A METHODOLOGY FOR PREDICTING THE SIGNIFICANT POTENTIAL CONTRACT RISKS AT THE TENDER EVALUATION STAGE FOR CONSTRUCTION PROJECTS AT STATE ENERGY COMPANIES IN TRINIDAD AND TOBAGO

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ABSTRACT. This research paper will present a mathematical model for predicting the significant potential contract risks at the tender evaluation stage for construction projects at state energy companies in Trinidad and Tobago, West Indies. This paper will demonstrate that statistical tools such as Monte Carlo Simulation, Linear/Logistic Regression and PERT can be used to correctly predict the significant potential contract risks, namely: Cost Risk; Schedule Risk; Quality Risk; Health, Safety & Welfare Risk and Logistics Risk. It will also be shown that further research was conducted to verify and validate the mathematical model. The key findings were as follows:

a. The mathematical model has a 78% prediction capability. The results show that the data regresses linearly rather than logistically. The R2 value (linear) is in 76% of the cases > 0.6, The Cox and Snell's as well as the Nagelkerke (logistic) is in 100% of the cases < 0.5.
b. The mathematical model determined weightings for future tender evaluations: cost at 59% with schedule; quality; health, safety and welfare and logistics at a combined 41%.
c. The mathematical model predicted that in 83% of the cases the cost increased in order to lower the risk.
d. The research also proved to date that in 89% of the cases construction contracts were awarded solely based on cost.
e. The linear regression equation is as follows:

   $Y = A + B_1X_1 + B_2X_2 = 0.178 + 0.267X_1 + 0.245X_2$ where:
   - Y is the Probability of Risk
   - X_1 is the Variation in Cost (Difference between In-House Estimate of Cost and Bid Price)
   - X_2 is the Variation in Duration (Difference between In-House Estimate of Time and Bid Duration)

This research significantly contributes to the existing knowledge base by providing a rapid method for tender evaluations. The overarching benefits include the reduction of time, cost and effort in executing tender evaluations thus increasing accountability, transparency and public confidence in procurement in Trinidad and Tobago.

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INTRODUCTION

The motivation for this research paper was the determination of a solution to a recurring procurement issue observed in the energy sector of Trinidad and Tobago. It was observed that the performance of awarded bidders was not proportional to the assessment they received at the time of bid evaluation. The research undertaken by this author seeks to find a solution to this disparity.

This research paper is relevant not only to the energy sector but to the entire construction sector in the Republic of Trinidad and Tobago. This is particularly noted in the White Paper for the Reform of the Public Sector Procurement Regime (Ministry of Finance 2012). The White Paper noted that: *"It is essential that procurement attains the best quality of property and services for the price that is paid, or the lowest price for the acceptable quality of property and services. Accepting the lowest price is not necessarily an indicator of best Value for Money."* The recently concluded Commission of Enquiry into the Construction Sector of Trinidad and Tobago (Joint Consultative Council (JCC) 2012) also noted that: *""Procedures and criteria for assessment of tenders and making recommendation for award should be uniform". In the Commissioner's view no convincing comparison has yet been presented from which reliable conclusions can be drawn as to the relative performance of local and foreign contractors or consultants."*

These two procurement documents justify the need for an accurate methodology for the prediction of significant potential contract risks at the tender evaluation stage for construction projects at state energy companies in Trinidad and Tobago. It is anticipated that such a methodology would result in tender evaluations being assessed on lowest risk rather than lowest price. This is particularly true for the current construction climate in the country where the relationships among risk, procurement, quality, cost, time, transparency and public accountability are being tested and consistently evaluated.

RESEARCH HYPOTHESES

Null, H_0: The significant potential contract risks cannot be predicted at the tender evaluation stage for construction projects at state energy companies in Trinidad and Tobago.

Alternative, H_1: The significant potential contract risks can be predicted at the tender evaluation stage for construction projects at state energy companies in Trinidad and Tobago.

These Hypotheses will be tested at the 95% Confidence Level.

LITERATURE REVIEW

In order to develop a mathematical model for the prediction of significant potential contract risks at the tender evaluation stage of construction projects in Trinidad and Tobago, a literature review was done on research which focused on similar prediction models in the field of tender evaluations.

Research on Population Size and Sample Size

The Ministry of Planning and Development of the Government of the Republic of Trinidad and Tobago (GORTT) annually publishes a document entitled the: “Public Sector Investment Programme (PSIP)”. The PSIP document is based on the Budget for Trinidad and Tobago for each fiscal year. The document outlines both the current and proposed construction projects in each public sector.

The Population Size for the research is defined as the number of evaluated, awarded and completed construction contracts executed by state energy companies in the 2011 fiscal year. There are currently seven (7) state energy companies in the energy sector. The estimated number of construction programmes executed in 2011 was thirty (30).

Sample Size = $[\{Z^2 \times (p) \times (1-p)\} + ME^2] / ME^2$
Z = 1.96 for 95% confidence level, thus $Z^2 = 3.8416$
P = Population Proportion = 0.5, thus 1 – p = 0.5
Margin of Error = ± 10% = 0.1
Sample Size = 97 no.

It should be noted that the Central Limit Theorem states that: *"As the sample size n increases, the distribution of the sample average of these random variables approaches the normal distribution with a mean μ and variance σ^2 irrespective of the shape of the original distribution".* The Theorem also states that in the case where the sample size, n > 30 (with an infinite population and finite standard deviation) then the standardized sample mean converges to a standard normal distribution. Thus N = 97 is determined to be statistically significant.

Research on Key Performance Indicators (KPIs)

Latham (2001) researched methods for modernizing the construction industry in the United Kingdom. The author concluded that the: *"fallacy of awarding contracts solely on the basis of the lowest price bid only to see the final price for the work increase significantly through contract variations with buildings often completed late."*. One of the key conclusions of the Latham Report is that employers/clients tend to place emphasis on the lowest price approach which often leads to increased project risks such as high life cycle costs due to high maintenance costs. The Latham Report recommended the use of "sophisticated performance measures" or key performance indicators (KPI's) in order to ascertain the construction performance of a project.

Research on Tender Evaluations using a Risk Based Approach

The paper entitled "Reform of the Public Sector Procurement Regime" (White Paper 2005) was produced by the Government of the Republic of Trinidad and Tobago (GORTT). The main objective of the paper was to develop a holistic and efficient public procurement system for public sector companies or state agencies in Trinidad and Tobago. The paper examined, inter alia, the current procurement system (via the Central Tenders Board), the current best practices, current legislature and the preferred procurement model.

The Report of the Commission of Enquiry into the Construction Sector of Trinidad and Tobago (Joint Consultative Council (JCC) 2012) and more fondly known as the “Uff Report” was conducted to assess the state of procurement in Trinidad and Tobago. The main objective of the enquiry was to highlight corrupt practices in the procurement process and recommend procedures for reduction of corruption thereby increasing transparency and accountability in the award of contracts. The over arching findings of the report indicated that good procurement practices inclusive of proper and informed tender evaluations with risk based analyses would significantly reduce construction conflicts, time overruns, cost overruns, quality non-conformances and lower health, safety and welfare risks.

Kortanek, Soden, & Sodaro (1973) were trying to determine an appropriate bid price or in-house estimate based on risk. The authors used linear regression to show the relationship between risk and bid price at the tender evaluation stage. Linear regression was also used for the selection of the winning bid. Kortanek, Soden, & Sodaro (1973) were able to determine that the optimal bid price is a mathematical function of labour and material costs.

Johnstone & Bedard (2003) were attempting to ascertain whether risk management strategies could affect client acceptance decisions during tender evaluations. The authors incorporated risks in a mathematical equation using chi-squared analysis in order to select a winning bid.

Turner (1988) developed an algorithm for the evaluation of tenders. Turner (1988) used a linear programming model as a methodology for the evaluation of tenders. The model incorporated contract risks such as contract cost and suitability of the type of executing contract. Turner (1988) was therefore able to select a winning bid by using the model to assess and evaluate potential contract risk.

Research on Statistical Tools to Analyze and Predict Risk

Chee Hong Wong (2004) was concerned with the prediction of the contractor's performance at the tender evaluation stage. The author used logistic regression to predict the contractor's performance. Chee Hong Wong (2004) also used the tender evaluation criteria of thirty-one (31) clients and data from forty-eight (48) construction projects executed in the private and public sectors of the United Kingdom to build the model. The author then validated the model using data from twenty (20) independent construction projects. The model linked the evaluation criteria and the contractor's performance in order to predict project failures.

Hosmer & Lemeshow (2000) has extensively covered the topic of logistic regression. Schuyler (2001) described the categories of risk, criteria for analysis, decision making processes, decision trees, Monte Carlo Simulation, sensitivity analysis, statistical distributions, stochastic variance and other risk related topics.

METHODOLOGY

The method of data collection and mathematical model development will be presented in this section.

Data Collection

This researcher collected data from respondents using an online questionnaire generated by Survey Monkey. The type of data collected included:

a. Public Sector Investment Programme (PSIP) category

b. Engineer/In-House/Independent estimate of cost/budget
c. Engineer/In-House/Independent estimate of duration
d. Bid price of each bidder in tender action process
e. Bid duration of each bidder in tender action process
f. Actual final cost of awarded bidder
g. Actual final duration of awarded bidder
h. Predicted probabilities of risk for all bidders and actual performance for awarded bidder based on:
    - Performance
    - Quality of service
    - Product Output
    - Number of Defects
    - Health, Safety and Welfare Resources
    - Incidents/Accidents
    - Compliance with Health, Safety and Welfare Laws
    - Compliance with Environmental Laws
    - Availability of Materials/Equipment and Labour
    - Experience/Qualified Personnel
    - Overall Relevant Experience
    - Degree of Litigations/Claims and Court Matters

i. Feedback on the disparity, if any, between predicted probabilities of risks and the actual performances of awarded bidders.

j. Feedback on the award basis, i.e., the basis on which the contract was awarded in relation to the organization's strategic priority.

k. Feedback on whether further research in the prediction of significant potential contract risks at the tender evaluation stage is needed.

l. Feedback on whether more efficient and effective methodology for performing tender evaluations is needed.

m. Feedback on the user friendliness of the questionnaire.

n. Feedback on whether the implementation of the questionnaire as a project close out report in a company is possible.

Website link: https://www.surveymonkey.com/s/J2MLHBM

The distribution of the sampled data from state energy companies is as follows:

a. National Gas Company of Trinidad & Tobago: 10 No.
b. National Energy Corporation of Trinidad & Tobago: 10 No.
c. Petroleum Company of Trinidad & Tobago: 10 No.
d. Trinidad & Tobago National Petroleum: 0 No.
e. Lake Asphalt of Trinidad & Tobago: 0 No.
f. Trinidad & Tobago Electricity Commission: 6 No.
g. University of Trinidad & Tobago: 1 No.
h. Ministry of Local Government: 9 No.

Total sampled to date = 46 No.

Mathematical Model Development

The mathematical model was built using Microsoft Excel. A brief account of each of the nine (9) tabs in the model will be given.

Tab 1: The "Sum" tab summarizes the output of the mathematical model. It renders the following information for each data set:

a. The actual and predicted risk (average, linear and logistic) for both the recommended and awarded bidders.
b. The linear regression and logistic regression coefficients for the prediction equations. The goodness of fit factors are also displayed.
c. A choice is given to select one of three (3) calculated in-houses estimates: client; cost plus (cost plus fluctuating fee theory where

contractor is paid by the client for works executed plus a fee inversely variable to the increase or decrease of the agreed estimated cost by both parties) & PERT.

d. The recommended weightings for future tender evaluation assessments.
e. An assessment of cost versus risk in terms of whether the cost to manage the risk increases with decreasing risk.
f. A graphical comparative analysis of all risks using a Normal Distribution Curve. The normality tests results are also shown.

Tab 2: The "Surv" tab represents all the Data Sets obtained from the Online Questionnaire in a tabular format.

Tab 3: The "Cost" tab calculates the Probability of Cost Risk based on the Bidder's Price and Engineer/In-House/Independent Estimate of Cost. Two well accepted methods are used here: Monte Carlo Simulation (Schuyler 2001) and PERT Method (Schuyler 2001). These methods are used to determine the Expected Project Cost (Budget) and then compare it against the Bidder's Price. Additionally, the Project Management Institute's (PMI) Cost Performance Index (CPI) Formula is used to determine the Probability of Cost Risk.

The Monte Carlo Simulation (Schuyler 2001) is based on a series of computational algorithms which rely on repeated random sampling in order to obtain results. The method has a wide ranging assortment of applications in the fields of physical sciences, design, finance, business, telecommunications and gaming. This optimization method was chosen primarily to calculate the Expected Project Cost. The PERT Method (Program Evaluation and Review Technique) was developed by Frederic Taylor. This tool essentially facilitates fast and easy decision making. The Cost Performance Index (CPI) developed by the Project Management Institute is part of a widely accepted theory on Earned Value Management.

The procedural steps for each analyzing each data set are as follows:

a. The Worst Guess or Max. Cost is the maximum price submitted when all Tenderer's Prices are compared.

b. The Best Guess or Min. Cost is the minimum price submitted when all Tenderer's Prices are compared.

c. The Most Likely Cost is based on the Engineer/In-House/Independent Estimate.

d. A Contingency can be inserted if required.

e. PERT Cost Estimate = [Min. Cost (Best Guess) + 4 x Most Likely Cost + Max. Cost (Worst Guess)] / 6

f. The Monte Carlo Simulation (Schuyler 2001) is generated using random numbers and the PERT values, i.e., Worst Guess, Most Likely Cost and Best Guess. Hence the simulation determines 5,000 possible values of the Pert Estimate in order to get an array of possible values.

g. A Histogram is plotted using Excel's array function. The Expected Project Cost or Earned Value is the mean of the 5,000 possible values of the PERT Estimate. The F9 key can be used to continuously generate new random values.

h. The Cost Performance Index (CPI) is calculated as follows:

   - Predicted CPI = Expected Project Cost or Earned Value / Bid Price (Expected Actual Cost)
   - If CPI is less than 1 then it is expected that the project would be over budget with a Probability of Cost Risk = 1 – CPI.
   - If the CPI is greater than 1 then it is expected that the project would be completed within budget or below budget, thus, a Probability of Cost Risk = (CPI -1)/100.

i. The Expected Probability, Standard Deviation, Standard Error, 95% Upper and Lower Confidence Limits, Kurtosis and Skew are also determined. Kurtosis is a representation of the peakedness of the probability distribution while Skew is a representation of the asymmetry of the probability distribution.

Tab 4: The “Time” tab calculates the Probability of Schedule Risk based on the Bidder’s Duration and Engineer/In-House/Independent Estimate. Two well accepted methods are used here: Monte Carlo Simulation (Schuyler 2001) and PERT Method (Schuyler 2001). These methods are used to determine the Expected Project Duration or Earned Value and then compare it against the Bidder’s Duration. Additionally, the Project Management Institute’s (PMI) Schedule Performance Index (SPI) Formula is used to determine the Probability of Schedule Risk. The Monte Carlo Simulation was chosen primarily to calculate the Expected Project Duration. The PERT Method (Program Evaluation and Review Technique) essentially facilitates fast and easy decision making. The Schedule Performance Index (CPI) developed by the Project Management Institute is part of a widely accepted theory on Earned Value Management.

The procedural steps for each Data Set are as follows:

a. The Worst Guess or Max. Duration is the maximum duration submitted when all Tenderer’s Durations are compared.

b. The Best Guess or Min. Duration is the minimum duration submitted when all Tenderer’s Durations are compared.

c. The Most Likely Duration is based on the Engineer/In-House/Independent Estimate.

d. A Contingency can be inserted if required.

e. PERT Duration Estimate = [Min. Duration (Best Guess) + 4 x Most Likely Duration + Max. Duration (Worst Guess)] / 6

f. The Monte Carlo Simulation (Schuyler 2001) is generated using random numbers and the PERT values, i.e., Worst Guess, Most Likely Duration and Best Guess. Hence the simulation determines 5,000 possible values of the Pert Estimate in order to get an array of values.

g. A Histogram is plotted using Excel’s array function. The Expected Project Duration is the mean of the 5,000 possible values of the

PERT Estimate. The F9 key can be used to continuously generate new random values.

h. The Schedule Performance Index (CPI) is calculated as follows:
   - Predicted SPI = Expected Project Duration or Earned Value/ Tenderer's Duration (Expected Planned Value)
   - If SPI is less than 1 then it is expected that the project would be overtime with a Probability of Schedule Risk = 1 – SPI.
   - If the SPI is greater than 1 then it is expected that the project would be completed within time, thus, a Probability of Schedule Risk = (SPI – 1)/100.

i. The Expected Probability, Standard Deviation, Standard Error, 95% Upper and Lower Confidence Limits, Kurtosis and Skew are also determined. Kurtosis is a representation of the peakedness of the probability distribution while Skew is a representation of the asymmetry of the probability distribution.

Tab 5: The "Qual" Tab uses a modified version of the Cut Score Method or Angoff Method to establish the Risk Threshold or Most Likely Risk for Quality. This method is widely used in testing and examinations by educational institutions. The procedural steps for each Data Set are as follows:

a. Mean of Quality Risks, μ = Mean of Σ Average of each Tenderer's Quality Risks:
   - Performance
   - Quality of service
   - Product Output
   - Number of Defects

b. Variance, δ of Quality Risks = $\Sigma (X - \mu)^2 / n$ where X is the Average of each Tenderer's Quality Risks; μ is the Mean as defined above and n is the number of bids received.

c. Standard Deviation, $\gamma = \sqrt{\Sigma (X - \mu)^2}$ where all the terms have the same representations as above.

d. Most Likely Quality Risk/Risk Threshold = $\mu - \gamma$

e. The Worst Guess or Max. Quality Risk is the maximum of the Σ Average of each Tenderer's Quality Risks.

f. The Best Guess or Min. Quality Risk is the minimum of the Σ Average of each Tenderer's Quality Risks.

g. The Monte Carlo Simulation (Schuyler 2001) is generated using random numbers and the PERT values, i.e., Worst Guess, Most Likely Quality Risk and Best Guess. Hence the simulation determines 5,000 possible values of the Pert Estimate.

h. A Histogram is plotted using Excel's array function. The Expected Quality Risk is the mean of the 5,000 possible values of the PERT Estimate. The F9 key can be used to continuously generate new random values.

i. Probability of Quality Risk = Average of the Predicted Quality Risk and Expected Quality Risk.

j. The Expected Probability, Standard Deviation, Standard Error, 95% Upper and Lower Confidence Limits, Kurtosis and Skew are also determined.

k. Kurtosis is a representation of the peakedness of the probability distribution while Skew is a representation of the asymmetry of the probability distribution.

Tab 6: The "HSW" Tab also uses a modified version of the Cut Score Method or Angoff Method to establish the Risk Threshold or Most Likely Risk for Health, Safety and Welfare. The procedural steps for each Data Set are as follows:

a. Mean of HSW Risks, μ = Mean of Σ Average of each Tenderer's HSW Risks:

   - Health, Safety and Welfare Resources

- Incidents/Accidents
- Compliance with Health, Safety and Welfare Laws
- Compliance with Environmental Laws

b. Variance, δ of HSW Risks = $\Sigma (X - \mu)^2 / n$ where X is the Average of each Tenderer's HSW Risks; μ is the Mean as defined above and n is the number of bids received.

c. Standard Deviation, $\gamma = \sqrt{\Sigma} (X - \mu)^2$ where all the terms have the same representations as above.

d. Most Likely HSW Risk/Risk Threshold = $\mu - \gamma$

e. The Worst Guess or Max. HSW Risk is the maximum of the Σ Average of each Tenderer's HSW Risks.

f. The Best Guess or Min. HSW Risk is the minimum of the Σ Average of each Tenderer's HSW Risks.

g. The Monte Carlo Simulation (Schuyler 2001) is generated using random numbers and the PERT values, i.e., Worst Guess, Most Likely HSW Risk and Best Guess. Hence the simulation determines 5,000 possible values of the Pert Estimate.

h. A Histogram is plotted using Excel's array function. The Expected HSW Risk is the mean of the 5,000 possible values of the PERT Estimate. The F9 key can be used to continuously generate new random values.

i. Probability of HSW Risk = Average of the Predicted HSW Risk and Expected HSW Risk.

j. The Expected Probability, Standard Deviation, Standard Error, 95% Upper and Lower Confidence Limits, Kurtosis and Skew are also determined.

k. Kurtosis is a representation of the peakedness of the probability distribution while Skew is a representation of the asymmetry of the probability distribution.

Tab 7: The "Logi" Tab uses a modified version of the Cut Score Method or Angoff Method to establish the Risk Threshold or Most Likely Risk for Logistics. The procedural steps for each Data Set are as follows

a. Mean of Logistics Risks, μ = Mean of Σ Average of each Tenderer's Logistics Risks:
   - Availability of Materials/Equipment and Labour
   - Experience/Qualified Personnel
   - Overall Relevant Experience
   - Degree of Litigations/Claims and Court Matters

b. Variance, δ of Logistics Risks = $\Sigma (X - \mu)^2 / n$ where X is the Average of each Tenderer's Logistics Risks; μ is the Mean as defined above and n is the number of bids received.

c. Standard Deviation, $\gamma = \sqrt{\Sigma} (X - \mu)^2$ where all the terms have the same representations as above.

d. Most Likely Logistics Risk/Risk Threshold = $\mu - \gamma$

e. The Worst Guess or Max. Logistics Risk is the maximum of the Σ Average of each Tenderer's Logistics Risks.

f. The Best Guess or Min. Logistics Risk is the minimum of the Σ Average of each Tenderer's Logistics Risks.

g. The Monte Carlo Simulation (Schuyler 2001) is generated using random numbers and the PERT values, i.e., Worst Guess, Most Likely Logistics Risk and Best Guess. Hence the simulation determines 5,000 possible values of the Pert Estimate.

h. A Histogram is plotted using Excel's array function. The Expected Logistics Risk is the mean of the 5,000 possible values of the PERT Estimate. The F9 key can be used to continuously generate new random values.

i. Probability of Logistics Risk = Average of the Predicted Logistical Risk and Expected Logistics Risk.

j. The Expected Probability, Standard Deviation, Standard Error, 95% Upper and Lower Confidence Limits, Kurtosis and Skew are also determined.

k. Kurtosis is a representation of the peakedness of the probability distribution while Skew is a representation of the asymmetry of the probability distribution.

Tab 8: The “Reg” tab uses both linear and logistic regression for the quantitative analysis of risk. It should be noted that due to the mathematical complexities of both forms of regression the number of independent variables is limited to two (2) and the number of dependent variables is limited to (1).

The Linear Regression Prediction Model is of the form $Y = A + B_1X_1 + B_2X_2$ where:

- A, B_1 and B_2 are Linear Regression Constants to be determined.
- Y is the dependent variable which is the average of all risk.
- X_1 is the independent variable which is the variation in cost (numerical difference between bid price and in-house price).
- X_2 is the independent variable which is the variation in schedule (numerical difference between bid duration and in-house duration).

In order to regress Y against X_1 and X_2 the values of Y, X_1 and X_2 are tabulated and the equations overleaf are used to obtain the values of the constants, A, B_1 and B_2. It should be noted that N is the number of Data Sets. It can be concluded that the closer the R2 value is to 1 the higher the correlation among Y, X_1 and X_2 and the more accurate the prediction capabilities of the mathematical model.

Linear Regression Prediction Equations:

- $\square y^2 = \square Y^2 - [\square Y^2/n]$
- $\square x_1^2 = \square X_1^2 - [\square X_1^2/n]$

- $\square x_2^2 = \square X_2^2 - [\square X_2^2/n]$
- $\square x_1 y = \square X_1 Y - [\square X_1 \square Y/n]$
- $\square x_2 y = \square X_2 Y - [\square X_2 \square Y/n]$
- $\square x_1 x_2 = \square X_1 X_2 - [\square X_1 \square X_2/n]$
- $B_1 = \dfrac{[\square x_2^2 \; \square x_1 y] - [\square x_1 x_2 \; \square x_2 y]}{[\square x_1^2 \; \square x_2^2] - [\square x_1 x_2^2]}$
- $B_2 = \dfrac{[\square x_1^2 \; \square x_2 y] - [\square x_1 x_2 \; \square x_1 y]}{[\square x_1^2 \; \square x_2^2] - [\square x_1 x_2^2]}$
- $A = Y_M - B_1 X_{1M} - B_2 X_{2M}$

The Anova Table is constructed (as shown below) based on the aforementioned equations with the values varying for each Data Set. N.B. K = P + 1 where P = number of dependent variables (in this case, 2)

Source	DF	Sum of Squares	Mean Squares	F	SIG F	R2
Regression	K - 1	$SSR = \Sigma (Y'-Y_M)^2$	MSR = SSR/DF	MSR/MSE	FDIST in Excel	1 – (SSR/SST)
Residual	N - K	$SSE = \Sigma (Y-Y')^2$	MSE = SSE/DF			
Total	N – 1	SSE + SSR or $\Sigma (Y-Y_M)^2$				

The Logistic Regression Prediction Model is of the form:

$Y = 1 / [1 + e^{-L}]$ where L is a Logit and Y is the Probability of Risk.

Logit, L= Ln Odds = Ln [Y / (1-Y)] = $C + D_1X_1 + D_2X_2$ where:

- C, D_1 & D_2 are Logistic Regression Coefficients to be determined.
- Y is the dependent variable which is the average of all risk.
- X_1 is the independent variable which is the variation in cost (numerical difference between bid price and in-house price).
- X_2 is the independent variable which is the variation in schedule (numerical difference between bid duration and in-house duration).

In order to regress Y against X_1 and X_2 the values of Y, X_1 and X_2 are tabulated and the equations overleaf are used to obtain the values of the constants, C, D_1 and D_2. It should be noted that N is the number of Data Sets. It should be noted that the value of Y lies between 0 and 1 irrespective of the value of L thus restricting the prediction capabilities of the mathematical model to an acceptable probability value. In order to determine the values of C, D_1 and D_2 the Log Likelihood Method is used via the following steps:

a. A guess is made of the values of C, D_1 and D_2 and entered in the spreadsheet.

b. The Standard Error of the Logistic Coefficient, E = Variance of X / √ No. of Bidders where Var X = 1 for C, Var X = Var X_1 for D_1 and Var X = Var X_2 for D_2.

c. The Wald Statistic, W = Logistic Coefficient / E^2.

d. The Degrees of Freedom is equal to the number of Logistic Coefficients or predictor variables, in this case, 2.

e. The P-Value is the one tailed probability of the Chi-Squared Distribution using W and the Degrees of Freedom. For statistical significance the P-Value should lie between 0.045 and 0.055 in order to conform to the 95% confidence parameters. If the P-Value is within the range then the values of C, D_1 and D_2 are retained and further tested.

f. The Odds Ratio is calculated by the formula: OR = $e^{\text{Logistic Coefficient}}$

g. The 95% Confidence Interval for the Odds Ratio is calculated by the formula: Lower Bound = OR – (1.96 x Standard Error); Upper Bound = OR + (1.96 x Standard Error).

h. The Log Likelihood procedure is then executed using the following equations and Excel's Solver. For each bidder the following are calculated:

- The Odds = Y / 1- Y
- Binary Decision, Y_i is coded as either 1 (If Average Risk < Mean Average Risk) or 0 (If Average Risk > Mean Average Risk).
- P_i = Y and Log Likelihood, LL = ($Y_i \ln P_i$) + [(1-Y_i) ln (1-P_i)]. The LL for each bidder is summed.
- Excel Solver is then executed to determine the optimized Logistic Regression Coefficients which would fit the Data Set.
- The Cox and Snell's R2 for correlation is determined by first determining -2LL for the Full Model, i.e. with all coefficients and independent variables. The -2LL is then determined for the Null Model, i.e. Constant C only. The Cox and Snell's R2 is given by:

  $R2 = 1 - e^{-[(-2LL\ \text{Null Model}) - (-2LL\ \text{Full Model})]/n}$ where n is the number of data sets.

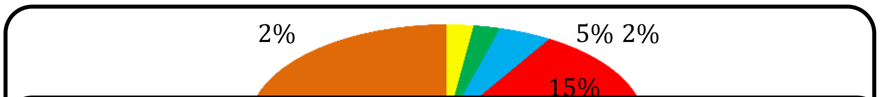
  It should be noted that for Logistic Regression the R2 value is not always applicable since it is a pseudo R2 and it is not generally considered as a powerful predictor of correlation as in the R2 value for Linear Regression.
- Nagelkerke R2 = 1 - $(\text{LL Null Model}/\text{LL Model})^{2/n}$

RESULTS

The results of this research are displayed in two (2) categories: Results of Sampled Data and Results of Mathematical Model Routing. All results are based on a sample size of forty-six (46) data sets to date. The projected sample size is sixty (60) data sets.

Results of Sampled Data

Figure 1- Pie Chart showing Distribution of Data Sets by Public Sector



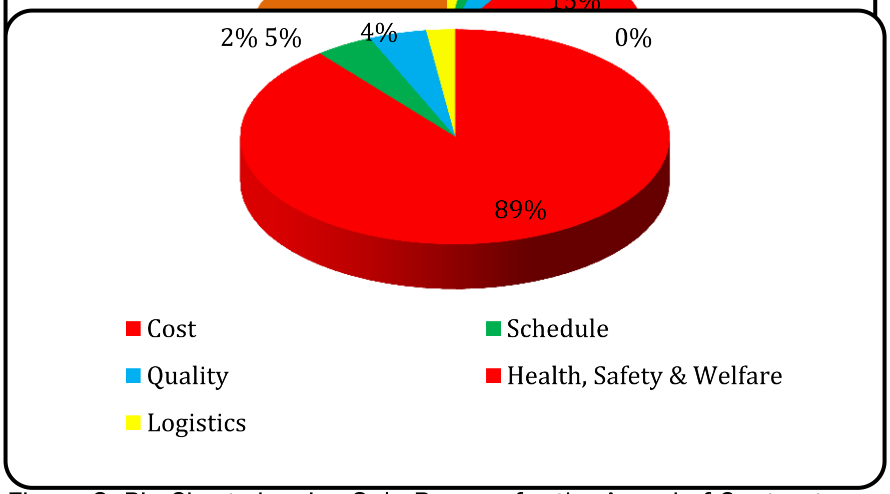


Figure 2- Pie Chart showing Sole Reason for the Award of Contract

Figure 3- Pie Chart showing Need for Further Research in Prediction of Risk

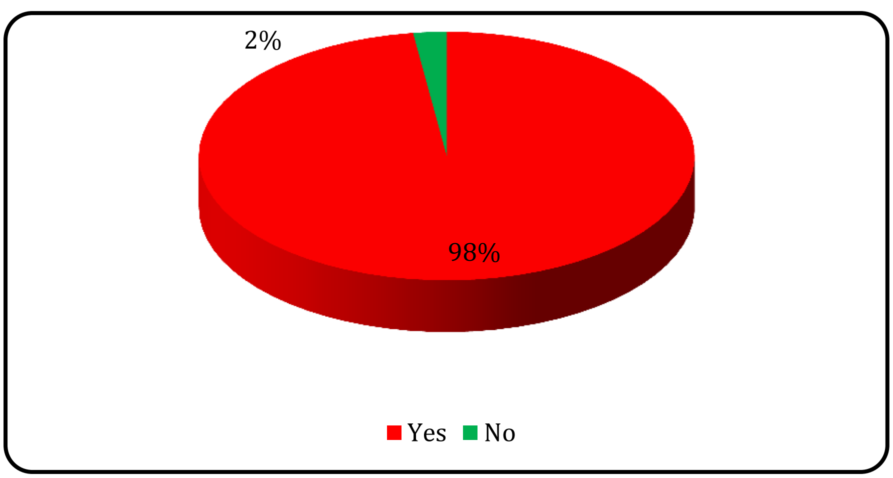
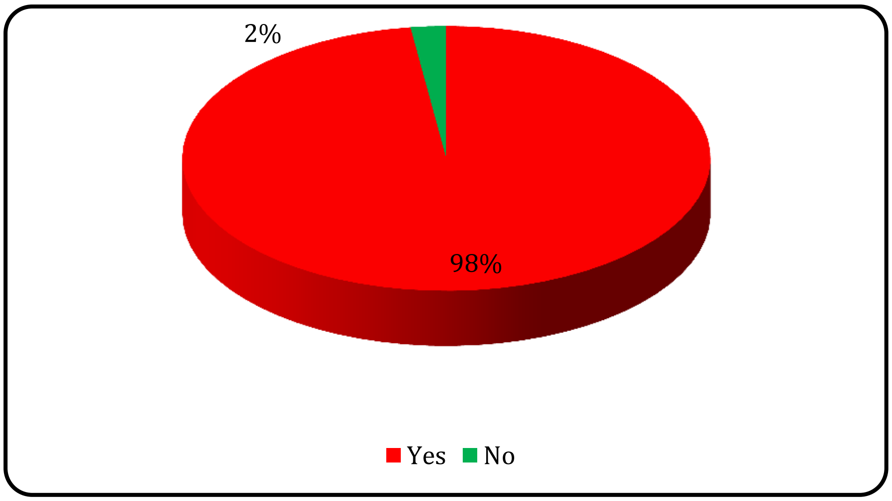


Figure 4- Pie Chart showing Need for Quick and Risk Based Method of Tender Evaluations



Results of Mathematical Model Routing

Table 1: Prediction Capability (Using Client In-House Estimate)

Data Set	Actual Risk	Predicted Average	Predicted Linear	Predicted Logistic	Predicted Max. Risk	Prediction Capability
1	**23%**	17%	17%	23%	**23%**	Acceptable
2	**23%**	22%	22%	23%	**23%**	Acceptable
3	**23%**	18%	17%	22%	**22%**	Acceptable
4	**23%**	19%	21%	26%	**26%**	Acceptable
5	**23%**	24%	24%	27%	**27%**	Acceptable
6	**23%**	28%	28%	26%	**28%**	Acceptable
7	**9%**	31%	53%	34%	**53%**	Acceptable

8	**9%**	14%	14%	15%	**15%**	Acceptable
9	**9%**	17%	11%	16%	**17%**	Acceptable
10	**23%**	15%	12%	14%	**15%**	Unacceptable
11	**9%**	11%	14%	17%	**17%**	Acceptable
12	**23%**	16%	23%	28%	**28%**	Acceptable
13	**9%**	24%	22%	24%	**24%**	Acceptable
14	**71%**	16%	26%	18%	**26%**	Unacceptable
15	**71%**	23%	19%	23%	**23%**	Unacceptable
16	**71%**	34%	55%	38%	**55%**	Unacceptable
17	**9%**	34%	38%	38%	**38%**	Acceptable
18	**23%**	22%	12%	23%	**23%**	Acceptable
19	**9%**	18%	11%	16%	**18%**	Acceptable
20	**9%**	21%	14%	18%	**21%**	Acceptable

If Actual Risk is either less than or within ±5% of Predicted Maximum Risk, then the Prediction Capability = Acceptable. If Actual Risk is greater than ±5% of Predicted Maximum Risk, then the Prediction Capability is Unacceptable.

Data Set	**Actual**	**Predicted Average**	**Predicted Linear**	**Predicted Logistic**	**Predicted Max. Risk**	**Prediction Capability**
21	**9%**	17%	7%	17%	**17%**	Acceptable
22	**23%**	13%	13%	16%	**16%**	Unacceptable
23	**23%**	20%	17%	22%	**22%**	Acceptable
24	**23%**	31%	23%	23%	**31%**	Acceptable
25	**50%**	41%	42%	38%	**42%**	Unacceptable
26	**23%**	38%	38%	44%	**44%**	Acceptable
27	**23%**	46%	53%	51%	**53%**	Acceptable
28	**23%**	10%	10%	21%	**21%**	Acceptable
29	**23%**	16%	18%	23%	**23%**	Acceptable
30	**9%**	26%	12%	32%	**32%**	Acceptable
31	**23%**	16%	10%	18%	**18%**	Acceptable

32	**9%**	14%	13%	18%	**18%**	Acceptable
33	**23%**	11%	22%	15%	**22%**	Acceptable
34	**23%**	16%	21%	24%	**24%**	Acceptable
35	**23%**	14%	12%	23%	**23%**	Acceptable
36	**23%**	22%	15%	28%	**28%**	Acceptable
37	**50%**	15%	18%	27%	**27%**	Unacceptable
38	**50%**	40%	39%	40%	**40%**	Unacceptable
39	**23%**	20%	12%	26%	**26%**	Acceptable
40	**9%**	21%	16%	22%	**22%**	Acceptable

If Actual Risk is either less than or within ±5% of Predicted Maximum Risk, then the Prediction Capability = Acceptable. If Actual Risk is greater than ±5% of Predicted Maximum Risk, then the Prediction Capability is Unacceptable.

Data Set	Actual	Predicted Average	Predicted Linear	Predicted Logistic	Predicted Max. Risk	Prediction Capability
41	**23%**	17%	7%	24%	**24%**	Acceptable
42	**9%**	13%	16%	19%	**18%**	Acceptable
43	**23%**	13%	16%	22%	**22%**	Acceptable
44	**23%**	14%	14%	1%	**14%**	Unacceptable
45	**50%**	28%	23%	47%	**47%**	Acceptable
46	**50%**	18%	16%	36%	**36%**	Unacceptable

If Actual Risk is either less than or within ±5% of Predicted Maximum Risk, then the Prediction Capability = Acceptable. If Actual Risk is greater than ±5% of Predicted Maximum Risk, then the Prediction Capability is Unacceptable.

Figure 5- Pie Chart showing Prediction Capability

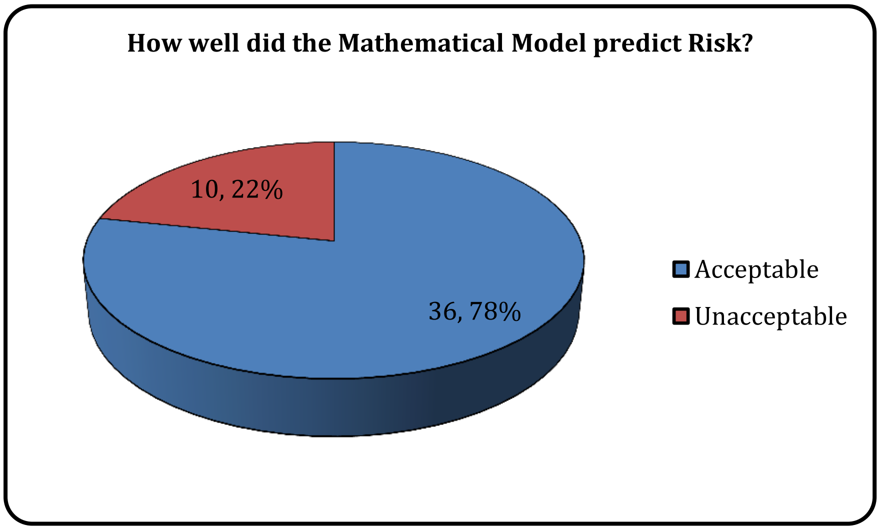


Table 2: Prediction Equations (Using Client In-House Estimate)

Data Set	Linear Regression			Logistic Regression			Goodness of Fit
	A	B_1	B_2	C	D_1	D_2	R2, CS, N
1	0.260	-0.242	-0.850	-1.270	0.117	0.746	0.95,0.02
2	0.245	-0.305	0.694	-1.218	0.119	0.748	1.00,0.00
3	0.125	1.865	0.030	-1.330	0.114	0.748	0.94,0.04
4	0.193	0.168	0.367	-1.130	0.124	0.759	0.90,0.00
5	0.231	0.417	0.105	-1.007	0.149	0.773	0.62,0.00
6	0.256	0.376	-0.584	-1.061	0.143	0.771	0.65,0.01
7	0.061	1.163	305.773	-0.704	0.165	0.781	0.40,0.01
8	0.131	0.002	0.887	1.616	-0.054	0.781	1.00,0.02

9	0.054	1.163	214.704	-1.622	-0.067	0.780	**0.70,0.00**
10	0.097	0.116	0.103	-1.794	-0.084	0.780	**0.32,0.05**
11	0.084	0.101	0.226	-1.629	-0.013	0.797	**0.63,0.03**
12	0.160	-0.085	1.686	-1.221	0.281	0.842	**0.69,0.04**
13	0.003	5.326	5.779	-1.162	0.327	0.849	**0.51,0.00**
14	0.084	1.706	167.343	-1.550	0.310	0.849	**0.36,0.03**
15	0.010	8.851	19.014	-1.201	0.329	0.849	**0.46,0.00**
16	0.174	3.784	348.098	-0.5	0.346	0.849	**0.39,0.00**
17	0.000	3.826	0.000	-0.516	0.346	0.849	**0.00,0.00**
18	0.053	0.350	427.661	-1.244	0.273	0.849	**0.64,0.00**
19	0.023	0.886	46.296	-1.694	0.014	0.849	**0.29,0.00**
20	0.120	0.006	478.578	-1.628	0.024	0.849	**0.61,0.00**

Acceptable Fit Criteria, R2 > 0.6

Acceptable Fit Criteria, Cox & Snell's or Nagelkerke > 0.5

Data Set	Linear Regression			Logistic Regression			Goodness of Fit
	A	B_1	B_2	C	D_1	D_2	R2, CS, N
21	0.013	0.063	103.022	-1.625	0.078	0.849	**0.63,0.00**
22	0.129	0.022	0.835	-1.646	0.016	0.849	**0.99,0.00**
23	0.173	0.197	0.330	-1.293	0.522	0.855	**0.33,0.00**
24	0.162	0.358	0.335	-1.465	0.491	0.826	**0.77,0.01**
25	0.421	0.000	0.000	-0.836	0.512	0.897	**0.00,0.07**
26	0.355	0.014	0.224	-0.950	0.417	0.886	**1.00,0.05**
27	0.012	0.048	24.366	-1.250	0.117	0.846	**0.46,0.41**
28	0.088	0.093	-0.050	-1.283	-0.197	0.846	**0.93,0.03**
29	0.157	0.189	-0.072	-1.193	-0.085	0.848	**0.98,0.03**
30	0.071	0.346	282.390	-0.746	0.128	0.870	**0.66,0.03**
31	0.031	0.735	61.181	-1.452	-0.452	0.870	**0.60,0.00**

32	0.013	0.301	39.684	-1.350	-0.432	0.870	**0.64,0.01**
33	0.029	0.472	142.885	-1.537	-0.532	0.870	**0.34,0.02**
34	0.207	0.000	0.000	-1.027	-0.389	0.870	**0.00,0.12**
35	0.078	0.126	234.369	-1.045	-0.407	0.870	**0.77,0.03**
36	0.105	0.020	314.678	-0.695	-0.070	0.870	**0.65,0.06**
37	0.178	0.000	0.000	-0.729	-0.296	0.870	**0.00,0.30**
38	0.306	0.015	0.105	-0.699	-0.127	0.899	**0.94,0.04**
39	0.055	0.674	110.359	-0.926	-0.509	0.790	**0.73,0.03**
40	0.011	0.503	21.020	-1.085	-0.557	0.790	**0.60,0.04**

Acceptable Fit Criteria, R2 > 0.6

Acceptable Fit Criteria, Cox & Snell's or Nagelkerke > 0.5

Data Set	Linear Regression			Logistic Regression			Goodness of Fit
	A	B_1	B_2	C	D_1	D_2	R2, CS, N
41	-0.100	-0.125	2.000	-1.091	-0.559	0.790	**0.79,0.11**
42	0.126	0.010	0.012	-0.729	-0.360	0.862	**0.71,0.01**
43	0.136	0.212	1.121	-1.086	-1.670	0.684	**0.91,0.01**
44	0.358	-0.013	-1.454	1.747	-1.132	0.769	**1.00,0.39**
45	0.194	0.004	0.291	2.082	-0.222	0.791	**0.64,0.76**
46	0.141	0.003	0.268	2.072	-0.346	0.791	**0.64,0.14**

Acceptable Fit Criteria, R2 > 0.6

Acceptable Fit Criteria, Cox & Snell's or Nagelkerke > 0.5

Figure 6 - Pie Chart showing Goodness of Fit for Linear Regression

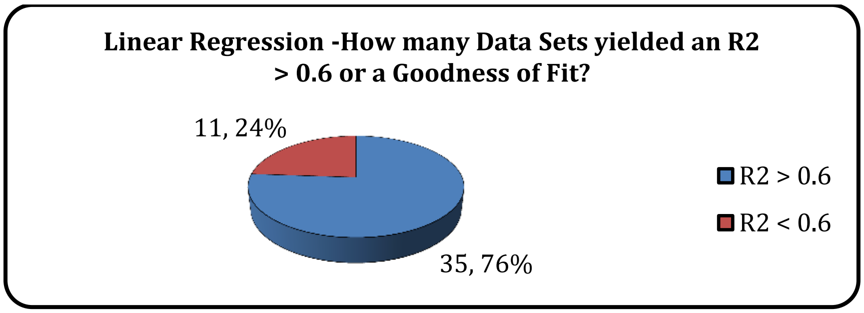


Figure 7 – Pie Chart showing Goodness of Fit for Logistic Regression

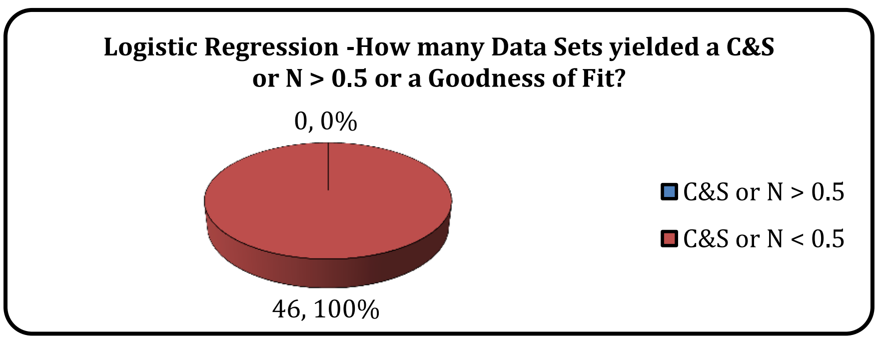


Table 3: Most Likely Values of the Coefficients (Using Client's Estimate)

Linear Regression			Logistic Regression		
A	B_1	B_2	C	D_1	D_2
0.178	0.267	0.245	-0.692	-0.081	0.812

Linear Regression Equation:

$Y = A + B_1X_1 + B_2X_2$

$Y = 0.178 + 0.267X_1 + 0.245X_2$ where:

a. Y is the Probability of Risk

b. X_1 is the Variation in Cost (Difference between In-House Estimate of Cost and Bid Price)
c. X_2 is the Variation in Duration (Difference between In-House Estimate of Time and Bid Duration)
d. R2 > 0.6: 76% of data sets, hence data acceptably correlates and/or regresses linearly.

Logistic Regression Equation:

$Y = 1 / [1 + e^{-L}]$ where $L = C + D_1X_1 + D_2X_2$

$Y = 1 / [1 + e^{-(-0.692 - 0.081X1 + 0.812X2)}]$ where:

a. Y is the Probability of Risk
b. X_1 is the Variation in Cost (Difference between In-House Estimate of Cost and Bid Price)
c. X_2 is the Variation in Duration (Difference between In-House Estimate of Time and Bid Duration)
d. Cox & Snell's/Nagelkerke > 0.5: 0%, hence data does not acceptably correlate and/or regress logistically.

Figure 8 - Pie Chart showing Recommended Weights for Future Tender Evaluations

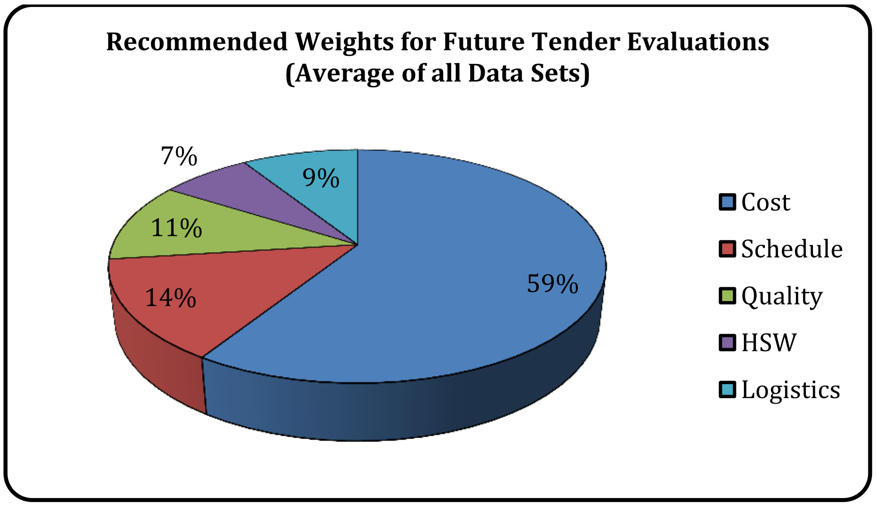


Figure 9 - Pie Chart showing relationship between Cost and Risk

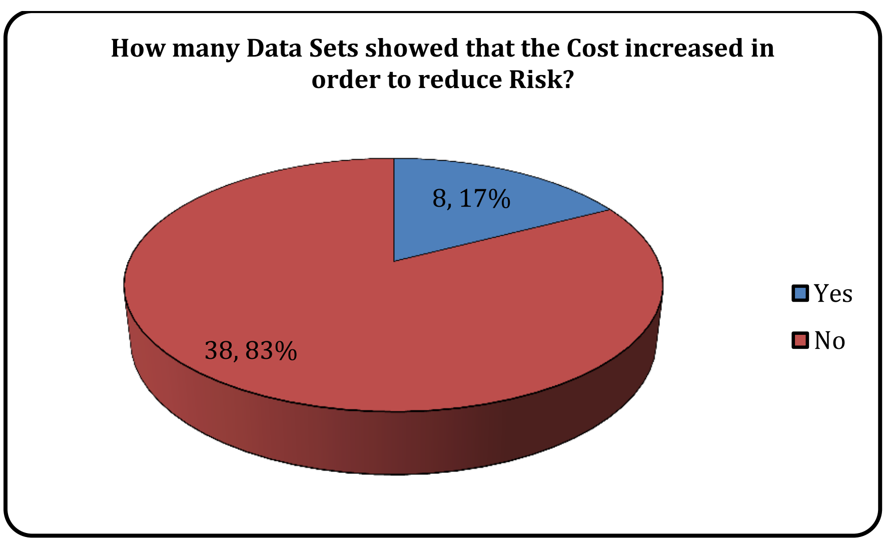


Figure 10 - Pie Chart showing Normality of Data

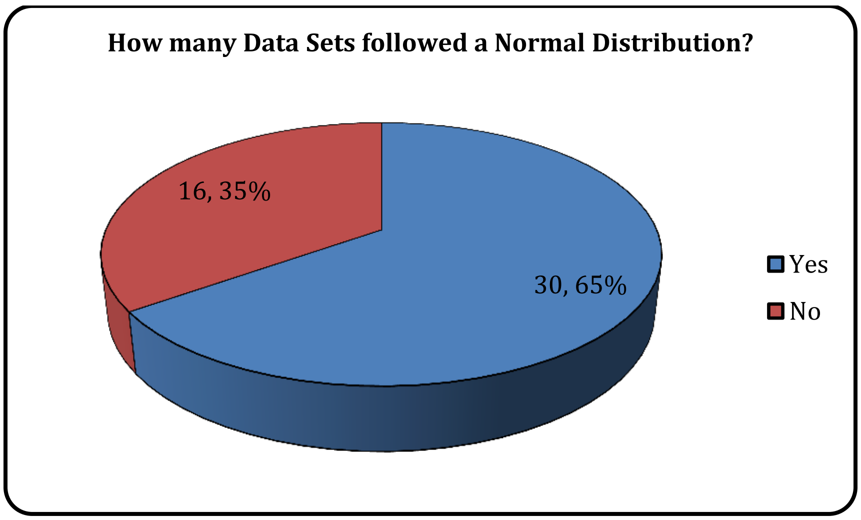


Figure 11 - Pie Chart showing Confidence Interval Prediction

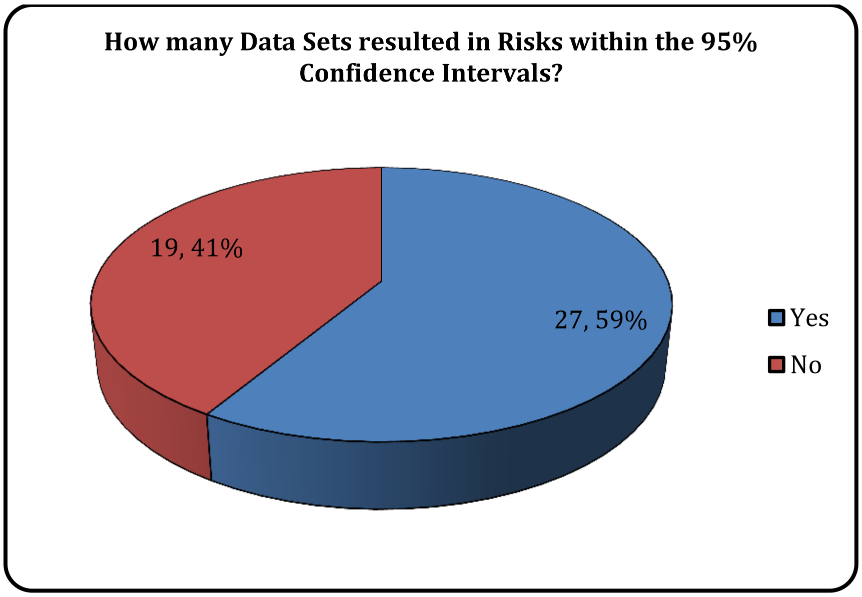
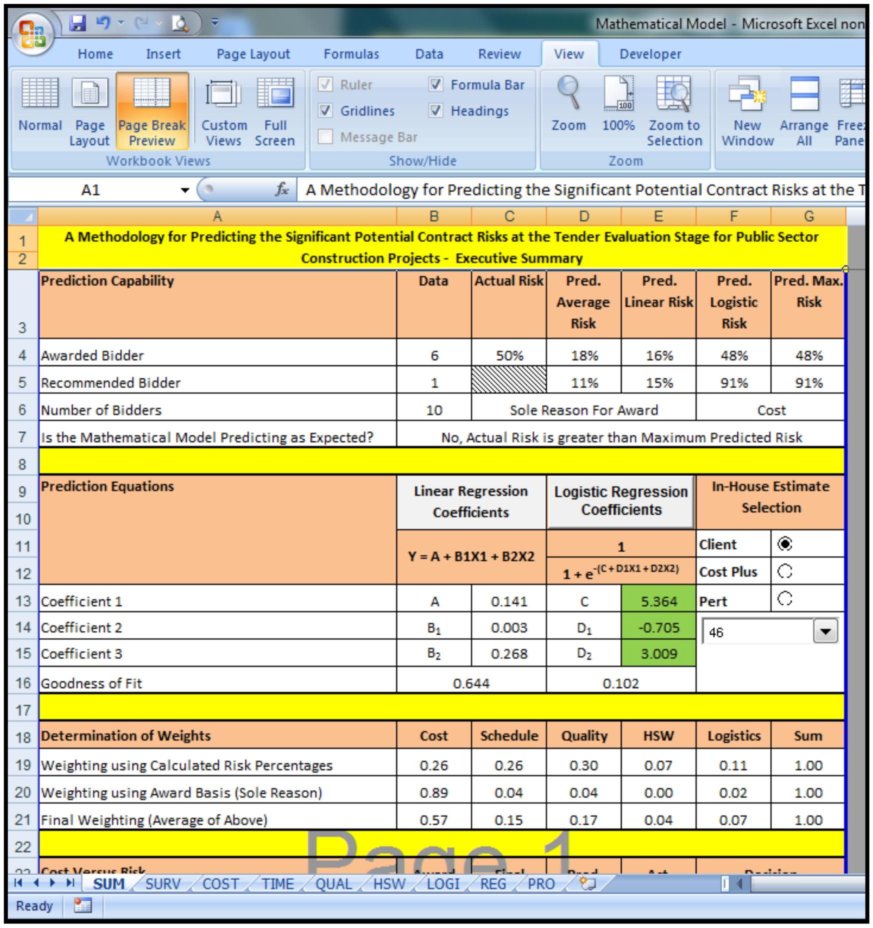


Figure 12 – Typical Output from Mathematical Model (Microsoft Excel)



A Methodology for Predicting the Significant Potential Contract Risks at the Tender Evaluation Stage for Public Sector Construction Projects - Executive Summary

Prediction Capability	Data	Actual Risk	Pred. Average Risk	Pred. Linear Risk	Pred. Logistic Risk	Pred. Max. Risk
Awarded Bidder	6	50%	18%	16%	48%	48%
Recommended Bidder	1		11%	15%	91%	91%
Number of Bidders	10	Sole Reason For Award			Cost	
Is the Mathematical Model Predicting as Expected?	No, Actual Risk is greater than Maximum Predicted Risk					

Prediction Equations	Linear Regression Coefficients		Logistic Regression Coefficients		In-House Estimate Selection	
	$Y = A + B1X1 + B2X2$		$\frac{1}{1+e^{-(C+D1X1+D2X2)}}$		Client	◉
					Cost Plus	○
Coefficient 1	A	0.141	C	5.364	Pert	○
Coefficient 2	B_1	0.003	D_1	-0.705	46	
Coefficient 3	B_2	0.268	D_2	3.009		
Goodness of Fit	0.644		0.102			

Determination of Weights	Cost	Schedule	Quality	HSW	Logistics	Sum
Weighting using Calculated Risk Percentages	0.26	0.26	0.30	0.07	0.11	1.00
Weighting using Award Basis (Sole Reason)	0.89	0.04	0.04	0.00	0.02	1.00
Final Weighting (Average of Above)	0.57	0.15	0.17	0.04	0.07	1.00

Cost Versus Risk

DISCUSSION

The overarching conclusion is that the mathematical model can predict the significant potential contract risks at the tender evaluation stage for construction projects at state energy companies in Trinidad and Tobago. However, this author recognizes that the 78% prediction capability of the model should be increased to an acceptable prediction capability of 95% for statistical significance to be achieved. To achieve this further research would be required in order to continuously retest and enhance the prediction capability of the mathematical model. The further research would also involve additional data collection in order to achieve the determined sample size.

The results also show that the data regresses linearly rather than logistically. The R2 value, which indicates goodness of fit in linear regression, is in 76% of the cases > 0.6, which points to an acceptable correlation of the data. However, the Cox and Snell's as well as the Nagelkerke, which indicates goodness of fit in logistic regression, is in 100% of the cases < 0.5, thus indicating a poor fit of the data. The implication is that the data regresses linearly rather than logistically thus leading to the conclusion that the overall risk is related to the individual risks linearly or proportionally, rather than exponentially.

The results also show the recommended weightings for future tender evaluations. The subject of weightings has been at the centre of much debate in modern procurement in Trinidad and Tobago. The acceptance of the tender based on price only has shown to yield both positive and negative results. In the analysis the cost is weighted at 59% while schedule; quality; health, safety and welfare and logistics are weighted at a combined 41%. It is interesting that the analysis revealed that schedule is weighted at 14%; quality at 11%; health, safety and welfare at 7% and logistics at 9%. The conclusion to be drawn is that cost, as expected, continues to dominate the weightings.

Other results show that in 83% of the cases the cost increased in order to lower the risk. Additionally, 65% of the data followed a normal distribution while 59% of the data demonstrated that the predicted risks fell within the 95% confidence intervals. One could conclude that the mathematical model confirms that in order to manage and lower risk the cost must be increased, hence leading to further research in the accurate determination of contingency at the tender evaluation stage. This researcher also recognizes that the mathematical model should be further refined in order to improve ability of the model to predict within 95% confidence intervals.

The research also proved to date that in 89% of the cases construction contracts were awarded solely based on cost. Lowest price has been the main factor in the award of construction contracts in Trinidad and Tobago. This researcher is of the view that based on the findings, that the other factors should be also considered in awarding contracts. The weightings analysis points to this conclusion where cost is weighted at 59% and all other factors at 41%. The research also proved that 98% of the respondents highlighted the need for further research in prediction of risk in tender evaluations. The research also proved that 98% of the respondents highlighted the need for a quick method of executing tender evaluations. This researcher has sought to address these foregoing deficiencies by producing a rapid rule of thumb for the prediction of risk. The linear regression equation is as follows:

Linear Regression Equation:
$Y = A + B_1X_1 + B_2X_2$

$Y = 0.178 + 0.267X_1 + 0.245X_2$ where:

a. Y is the Probability of Risk
b. X_1 is the Variation in Cost (Difference between In-House Estimate of Cost and Bid Price)
c. X_2 is the Variation in Duration (Difference between In-House Estimate of Time and Bid Duration)

In conclusion this researcher proposes the following steps to further refine the mathematical model and increase its predicting accuracy:

a. Sample more respondents in order to increase the number of data sets which would be routed through the mathematical model.
b. Compare the actual cost and actual duration to both the in-house estimate of cost and duration as well as to compare the same with the awarded bidder's cost and duration. Any emerging trends would be incorporated into the mathematical model.
c. Graph a tender reconciliation model showing the tender costs in relation to the in-house costs. Any emerging trends would be incorporated into the mathematical model.
d. Improve the content of the literature review by continuously researching mathematical methods of risk analysis for tender evaluations.
e. Retest and reprogram the mathematical model in order to increase its prediction capability.

ACKNOWLEDGEMENTS

The author of this paper would like to sincerely thank Professor Andrew K. Petersen of the University of Maine, Germany and

Professor Timothy M. Lewis of the University of the West Indies for their steadfast advice as supervisors of the author's research. Their valuable and specific guidance has greatly assisted the author not only with the research paper but also the overall research aim to determine a more efficient method of executing tender evaluations. The author would also like to thank his wife, Crystal Samuel and his daughter Caitlyn Courtney Samuel for the love, support, understanding and patience while the author was assembling this paper.

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