Establishing a link between contractor selection strategy and project outcomes: A simulation study

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ABSTRACT

Perceived benefits of the best value strategy and the problems the lowest price strategy has caused in the construction industry; has led to the increase in the use of the best value strategy in selecting contractors. Whilst there is research that have tried to establish a direct relationship between a contractor selection strategy and the project outcomes, there are hardly any empirical research that tries to establish this relationship. This paper presents a quantifiable method of assessing the risk of selecting different contractor selection strategies using educational facilities projects in the UK. A Monte-Carlo simulation study was conducted to assess how the lowest priced contractor would have fared against the best value contractor had it been awarded the contract instead. It was concluded that selecting the best value contractor in educational facilities projects is not necessary in terms of cost. Furthermore, though the results are limited to educational facilities project, the method can be adapted to other sectors.

INTRODUCTION

Selecting the most appropriate contractor plays a significant role in ensuring project success; in a tendering process, choosing the best tender is an important step. Holt et al. (1994) say that in the UK selecting the lowest bidder is the most prevalent way of selecting contractors. But

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construction projects are becoming more complex that there should be more criteria used in the selection process. (El-Abbasy et al., 2013). Nureize and Watada (2011) state that contractor selection is a critical decision that has a significant influence on the project's success, hence, decision makers should consider using multiple criteria to award a contract. For example, if the award criterion is best value or the Most Economically Advantageous Tender (MEAT), it will involve scoring the contractors' tenders on price and quality and ranking them; and there is no set way to do this as each organisation has their own unique way of carrying it out. According to AGC and NASFA (2008), the best value tender "*is a selection process for construction services where total construction cost, as well as, other non-cost factors are considered in the evaluation, selection, and final award of construction contracts.*" This definition clearly identifies the involvement of factors other than just the cost in best value method and differentiates it from an approach in which the lowest tender is selected. Furthermore, it shows that selecting on best value is more complex than just awarding to the lowest tender. Hence, why awarding to the lowest bidder is still widely used in the UK (Eke and Elgy, 2017). This indicates that in order to get more industry professionals to adopt the best value concept, more evidence must be shown on how it can affect a construction project. This is because overruns (cost and time) in construction projects in general have been prevalent; the Glenigan UK Industry Performance Report (2016) show that only 56% construction project met or bettered the cost figure agreed at the start of the construction phase in 2015. Furthermore, only 48% of construction projects in 2015 met or bettered the length of time agreed at the start of the construction phase. These overruns cannot be solely attributed to wrong contractor selection, as there are other reasons why projects overrun that has little to nothing to do with the contractor i.e. design changes and force majeure. However, previous evidence suggests a strong link between the two (Assaf and Al-Heijji, 2006; Mulla and Waghmare, 2015; Olaniran, 2015).

Selecting contractors on best value is often advocated as the best solution to the problem. However, there is little research on how selecting the best value contractor affects project outcomes; specifically, the total cost and time of a project. In El-Abassy et al (2013) paper that developed a model to help clients select the best value tender, the authors recommended a further study: *'if the developed model determined the best contractor for a project whose submitted price is not the lowest price, then an analysis should be done to show what-if scenarios for the contractor with the lowest price if he/she is awarded the contract instead. The analysis can include the response to claims for this contractor, the rework that may occur during the project because of inadequate past experience, for example, or any other weak points for the contractor with the lowest price that may result in an extra cost beyond the original price. These extra costs might include (1) rework because of bad quality, (2) delays because of incompetence, (3) short* *life cycle because of bad quality material, (4) operation and maintenance problems because of inadequate experience, and (5) many claims because of bad management.'*

This paper seeks to introduce a model that can establish the above relationship; how the lowest tenderer would have performed against the best value contractor. However, from the recommendation we see that the authors have already leapt to the conclusion that selecting the lowest tenderer will result to poor quality, incompetency etc. Though there is a chance that this might be the case, it is not always so. Yu and Wang (2012) state that the market should dictate what strategy to go for; meaning that there are times when it is best to opt for the lowest tender strategy, and times when to choose the best value tender. However, up to date there has been no quantitative assessment of the frequency distribution of the final outcome cost and duration of either selection strategy. The client may want to know not just the expected outcome cost of a particular strategy but also what would be the probability of a strategy leading to an extremely high final cost. Such a frequency distribution can point out whether there is a chance that one selection criteria would give the lowest cost on average but could, on occasions, give to outcome costs so high that far exceeds the budget. The proposed model seeks to presents the likely outcomes (in terms of final cost and duration) to expect by selecting either the best value or the lowest tenderer.

Therefore, the aim of this research is to provide a quantifiable method of assessing the risk of selecting either the best value contractor or the lowest tenderer. The primary objective of the study is to establish how the lowest tenderer would have fared if it was awarded the contract instead of the best value contractor (when the best value contractor is no the lowest tenderer).

The rest of the paper is organised as follows. First, a literature review briefly touched on performance indicators in construction projects in the UK. This established cost and time as key performance indicators. Furthermore, as the research seeks to examine the relationship between a contractor selection strategy and project outcomes, it was important to establish that there are other reasons why a project might fail that had little to do with the contractor selection strategy. The research methodology, data collection, model development and implementation explain the whole model and its structure.
Finally, the conclusions are drawn and implications are identified (or recommendations are made).

LITERATURE REVIEW

There are different parameters that are used to determine the performance of construction projects. However, according to Angus et al. (2005) construction projects have traditionally measured project performance success by cost, time, and quality.

- **Cost**: Total cost of project not the initial bid price.
- **Time**: The actual duration of the project
- **Quality**: Reliability of the contractor/project? Client satisfaction?

The UK Glenigan Report (2016) indicate, just as Angus et al. (2005) stated, cost, time, and quality are traditionally the measuring tool of project success. While cost and time can be easily measured, quality is much more difficult to gauge; this is due to the fact that at times the quality of a project can only be known long after a project has been completed. The process of costing quality may be challenging, the concept was first introduced in 1951 by Juran; this concept is called the 'cost of quality' (COQ hereafter). COQ is the 'price for non-conformance.' (Crosby, 1979). It is the cost incurred because of not delivering the product or service right in the first place; in other words, the overrun cost. While this method of quantifying quality is straightforward and clear, is this universal? The overrun cost, however, was factored into the model. Furthermore, quality is a subjective term that is likely to differ from client to client, hence, the parameters set for this research is cost and time.

Wrong contractor selection strategy leads to all sorts of problems: disputes, lengthy dispute resolution, project or contractor termination, low quality products and defects. However, cost and time overruns are the most prominent problem in the construction industry. The construction industry sees many sorts of projects from housing, infrastructure, industrial, and commercial; whether it is to build, refurbish, or maintain. Some of these projects are simple, while others are more complicated; some are small, others are large, and some are scheduled to be completed under a year, while others may go on for multiple years. Basically, no matter the size of the project, they all have a chance of overrunning on their budget and estimates due to risk and uncertainty associated with executing a construction project. Sadly, construction projects make the headlines for the wrong reasons; mostly because of overrunning their budget and time estimates.

According to Flyvbjerg (2008) and Love et al. (2012) main reasons for cost overruns are optimism bias and strategic misrepresentation. Optimism bias is a psychological explanation for overruns which is to do with people being overly positive in making predictions about the outcomes of future planned actions (Siemiatycki, 2010). In the context of construction projects; this is the same as underestimating the time and cost of delivering a project. While strategic misrepresentation refers to people knowingly underestimating the time and cost needed to deliver a project in order to win the contract (Flyvbjerg, 2008). Therefore, is it impossible to imagine an optimism bias client that wants to effectively complete its dream project at the lowest cost possible, falling for a contractor who has excessively underestimated costs in order to win the project? This is still the case.

Contractors can be selected based on price only (lowest tenderer), or on a combination of price and quality; the latter is called best value or most economically advantageous tender (MEAT) (Bergman and Lundberg, 2013). For the best value strategy, clients will have to weigh each quality dimension to come to a final overall score, how much to weigh quality against price, and which formula to use to combine the quality score and the price into one overall score, so that the tenders can be ranked (Mateus et al., 2010). The literature is filled with developed models to help clients select the best value contractor such as simulation, simple weighting, Analytical network process (ANP), Analytical Hierarchy Process (AHP), simulation and multi-utility theory are some examples of the tools. In 2009, Lo and Yan developed simulation models to analyse contractors' pricing behaviour and dynamic competition process under the qualification-based system. This model makes it possible to identify unrealistic tenders. El Asmar et al. (2009) also used simulation to assess contractors by to quantifying and combining criteria into a single score for each contractor.

A mistake to this type of research is assuming that it could be used to assess contractors in all types of projects. Construction projects are complex and dynamic and it needs usually differ; therefore, models should be able to take this into consideration (Eke et al., 2017). There are methods however that existed which are being used as contractor selection approaches to account for the specific needs of projects. One is the AHP, this is a popular technique used for ranking and prioritising criteria used in selecting contractor; it is able to analyse multi-criteria problems according to pairwise comparison scale (Eke et al., 2017). Fong and Choi (2000) say that the technique can

identify contractors with the best skill to reach satisfactory project outcomes in a contractor selection process which is not based simply on awarding to the lowest tender.
AHP can also be combined with other tools to assist decision makers such as fuzzy logic and ANP. The ANP for example, can be considered as an extension of AHP; as Cheng and Li (2004) points out that it allows for interdependencies between criteria in selecting contractors. Another concept of best value modelling that was specific to project needs is the one introduced by Abdelrahman et al. (2008). This is the combination of the AHP and the weighted average method to quantify the qualitative effect of subjective factors in selecting the contractor. Though the study was relatively easy to understand and implement, there is a high level of subjectivity to the weights given to the criteria as this was at the researchers' discretion. Furthermore, there is also no real evidence that using these criteria to evaluate and select the contractors will result in project outcomes success. The main purpose of their study however, was to assist in selecting the best value contractor not whether the best value contractor will be successful or not (Eke et al., 2017).

Therefore, the models that were examined in the literature will aid clients in selecting the best value tender. The model in this paper helps clients see the effect these strategies: whether lowest priced or best value, have on project outcomes: final cost and duration.

RESEARCH METHODOLOGY

This research involved using Monte Carlo simulation and frequency distribution to model the effect of a contractor selection strategy on the outcome of a construction project; with the outcome being cost and time. The paper starts by performing a brief literature review of the different developed models used to aid clients select the best value contractor. The model introduced in this paper will see the effects of this strategy on the project outcome.

Monte Carlo simulation is not a new technique. Peleskei et al. (2015) say that German authors Girmscheid and Busch (2007) recommend the Monte Carlo simulation tool for quantifying risk. In using the Monte Carlo simulation tool each risk has a minimum, maximum, and the most reliable outcome (Panthi et al., 2009). Below are some examples of this approach in construction:

- Wall (1996) collected 216 office building from the Building Cost Information Service (BCIS) database of the Royal Institution of Chartered Surveyors (RICS) to outline the issues that should be recognised when using Monte Carlo methods. The study concluded that lognormal distributions are superior to beta distributions in representing a data set. Furthermore, the result of this study show that the effect of excluding correlations is more profound than the effect of choosing between lognormal and beta distribution to represent a data set.

- Panthi et al., (2009) study combined Monte Carlo with Analytical Hierarchy Process (AHP) to combine the risk distributions of various Bill of quantities items in hydropower construction projects. This resulted in a risk adjusted cost from which the contingency was determined.
- Wang et al., (2010) applied the Monte Carlo simulation method to life cycle cost analysis with the help of @RISK software on Private Finance Initiative (PFI) to estimate total cost. The study found that the traditional model underestimated total costs by 6%.
- Peleskei et al., (2015) study reaffirmed that Monte Carlo simulation can be a helpful tool for risk managers and can be used for cost estimation in construction projects. The study also found that cost distributions are positively skewed and cost elements seem to have some interdependent relationships.

There are other alternatives to Monte Carlo simulation that help clients form project estimates. There are the traditional methods which involves using Bill of quantities, superficial method, and functional unit method to form estimates. Then there are the mathematical models such as regression analysis that can be used to predict cost. There is also the Artificial Neural Network (ANN) to predict the final cost of a project.

However, none of this prediction is guaranteed to be true, hence the reason why there is a Mean Absolute Percentage Error (MAPE) to gauge how effective these models are. A MAPE of below 10% signifies a good model. However, the effect of that 10% or less is unknown. Therefore, the aim of the model is not to predict the final outcome, rather to produce frequency distributions of the likely outcomes given a selection strategy, in this case the lowest priced strategy. Monte Carlo simulation technique is the appropriate tool for this as the method explores all the possible outcomes to a scenario under certain bounds of variability expressed in the model, in which the outcome is determined by the likelihood of the minimum and maximum values occurring for each scenario (Wang et al., 2012). This in turn, will help decision-makers in making better decisions in regards to the strategy they choose to adopt. Furthermore, previous studies where Monte Carlo simulation was utilised in similar research is strong evidence that the method is the appropriate tool for this research.

DATA COLLECTION

The dataset used to develop the model was from the BCIS database. In this database, data from 120 UK educational facilities projects were extracted to develop the model; all of which selected the lowest tender. There is the increasing use of selective tendering generally; most of the projects collected from the BCIS database for this model used selective tendering, as well as the projects used to validate the model. Selective tendering involves having a preferred list of contractors and usually select the one that offers the lowest price when a project comes up. In the process of searching for real project cases from industry players to validate the model, the best value strategy was hardly used. In most cases when it was used, the lowest tendered contractor turned out to be the best value contractor. Therefore, this research was important to this sector as a way of either validating common practice or as a nudge to reconsider strategies. Data processing techniques were then utilised to clean the data derived from projects.
Model Development Procedure is depicted in Figure 1. The BCIS database is the leading provider of cost and price information to the construction industry. The BCIS database is considered a traditional method of estimating costs; and it is used by clients, contractors, and consultants. Their historic data goes back 50 years. Furthermore, it has also been used to conduct research; *"Wall (1997) collected 216 office building from the BCIS database of RICS to outline the issues that should be recognised when using Monte Carlo methods."*

Each project showed:

- Tender bids received from all the contractors that bided for the project (contractors were anonymous).

- The initial bid price of the lowest tenderer (which was the selection criteria used).

- The client's expected duration.

- Final project outcomes: Final Cost, and Actual Duration.

At least form the reasons given, all 120 projects where cases where the contractor select had a direct effect on the project outcomes. Reasons such as design changes that affected the final cost and duration of the projects were not used for this study; the BCIS database states the reasons for overruns. The study was to see whether awarding the project to the lowest tender will result in a higher outcome cost, and duration than awarding to the best value tender.

From the dataset of 120 project cases, correlations were derived between: the initial tender price amount (TP), the difference between the final cost of the project and the tender accepted price (Overrun Cost), and the difference between the actual duration of the project and the expected duration of the project (Delay) using Excel (see Table 1 for correlation):

Table 1 shows the correlation between the Tender Price (TP), the Overrun Cost and Delay of all 120 projects that selected the lowest tenderer. The correlation between TP and Overrun Cost is 0.57 which normally means that the higher the tender price the higher the overrun cost. However, in this case the model considers the tender price of the lowest tenderer. Therefore, the positive correlation is interpreted as larger projects would incur larger overruns. The correlation between TP and Delay is -0.022; a negative correlation here signifies that the higher the TP the lower the Delay. However, the correlation is closer to zero, meaning that there is little to no relationship between the two variables. This is also the case with the correlation between Overrun Cost and Delay (0.021); although this is positive there is little to no relationship between the two variables. The correlations derived from this dataset was then inputted into the model to produce frequency distributions of likely outcomes of the lowest tenderer in educational facilities projects.

MODEL DEVELOPMENT AND IMPLEMENTATION

The final outcome of any construction project consists of a number of components: The final outcome price, the quality of the finished product, any overrun on the project duration etc. All these are linked to the original tender price, the quality and reputation of the contractor and a number of random factors that can only be described in probabilistic terms such as bad weather, unforeseen ground conditions etc. Each of these components has a probability distribution associated with it and crucially correlated to the other components. Remember that quality was excluded as a parameter for this research. However, for example it is expected that a high overrun cost is correlated with unduly low tender price. This is not to say that every low initial tender price incurs a higher cost and delay time, merely that it may be a tendency. The strength of the tendency is measured by the correlation between low tenders and the difference between the final cost of the project and the tender price (Overrun Cost). In simple terms this can be expressed as the correlation coefficient, ρ (Eke and Elgy, 2017). In order to generate a set of correlated random numbers a simple equation will be used

$$x = A\eta \quad (1)$$

Where x is a vector of n correlated random numbers of mean zero and unit standard deviation, which will be rescaled later to produce quality, overrun, tender price later. **A** is an **n*n** matrix of coefficients and **η** a vector of **n** independent random numbers to some distribution with zero mean and standard deviation of one (Eke and Elgy, 2017).

$$\begin{bmatrix} \mathbf{x_1} \\ \mathbf{x_2} \\ \mathbf{x_3} \\ \cdots \\ \mathbf{x_n} \end{bmatrix} = \begin{bmatrix} \mathbf{a_{1,1}} & \mathbf{a_{1,2}} & \mathbf{a_{1,3}} & \cdots & \mathbf{a_{1,n}} \\ \mathbf{a_{2,1}} & \mathbf{a_{2,2}} & \mathbf{a_{2,3}} & \cdots & \mathbf{a_{2,n}} \\ \mathbf{a_{3,1}} & \mathbf{a_{3,2}} & \mathbf{a_{3,3}} & \cdots & \mathbf{a_{3,n}} \\ \cdots & \cdots & \cdots & \cdots & \mathbf{a_{1,1}} \\ \mathbf{a_{n,1}} & \mathbf{a_{n,2}} & \mathbf{a_{n,3}} & \cdots & \mathbf{a_{n,n}} \end{bmatrix} \begin{bmatrix} \boldsymbol{\eta_1} \\ \boldsymbol{\eta_2} \\ \boldsymbol{\eta_3} \\ \cdots \\ \boldsymbol{\eta_n} \end{bmatrix}$$

Matalas (1967) proposed a method of evaluating ***A***.
Post multiply both sides of equation 1 by ***xt*** gives

$$\boldsymbol{xxt = A\eta(A\eta)t}$$
$$\boldsymbol{xxt = A\eta\eta tAt} \quad \boldsymbol{(2)}$$

If we take the expected values of these then the expected value of ***xxt E(xxt)*** is the correlation matrix between all of the values, ***M***

$$\mathbf{M} = \begin{bmatrix} \mathbf{1} & \boldsymbol{\rho_{1,2}} & \cdots & \boldsymbol{\rho_{1,n}} \\ \boldsymbol{\rho_{2,1}} & \mathbf{1} & \cdots & \boldsymbol{\rho_{2,n}} \\ \cdots & \cdots & \cdots & \cdots \\ \boldsymbol{\rho_{n,1}} & \boldsymbol{\rho_{n,2}} & \cdots & \mathbf{1} \end{bmatrix}$$

Since the η values are independent of one another their expected cross correlations are zero with the diagonal elements the variances of the elements, 1. This is the identity matrix I. Any matrix pre or post multiplied by the identity matrix is unaltered therefore the expected values give.

$$\boldsymbol{M = AAt} \qquad \boldsymbol{(3)}$$

Any matrix multiplied by its own transpose will give a symmetrical matrix and the correlation matrix is bound to be symmetrical. This means that there is effectively only ***n (n + 1) /2*** independent variables in ***A***. There are numerous ways to evaluate these independent variables, for example by assuming $\boldsymbol{A}$ is upper triangular or using the eigenvectors and eigenvalues of $\boldsymbol{M}$. Since Matlab has a function to do this, this will be the function used.

It should be noted that if a negative eigenvalue is present in $\boldsymbol{M}$ the matrix $\boldsymbol{A}$ will not be entirely real but have an imaginary component. This is possible if there are inconsistent correlations in the matrix $\boldsymbol{M}$. This happened with surprising frequency when pair wise instead of case wise correlations was used to evaluate the correlations. The higher $\boldsymbol{n}$ the more likely this inconsistency is likely to occur. The estimation of correlation coefficient between the components of the construction projects proved tricky to estimate and some "tweaking" was required to ensure they were consistent (Eke and Elgy, 2017).

Though no frequency distributions were assumed for $\boldsymbol{x}$ or $\boldsymbol{\eta}$, Quenouille (1957) showed that the estimates were maximum likelihood estimates when $\boldsymbol{x}$ and $\boldsymbol{\eta}$ were normally distributed. However, it is possible to determine the distributions of $\boldsymbol{x}$ and $\boldsymbol{\eta}$ by fitting the model to the observed data and examining the resultant distributions. Due to the small number of samples common distributions such as normal and lognormal (additive and multiplicative errors respect) make sensible choices with the parameters estimated from the sample data (Eke and Elgy, 2017).

The correlation from Table 1 are then used to generate random numbers that are inputted into the model. This will generate frequency distribution of all the tender bid price accepted (instructed to always be the lowest tender), the overrun costs, and delay time. These distributions are then used to calculate the frequency distributions of the project outcomes: Final Cost and Actual Durations.

Final Cost = Tender Price + Overrun Cost (4)

Actual Duration = Client's expected duration + Delay   (5)

The aim of the study was to show how the lowest tender would have fared on a project that has already been awarded to the best value tender. So, the model is tested on three real educational facilities projects to see whether it was able to predict the frequency distribution of all the possible outcomes. If the actual project outcome is within the frequency distribution of outcomes predicted by the model, this validates the model. Table 2 shows the initial bid price amount of the 3 projects awarded to the cheapest. It shows the submitted price of each contractor and the clients' expected duration (ED). While Figure 2, summarises the quantifiable model (dotted line here shows the next stage of the model).

RESULTS

Again, the research aims to show how the lowest tenderer would fare in a contract awarded on best value whose price is not the lowest price. Therefore, the model had to first be tested and validated with projects that awarded to the lowest tenderer. Figures 3 and 4 of the frequency distributions of cost and time for the lowest tenderer in Project 1, shows that the model was able to capture the range of outcomes of lowest tender selected contracts. Therefore, the model could now be tested on best value tender selected projects whose price is not the lowest price. In this case, the actual outcomes that are displayed on the Figures are the actual outcomes achieved by the best value contractor. In Table 3, Project 4 and 5 selected Contractor C, while Project 6 selected Contractor B.

DISCUSSION

The best value contractor delivered the project on time (89 days) despite overrunning in cost by almost £30,000. Furthermore, the maximum final cost the lowest tendered would have incurred if it had been awarded the project is just £620 over the actual cost of the project, though the risk of it happening was miniscule. This would possibly suggest a scope was added to the project, a design change, or an unforeseen situation developed that affected the cost of the project. Apart from that, the result showed that the lowest tenderer would likely complete the project at a lesser cost to the best value contractor; despite incurring cost overrun. The results for Project 6 show that minimum cost expected for the lowest tenderer is £288,980, while the maximum is £343,820. The average cost expected for the lowest tenderer in Project 6 is £317,660. The chance of the minimum or maximum cost occurring for Project 6 was low however, it notifies clients that it still possible; especially with the maximum expected cost.

In the case with Project 4 and 5, we see that even though the lowest tenderer is likely to overrun in terms of cost, their final costs fell below the price the client would pay to the best value tenderer whose price is not the lowest price. Project 4's maximum expected final cost for the lowest tenderer is £4,328,600 with an average final cost of £4,309,000. This is below the price that the client would initially pay to the best value tenderer. Also, in Project 5 the lowest tenderers maximum expected final cost is £2,120,100 with an average final cost of £2,123,918. Again, this is below the £2,123,918, the client would initially pay to the best value tenderer. Therefore, when comparing the lowest tenderers' cost overrun to the best value tenderer, we find that it is not as bad as it seems.

At the beginning of this paper it was mentioned how only 56% of projects met or came under budgets that were agreed at the start of the construction phase. On face value, this is not pleasant. However, what if an analysis showed that of the 44% of projects that overran, majority of them still came under the cost that a client would have initially paid to the next highest tender? This improves the narrative.

Having said that, the notion of selecting the best value contractor does not depend solely on cost. Projects needs differ, clients' needs differ too; therefore, criteria for best value will differ too. A client's best value expectation may be to deliver a project on time. Going by that expectation, the results show that there is a higher chance of the lowest tenderer exceeding client's expected duration, even though the deliver at a lesser cost than the best value contractor. This is supported by Assaf and Al-Hejji (2006) and Olaniran (2015) study that found that the most frequent nature of performance problems caused by awarding to the lowest tender is project delay. The results of this simulation experiment, show that there is a risk that the lowest tenderer would exceed clients' expected duration time, therefore, how risk averse is the client? i.e. 'Would the client be willing to risk exceeding agreed duration time for a lower cost?' These are the kind of trade-offs clients would have to consider when making these decisions. Yu and Wang (2012) study which states that clients should use the market to dictate what strategy to select. In the educational facilities sector, the results show that it is okay to select the lowest tenderer as they can deliver projects in terms of final costs. This may be due to the fact that in educational facilities projects, requirements are usually familiar, and building parameters are not very complex. However, the strength of this study is also in its ability to show when projects may not turn out as planned; regardless of how slight the chances are. Therefore, the research objective of providing a quantifiable method that would assess how the lowest tenderer would have likely fared was achieved.

SENSITIVITY ANALYSIS

The correlations inputted into this simulation model is an important aspect of the experiment. Therefore, it is important to determine how sensitive the correlations are to results. Using Project 1, a sensitivity analysis was conducted to observe the number of times the lowest priced tender is the best overall tender if the correlations between TP and Overrun Cost in Table 1 altered. For the lowest tenderer to be considered the best overall tender in this case it means that its final cost has to be below that of the next highest bidder. Figure 11 shows that there is a high chance that the lowest tenderer would still the best tender in terms of cost. This is because the standard deviation of Project 1's tender prices was over a £100,000 and the maximum the lowest tender can overrun by is £30,000; which means regardless of a change in correlation the lowest bid will most likely be the best overall bid in terms of cost. Figure 12 showed however, that if you reduce the standard deviation of the tender price; basically, by just disregarding the highest bid in Project 1 and re-run the model, the probability of the lowest tenderer being the best tender reduces.

•The X-axis is the correlations that ranges from -0.8 to 0.8 (removing the extremities of -+1), with a step of 0.05; this is then given a range from 0 to 35.
•The Y-axis is the standard deviation of Diff that ranges from £1000 to £30,000; this is then given a range from 0 to 30.
•The Z-axis counts the number of times that the lowest tenderer did turn out as the best overall tender; in other words, if the amount of time that the lowest tender's final cost, turns out to still be lower than the next highest bid.
•The model was given 5000 realisations.

The results showed that given the range of Overrun Cost, when it is a highly negative correlation there is at least a 90% chance that the lowest tenderer is the best tender with a standard deviation of £100,000. However, when it is £30,000 it is as low as 20%. The likelihood of the lowest tenderer being the best tender increases as the correlation becomes more positive, given the range of Overrun Cost. The standard deviation and correlations were both altered to show the surface of the curve; as it would have been impossible to derive these results by just altering the correlations. Project 1's model results showed that there is a high chance of the lowest tenderer turning out to be the best tender in terms of outcome cost. The sensitivity analysis results support Project 1's model results.

LIMITATION

1. **More detailed best value tender selected projects.**

The developed model would have benefited greatly from knowing the contractors' quality scores in these projects. The model can incorporate quality when the quality criteria, weights to the criteria, price to weight ratio, and contractors' quality scores are known. However, the model would have also benefitted more from knowing the quantitative implications the quality scores have on project outcomes. Indeed, the parameters for outcome in this research is limited to: Final Cost and Duration. There is difficulty in quantifying quality (non-price criteria), clients would have their own way of doing so. The model could be further improved by partnering with a client to develop the model that can also incorporate a quantified quality to its parameters. Furthermore, the developed model could have also benefited had it been tailored to a company's needs. The dataset used to develop the model is from the BCIS, however the results of the model may not be applicable to every company. The results would be useful to companies that work in the Educational facility sector. However, the blueprint given can be mirrored to any company that is looking to conduct this analysis.

2. **Limited to Educational Facilities sector.**

The model is sector specific. The model was focused on Educational facilities projects, therefore applying a model that has been based on Educational facilities project to any other sector may produce misleading results. However, using the same blueprint in collecting dataset of past projects in a different sector e.g. Industrial sector, would produce a model that is specific to the sector. Undertaking this research in multiple sectors using the same procedure would also be a good way of comparing different sectors, to know the strategy that is best suited to a particular sector.

3. **Too reliant on data?**

When awarding a contract, the real world only awards one contract to the winner. So, for example if one had a contract to build a new basketball court, we cannot build two identical basketball court; with one using the lowest tenderer and the other using the best value tenderer whose price is not the lowest price. And simultaneously build multiple basketball courts to get an overall probability distributions of project outcomes. Therefore, it is not possible to truly verify the models developed. The only way to continually verify the model is if there is a healthy dataset of projects that have used the two strategies. The model is heavily reliant on data.

RECOMMENDATION

1. **Modelling Quality.**

The research accounted for final cost and time, but not quality due to the fact the quality/reliability scores of the contractor were not given. Assuming there were the quality scores of the contractors selected in the projects collected, this would have been incorporated into the model by creating a fourth input. At the moment, there are three (TP, Overrun Cost, and Delay). With the quality score of the contractor first, the correlation between the TP, Overrun Cost, Delay, and Quality would have been found and inputted into the model to produce the likely final costs, duration, and quality of the project.

Furthermore, the more quality criteria that is available to model, the better the results. Assuming a client always selected contractors based on price, approach, health and safety, experience, resources, and programme, we now have eight inputs instead of just four. By analysing, the client's dataset and the weights applied to each criterion, the model will be able to explore the relationship these criteria have on final cost and duration of the project. Furthermore, this would also be able to measure the client's risk aversion; by examining the weights the client applies to each criterion. For example, if Price to Quality ratio is 30:70 i.e. Price is weighted 30% and Quality are weighted as:

- Approach 10%: A qualitative assessment of the intended approach and it's feasibility
- Health and Safety 10%: A qualitative assessment based upon interaction with company and H&S criteria.
- Experience 30%: A qualitative assessment based upon demonstrated experience.
- Resources 10%: A qualitative assessment of company and supply chain fortitude.
- Programme 10%: A qualitative assessment based upon the deliverability and speed of the programme

This says that the client values accepting the lowest tender, perhaps at the risk of speed (with Programme weighted 10%). The model would also be able to show how the contractors' ranking is affected with different weights placed on the criteria. It has been noted that selecting on the lowest tender is relatively straightforward, best value on the other hand can be selected in different ways. Particularly, in ways that weights tender price to quality when analysing tenders: 60:40, 50:50 etc. The model indeed has the capability of incorporating the different selection criteria and subsequently analysing the effect it has on project outcomes. The notion is that each client will have a different method on selecting contractors on best value, therefore understanding the client's requirement, will demonstrate the client's risk aversion and is crucial to the model achieving the results needed.

CONCLUSION

From 120 educational facilities projects in the UK, correlations were derived and inputted into a model that was tested on three actual projects in the educational facilities sector that used the cheapest bid strategy. The initial test was to see whether the actual outcomes of these three projects would fall within the frequency distribution of project outcomes that the model predicted. Then, the same model was then tested on three real educational facilities projects in the UK that selected the best value tender whose price was not the cheapest. The results showed that though it is likely that the lowest tenderer would deliver at a lesser cost than the best value tenderer, it will likely overrun in terms of cost and time; although the cost would likely be cheaper than that of the best value tenderer. Therefore, it boils down to how risk averse the client is in taking the chance, and what best value is to him/her. The findings are supported by Assaf and Al-Hejji (2006) and

Olaniran (2015) study that found that the most frequent nature of performance problems caused by awarding to the lowest tenderer is project delay. Furthermore, the model results show that the there are situations where the market shows that selecting the best value tender is not necessary. This supports Yu and Wang (2012) study which states that clients should use the market to dictate what strategy to select. In the educational facilities sector, the results show that it is okay to select the lowest tenderer as they can deliver projects in terms of final costs. This is because even though the lowest tenderer may overrun, the cost is usually less than what the client would have paid the best value tenderer whose price is not the lowest price. However, on the other hand the lowest tenderer would take longer to deliver the project. So, if a client is looking to execute the project on a strict deadline, use the best value strategy.

There are limitations to the data used to formulate the simulation model. The plan was to collect a number of past similar projects that have all selected the lowest priced tender. This would enable the model predict how the lowest tenderer would usually fare in similar projects. This was achieved. The next stage was then to test the model on similar projects that have all selected the lowest priced tender and see whether the actual project outcomes were within the frequency distribution of project outcomes predicted by the model. This has also been achieved.

Finally, the next stage was to then test the model on projects that used the best value strategy of which the selected contractor did not have the lowest price to see how the lowest priced contractor would fare instead. This was achieved however, the contractor scores of these projects were not provided. Therefore, the assumption is that each contractor that tendered is capable of delivering the project. This is often not the case, therefore it is important to state that aim of the study was to assist in evaluating contractors, not as the tool to evaluate contractors. The model does not consider the contractor's quality score; therefore, this requires further study in order to know how the contractor's quality score affects outcomes. There are also cases whereby the best value tender would be the lowest tender, but, the study only looked at projects where the best value tender was not the lowest tender.

Results of this simulation study are limited to the educational facilities sector. The study should however, be reciprocated in other sectors; with individual clients, to see how the lowest and best value tenderers fare. Also, there may be a level of bias that comes with using the BCIS database. There is a high chance that companies would only report projects which went well; therefore, it is important to thread with caution. The main aim of the paper was to provide a quantifiable method of assessing the risk of choosing different contractor selection strategy: lowest price tender or best value tender. The first part of this aim was achieved, as the paper provided a quantifiable method of assessing how the lowest priced tender would fare in projects that was awarded to the best value tender whose price is not the lowest price. However due to a lack of a healthy dataset of past projects that have selected the best value tender in this sector, the model was unable to capture how the best value tender would likely fare in projects. Moving forward, a parallel modelling of the two strategies would provide a better comparison for clients to work with. The model can be customised and used by companies based on their own projects, or further tested using extended databases. The novel quantifiable method provides an empirical research that links the contractor selection strategy to project outcomes.

DATA AVAILABILITY

Data generated or analyzed during the study are available from the corresponding author by request.

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Table 1. Correlation between TP, Overrun Cost, and Delay

	TP	Overrun Cost	Delay
TP	1	0.570946	-0.02224
Overrun Cost	0.570946	1	0.021491
Delay	-0.02224	0.021491	1

Table 2. Lowest Tender Selected Projects

	A	B	C	D	E	F	ED
1	£737,586	£791,162	£793,524	£805,139	£831,777	£1,069,635	134
2	£1,802,892	£1,835,219	£1,894,698	£1,918,792	£1,942,107		225
3	£607,107	£610,510	£611,573	£620,263	£622,677	£649,873	225

Table 3. Best Value Tender Selected Projects

	A	B	C	D	E	F	ED
4	£4,299,664	£4,343,931	£4,371,596	£4,447,081	£4,724,370	£5,017,168	292
5	£2,096,388	£2,108,776	£2,123,918	£2,206,340	£2,278,743		134
6	£261,778	£313,826	£328,959	£376,187			89

Figure 1. Model Development Procedures

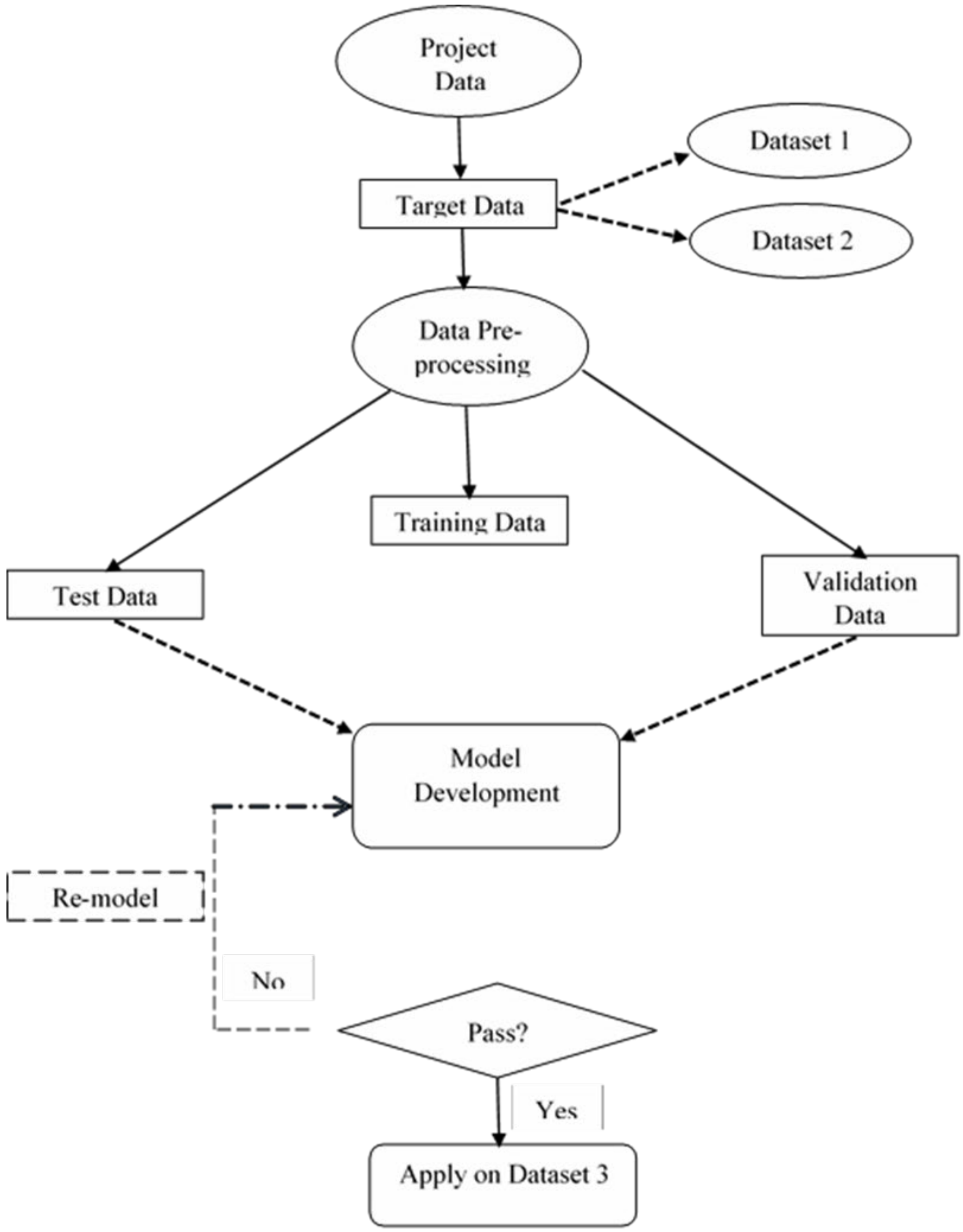

Figure 2: Summary of Developed Model

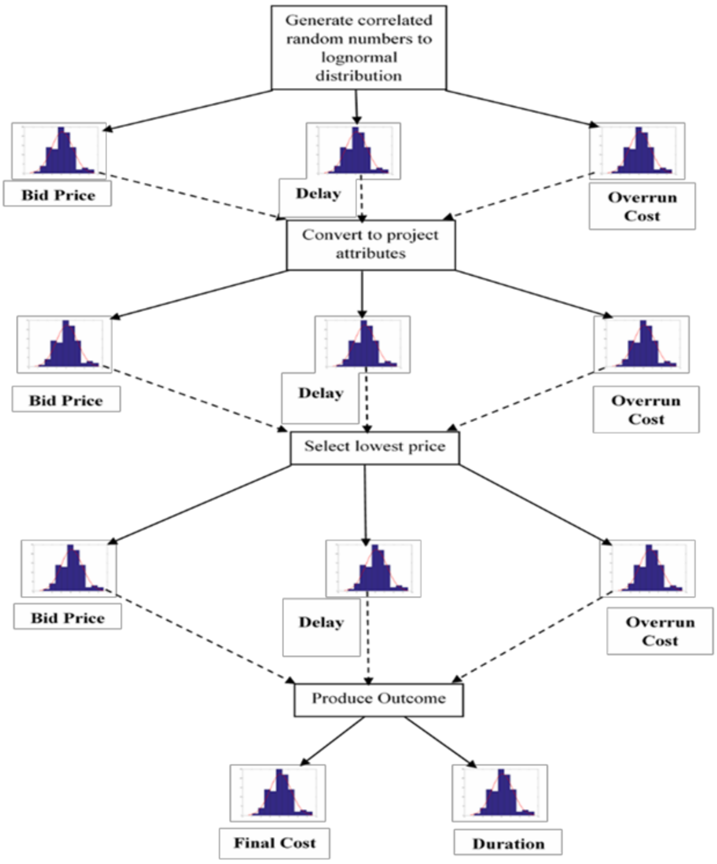

Figure 3. Project 1 Likely Final Cost

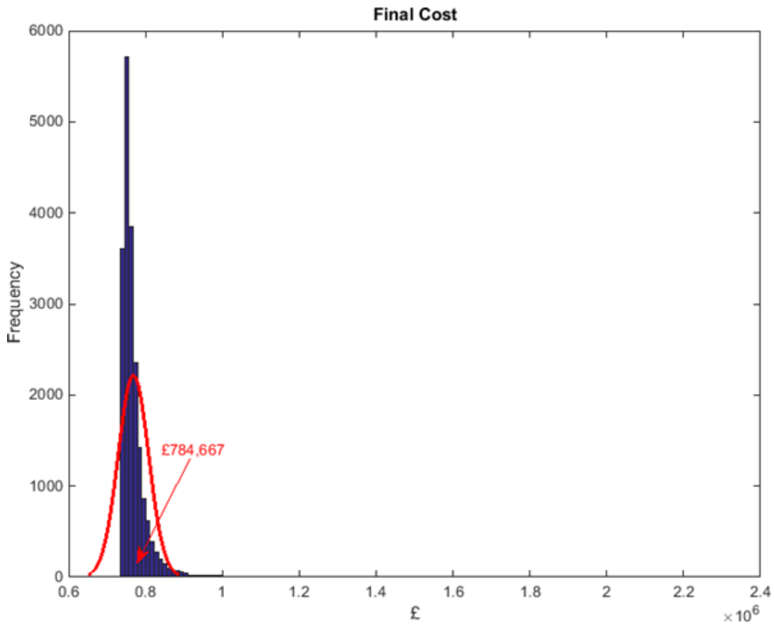

Figure 4. Project 1 Likely Actual Duration

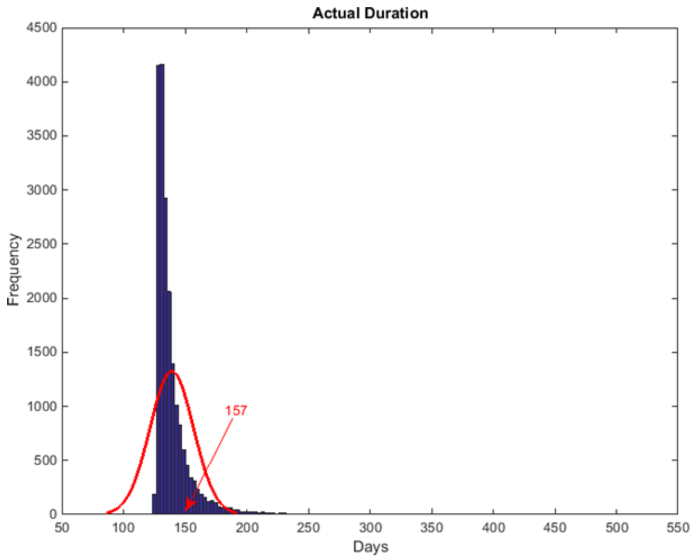

Figure 5. Project 4 Likely Final Cost

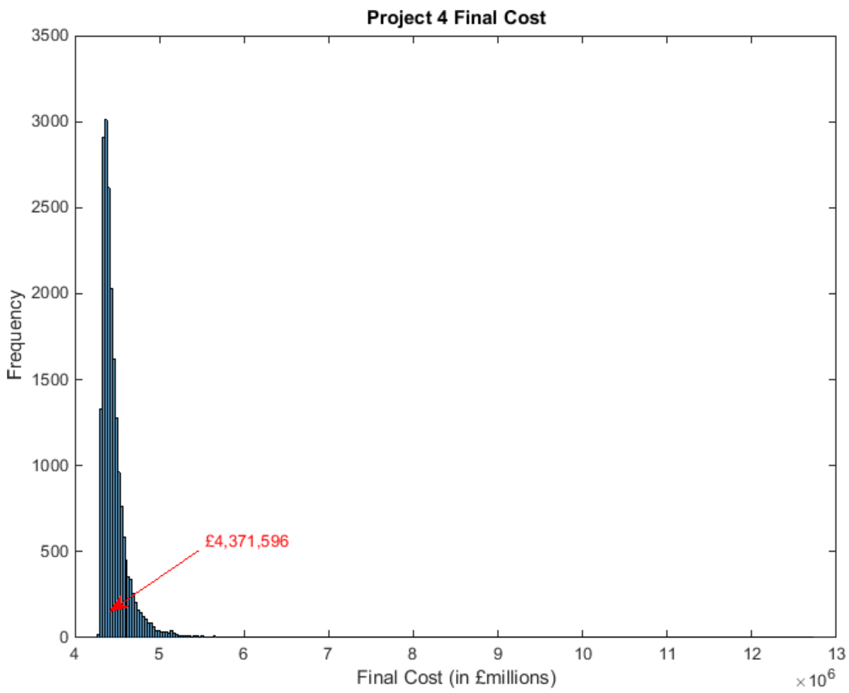

Figure 6. Project 4 Likely Actual Duration

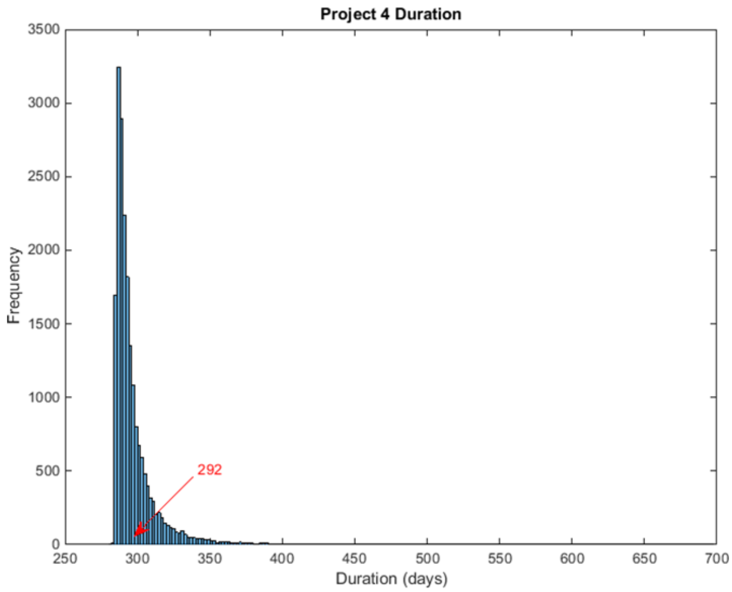

Figure 7. Project 5 Likely Final Cost

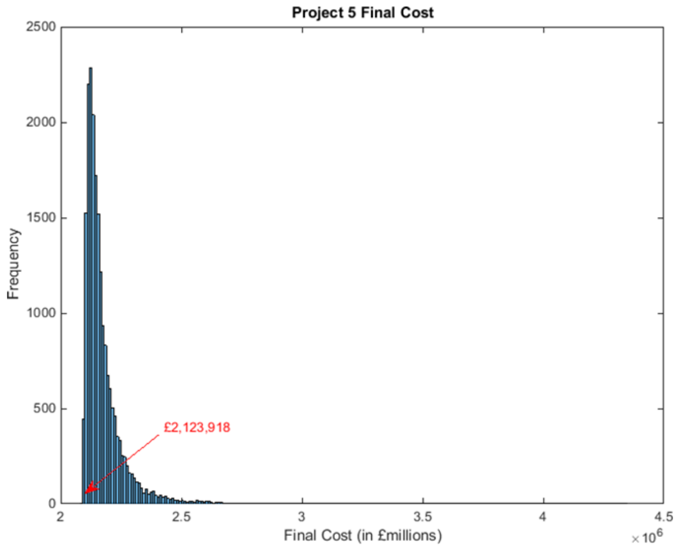

Figure 8. Project 5 Likely Actual Duration

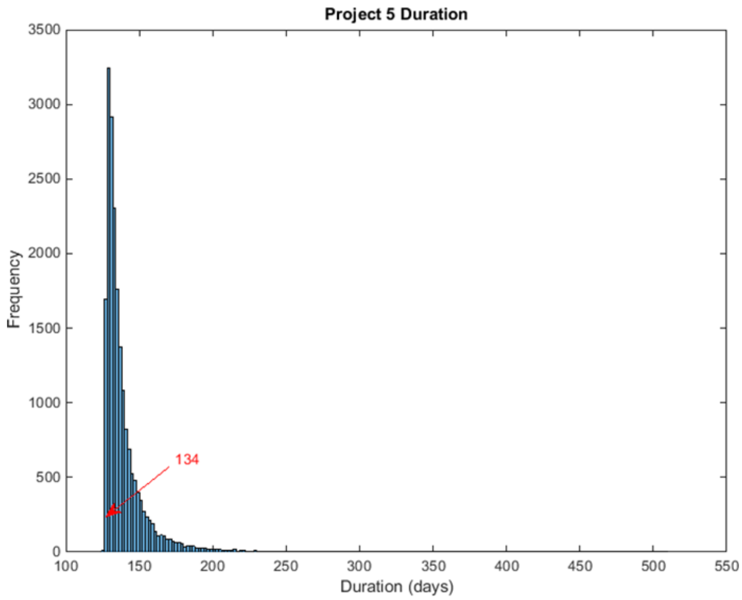

Figure 9. Project 6 Likely Final Cost

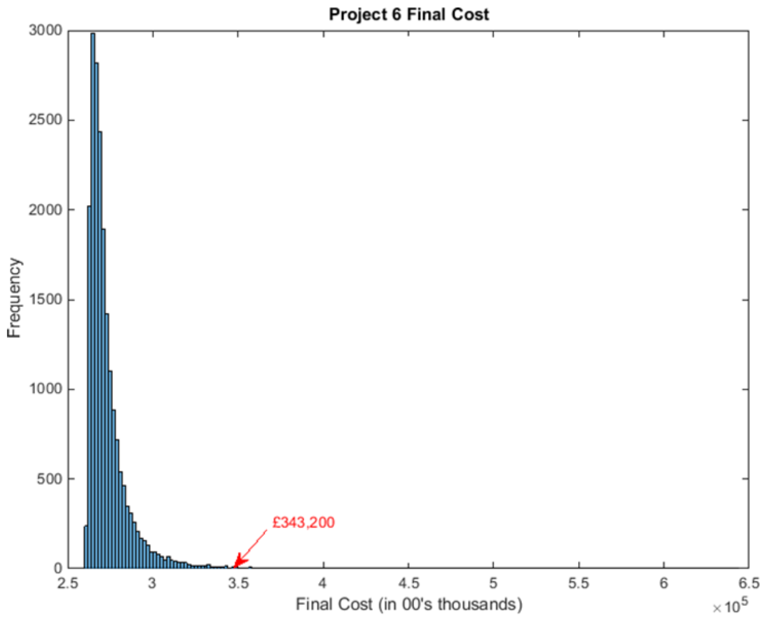

Figure 10. Project 6 Likely Actual Duration

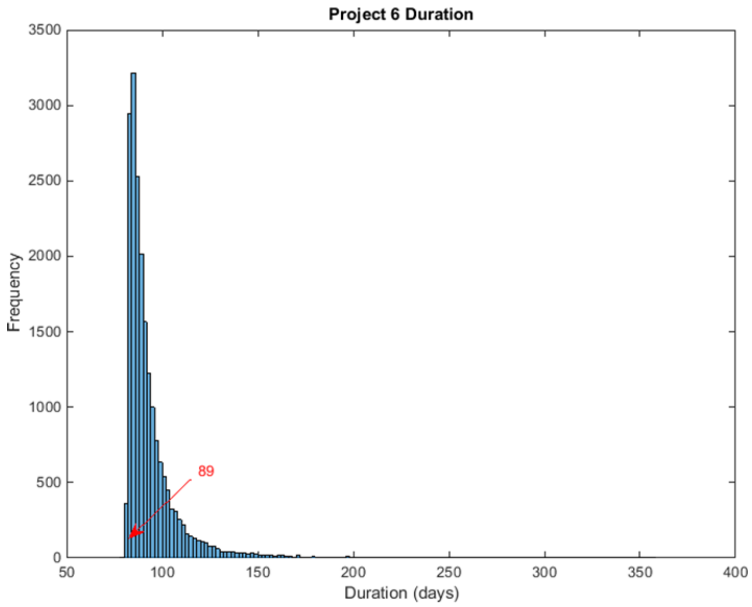

Figure 11. Correlation, Overrun Cost, and Count (std. £100,000)

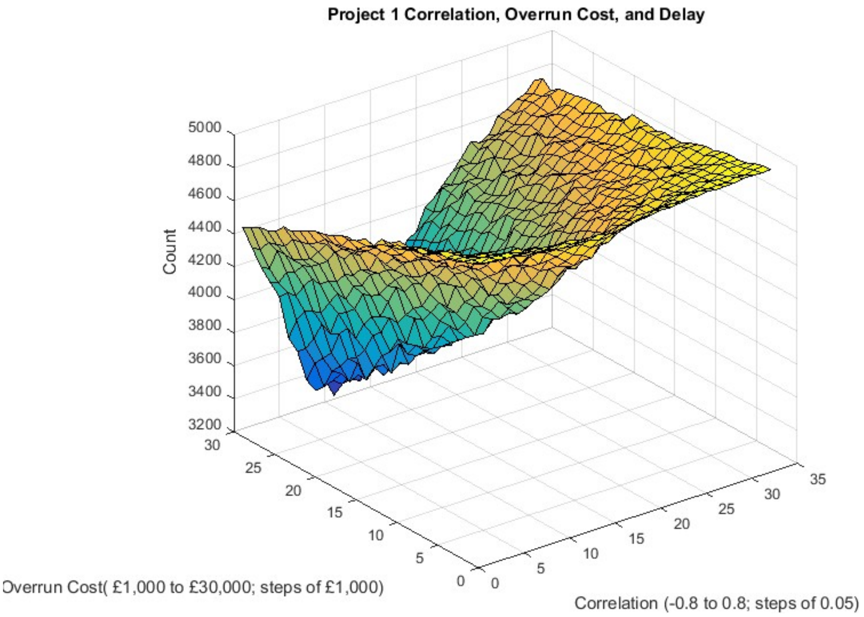

Figure 12. Correlation, Overrun Cost, and Count (std. £30,000)