statistical methodology as the analytical method. Statistics is widely used by individuals and organizations to analyse and understand data in order to make judgments and decisions throughout the natural and social sciences, medicine, business, economics and other areas (Corty, 2007). The main perspective of this study involving the analysis the correlation study examining the extent to which differences in one variable were related to differences in another variable (Leedy and Ormrod, 2005). Therefore, the statistical technique of regression analysis would be a suitable method of deriving a cost model (Buchanan, 1972). The analysis was carried out using multiple regression to examine the data and the SPSS (Statistical Package for the Social Sciences) was used in this study to assist in the statistical analysis, because it is one of the most used computer programs for statistical analysis in the social science (Argyrous, 2011). Two types of regression analysis were applied in this study.

- Stage 1 (Multiple Regression Analysis) – the establishment of the cost estimating model

- Stage 2 (Bivariate Regression Analysis, also named as Linear Regression Analysis) – the testing of the cost estimating model

3.1.1 Stage 1: Multiple Regression

In Stage 1, the multiple regression is used to establish the cost estimating model. Multiple regression is an extension of the linear regression analysis, in which several independent variables (IVs) are combined to predict a value on a dependent variable (DV) for each subject. The equation 3.1 below represents the best prediction of a DV from several continuous IVs:

$$Y' = A + BX_1 + BX_2 + BX_3 + BX_4 + \ldots + B_kX_k \qquad \text{(Eq. 3.1)}$$

Where Y' is the predicted value on the DV, A is the Y intercept (the value of Y when all the X values are zero), the Xs represent the various IVs (of which there are k), and the Bs are the coefficients assigned to each of the IVs during regression (Pallant, 2007). Pallant (2007) concluded that each independent variable is evaluated in terms of its predictive power, over and above that offered by all the other independent variables. The multiple regression analysis could also indicate how much unique variance in the dependent variable each of the independent variables explained. The elemental costs studied in this research were defined as the independent variables. The total cost analysed in this study was defined as the dependent variable. The standard multiple regression of SPSS categorised by Pallant (2007) was used to carry out the establishment of the cost estimating model in Stage 1. The primary goal of the regression analysis in this study is to investigate the relationship between the total cost and the elemental costs. Through the analysis, this study could identify what are the essential elemental costs to predict the total cost. The multiple regression analysis is also used to find the best prediction equation. There are 3 questions asked in the correlation study which are listed as below:

- How well do the independent variables (elemental costs) predict the dependent variable (the total cost)?

- How much variance in the total cost can be explained by those elemental costs?

- Which elemental costs have the strongest correlation relationships with the total cost? Which elemental costs have the weakest correlation relationships?

3.1.2 Stage 2: Bivariate Regression (known as Linear Regression)

Stage 2 is to test the reliability and effectiveness of the cost estimating model established in Stage 1 including the supporting theory. There are two variables included in Stage 2:

- Total cost of the project – calculated using the equation composed by the major cost contribution elements investigated using Equation 3.1

- The winning tender price – the successful contractor tendering price at the tender stage of each project

Bivariate regression has the ability to predict scores on one variable from scores on another variable. This is also called the simple regression, which is to discover the correlation relationship between two continuous interval variables. Therefore, Bivariate Regression was adopted in this stage.

Overall, in both multiple regression and bivariate regression analysis, this research carried out the process in using the Pareto Principle as a logical and systematic method to establish and test the cost estimating model based on the elemental costs excluding the preliminaries, overheads and profits. One of the purposes to analyse the elemental costs excluding preliminaries, overheads and profits is to eliminate the differentiation between each data. This can ensure the validation of the statistical analysis.

3.2 Phase 2: Interpretation of output from the statistical analysis

Following the above description regarding Phase 1 of this study, the interpretation of output from the statistical analysis can be defined into two parts:

- Part 1 – the establishment of the cost estimating model, this research used the Multiple Regression Analysis.

- Part 2 – the testing of the cost estimating model, this research used the Bivariate Regression Analysis (linear regression analysis).

3.2.1 Establishment of the cost estimating model

This part is to combine the multiple regression analysis and the Pareto Principle to establish a cost estimating model, which uses the major cost elements to predict the total construction cost of projects, especially in the early stages of the projects. In this part, five steps are taken to illustrate the details of the findings.

➢ Step 1: Analysing multi co-linearity

Multi co-linearity is designed to assist the researcher to analyse whether there is at least some relationship between the elemental costs and the total cost. This step also checked that the correlation between each elemental cost was not too high. If there are strong relationships between elements, these relationships will distort the final results of the multiple regression analysis regarding the relationships between the element costs and the total construction cost. The study referred the Pearson’s correlation coefficient between two independent variables shown on the Correlations table to assess whether there were any concerns in terms of multi co-linearity. A correlation of 0.7 or more is the warning sign (Tabachnick and Fidell, 2007). In this study, if two of the elemental costs were highly correlated, one of these costs would be omitted.

➢ Step 2: Checking outliers, normality, linearity, homoscedasticity and independence of residuals

The second step is to check the outliers, normality, linearity, homoscedasticity and independence of residuals. These critical values could be tested by a number of methods — Normal Probability Plot of the Regression Standardised Residual and Scatterplot.

- Normal Probability Plot – a reasonably straight diagonal line from bottom left to top right suggests no major deviations from normality, which means there is no presence of outliers.

- Scatterplot – If the Scatterplot of the standardised residuals does not achieve a roughly rectangular distribution (with most of the scores concentrated in the centre), this suggests that deviations and violations exist. Tabachnick and Fidell (2007) define outliers as cases that have a standardised residual of more than 3.3 or less than -3.3.

Tabachnick and Fidell's (2007) concluded that with large samples, it is not uncommon to find a number of outlying residuals. If only a few residuals are found, it may not be necessary to take any action. In a normally distributed sample, only 1 per cent of cases would be expected to fall outside this range.

- Step 3: Evaluating the model—Identifying how much of the variance in the dependent variable can be explained by the model including all independent variables.

This step looks in the Model Summary box and check the value given under the heading R Square. The R Square can indicate how much of the variance in the dependent variable (total cost) is explained by the model, which includes all the independent variables (elemental costs). For a small sample, the Adjusted R Square value provides a better estimate of the true population value than the normal R Square value (Tabachnick and Fidell's, 2007).

- Step 4: Evaluating each of the independent variables

This step is to answer the third question listed above, which of the variables included in the model contribute to the prediction of the dependent variable? This information is labelled as "Coefficients". The Beta value under Standardised Coefficients can be used to compare the different variables. 'Standardised' means that these values for each of the different variables have been converted to the same values so that the comparison is feasible. The larger the Beta coefficient value is, the stronger the unique contribution the particular elemental cost makes towards explaining the total cost, and vice verse. The value of "Sig" indicates whether a variable is making a statistically significant unique contribution to the equation. If the Sig. value is less than 0.05, the variable is making a significant unique contribution to the prediction of the dependent variable. If the Sig value is greater than 0.05, then that variable is not making a significant unique contribution to the prediction of the dependent variable Tabachnick and Fidell (2007).

- Step 5: Determining the cost estimating equation

This step is to use the results from Step 1 to Step 4 to establish the cost estimating model. This study used the cost per square metre as the measurement unit. Cost per square metre is the cost predictor most used by quantity surveyors, as it provides a measure of cost that is essentially independent of building size (Emsley, Lowe, Duff, Harding and Hickson, 2002). This was also applied to price/m2 and price/ft2, which could be calculated as (cost/m2 = total construction cost divided by gross floor area (GFA). GFA equals to FECA (Fully Enclosed Area) plus UCA (Unenclosed Area). In this study, further to Equation 3.1 listed in Section 3.1.1, when all the X value are zero, the value of Y is zero as well. Therefore, the above equation is rewritten as the below Equation 3.2:

$$Y' = BX_1 + BX_2 + BX_3 + BX_4 + \ldots + B_kX_k \qquad \text{(Eq. 3.2)}$$

3.2.2 Testing the cost estimating model

As described in the introduction paragraph of Section 3.1, the second stage is to test the cost estimating model using Bivariate Regression. The relationship analysed is the total construction cost predicted using major elemental costs excluding preliminaries, overheads and profits and the winning tender prices. According to the statistical theory of Bivariate Regression (Corty, 2007), three assumptions have been made.

1) Two variables were considered.

   Independent Variable X – The predicted construction cost, calculated by the equation with the major elemental costs ($/m2)

   Dependent Variable Y – The winning tender price ($/m2).

2) Hypothesis.

   The null hypothesis, H_0 is $\rho_{xy} = 0$

   States that there is no linear relationship between the predicted construction cost and the winning tender price.

   Thus, the alternative hypothesis, H_1 is $\rho_{xy} \neq 0$

   States that there is a linear relationship between the predicted construction cost and the winning tender price, and the observed correlation in the sample will reflect this.

3) The hypothesis is non-directional, therefore, a two tailed test is applied.

The statistical test used in this study was the Pearson product moment correlation coefficient, since the relationship between two interval level variables were examined (Corty, 2007). Three steps were set up for the statistical study of the testing.

- Step 1: Pearson product moment correlation coefficient 'r'

The Pearson product moment correlation coefficient r is used to verify the hypothesis. The r is value obtained from the linear regression analysis is described as follows:

1) According to the basic statistical rule, firstly, set up the Type I error as $\alpha = 0.05$ means that there is 5% chance making a Type I error. A Type I error is that we reject the null hypothesis when it is true. The intention of the test is to find there is a linear relationship between the two variables. Secondly, find the critical values of r— r_{cv} (Critical Values of r for Pearson Product Moment Correlation Coefficients When $\rho = 0$ (Corty, 2007), which is the cut-off point fr rejecting the null hypothesis.), based on the sample size.

2) Use the r^2 obtained by using SPSS software to calculate the absolute value of the observed value of r. If $r > r_{cv}$, then the null hypothesis is rejected. This indicates that there is a linear relationship existing between the predicted construction cost and the winning tender price.

- Step 2: Examining the strength and the meaningfulness of the correlation

As labelled above, this step is to examine whether the linear relationship between the predicted construction cost and the winning tender price is strong. In other words, examining the strength is to validate whether the predicted construction cost based on the major elemental costs is capable of forecasting the winning tender price. From the statistical principle, if the hypothesis is statistically different from zero, the next focus is to prove the statistical significance. Statistical significance means that the observed difference between samples is large enough to reflect a difference between populations, and the possibility of obtaining such a difference by chance is low. Practical significance means having a meaningful effect, and having relevance in practice (Corty, 2007). Three tests are applied to quantify the predictive capacity of a correlation coefficient, which could prove whether statistical significance represents practical significance.

1) Test I – Testing the strength of correlation, by creating a confidence interval of r at the 95% level (the most commonly calculated interval). The narrower the confidence intervals for a Pearson r, the smaller range within which the "real" correlation value, the population parameter, falls.

2) Test II – Testing the strength of association, by calculating a coefficient of determination with r^2. Cohen (1988) offered the 'effect size' theory about correlation in the social and behavioural sciences. He suggested that a variable that predicts ≈ 1% of variance has a small effect; one that predicts ≈ 10% of the variance has a medium effect; and one that predicts ≈ 25% has a large effect.

3) Test III – Testing the statistical power with r. The statistical power is the probability of correctly rejecting the null hypothesis. Power is defined as $1 - \beta$. β is a Type II error, which is incorrectly failing to reject the null hypothesis. The accepted convention is to set β at 0.20, and make power at 80%. This test is used to compare the calculated power from samples with conventional power in order to determine whether the power is significant enough and to find the minimum case number of samples.

In conclusion, the methodology can be displayed as the following flowchart Figure 1.

4. Conclusion

This paper has set out the literatures and methodology framework to set up a logical and systematic method in the establishment of the cost estimating model by using the Pareto Principle in order to improve the cost estimating accuracy and efficiency. This study described in this paper has also demonstrated the method of testing the reliability and effectiveness of the cost estimating model with the provisional theory. In the last four decades, the improvement of the cost estimating accuracy and efficiency has been a recurring subject in building economics. However, literature reviews suggested that the number of research studies directly investigating the methodology of testing and validating the reliability and effectiveness of the cost estimating model including the provisional theory is limited. Therefore, the need of carrying out this study is identified.

The methodology described in this study represents the outset of a series of investigation regarding using the Pareto Principle to discover a logical and systematic method in establishing and testing a cost estimating model in order to improve the cost estimating accuracy and efficiency. Further research could be:

- Conduct further analysis using the low-rise residential projects to test the theory described in this study

- Conduct further analysis using other types of projects, such as the high-rise residential projects and the office buildings.

- Conduct further analysis applying the same method on the trade format

These possible future works are to further prove the reliability of the methodology described in this paper. This also enables the finding of the logical and systematic method described in this study can be widely used in the building industry throughout different types of projects. However, there are some possible underlined issues, which the researchers would have to face. First of all, it is difficult to obtain a sufficient sample due to the poor data keeping habit and the sensitivity issue of the cost data in the construction industry. Second is the limitations regarding the assumptions of multiple regression used in the scientific and commercial fields – Theoretical Issues and Practical Issues (Green, 1990), which would could be further investigated and discussed in the future studies.

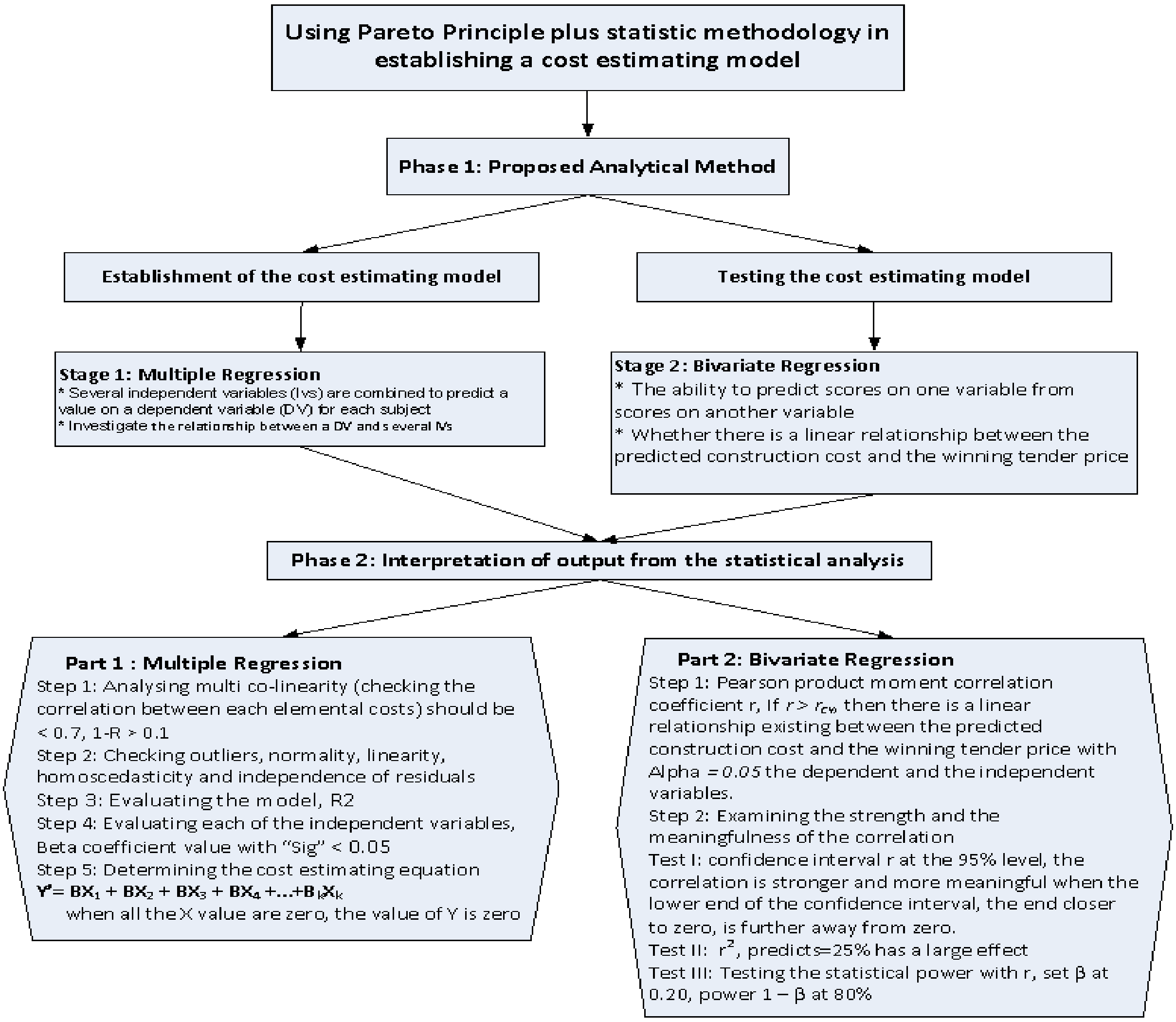

Figure 1: Methodology Flowchart

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