AN EVALUATION OF THE RISK FACTORS LEADING TO COST OVERRUN IN THE DELIVERY OF HIGHWAY CONSTRUCTION PROJECTS

Garry D. Creedy[1], Martin Skitmore[2] and Johnny K.W. Wong[3]

ABSTRACT

Accurate owner budget estimates are critical to the initial decision-to-build process for highway construction projects. However, transportation projects have historically experienced significant construction cost overruns from the time the decision to build has been taken by the owner. This paper addresses the problem of why highway projects overrun their predicted costs. It identifies the owner risk variables that contribute to significant cost overrun and then uses factor analysis, expert elicitation and the nominal group technique to establish groups of importance ranked owner risks. Stepwise multivariate regression analysis is also used to investigate any correlation of the percentage of cost overrun with risks, together with attributes such as highway project type, indexed cost, geographic location and project delivery method. The research results indicate a correlation between the reciprocal of project budget size and percentage cost overrun. This can be useful for owners in determining more realistic

[1] Dr. Garry D. Creedy, PhD, School of Urban Development, Queensland University of Technology, 2 George Street, GPO Box 2434, Brisbane QLD 4001,, Email: gcreedy@qldmotorways.com.au

[2] Prof. Martin SKITMORE, Professor of Construction Management and Economics, School of Urban Development, Queensland University of Technology, 2 George Street, GPO Box 2434, Brisbane QLD 4001, Australia. Email: rm.skitmore@qut.edu.au

[3] **Corresponding author**: Dr. Johnny KW WONG, Lecturer, School of Urban Development, Faculty of Built Environment and Engineering, Queensland University of Technology, 2 George Street, GPO Box 2434, Brisbane QLD 4001, Australia. Email: johnny.wong@qut.edu.au

decision-to-build highway budget estimates by taking into account the economies of scale associated with larger projects.

Key words: Construction management, cost estimates, cost overrun, highway construction, risk management.

INTRODUCTION

The problem of cost overrun, especially in the construction industry, is a worldwide phenomenon, and its effects are normally a source of friction between owners (especially government owners), project managers and contractors in terms of project cost variation subsequent to the owner's decision-to-build. Although, in theory, it might be expected that cost overruns have the same probability of occurring as cost underruns, cost overruns have a much higher frequency (Emhjellen et al. 2003). Highway construction is particularly affected by this, with projects historically experiencing significant construction cost overruns (e.g., Molenaar 2005). In the USA, for example, the actual construction costs of major transport infrastructure average 28 percent higher than estimated costs – with very little change over the past seventy years (Flyvbjerg et al. 2003). Likewise, reports show the cost overrun of highway projects to be significant in Australia (particularly in Queensland) over a relatively long period of time. For example, the Roads Implementation Program 2004–05 Reports (RIP) by the Queensland Department of Main Roads (2005) reports that 10 percent of projects costing more than $1 million (AUD) have an overrun of over 10 percent on programmed estimates.

Cost overruns of highway projects have a serious impact on program budgeting from the view of the owner. As argued by Wang and Chou (2003), the planning and programming of future highway construction projects are vitally important tasks in highway organizations. A construction program outlines how highway funds are to be spent over time and any deviation from the stated program often brings a quick response from the public, the press and politicians. When this occurs, highway organizations lose creditability and time is often taken defending deviation from the published program (Flyvbjerg et al. 2002). On the other hand, if a highway organization can produce realistic program estimates, especially at the decision-to-build stage, then the agency's image can be enhanced.

In addition, the level of project risk contingency in estimates has a major impact on financial outcomes for project owners. If contingency is too high, it might encourage poor cost management, cause the project to become uneconomic and aborted, or lock up funds that are not available for other projects (Dey et al. 1996). On the other hand, if the contingency allocation is too low, then it may be too rigid and set an unrealistic financial environment, resulting in unsatisfactory performance outcomes (Touran 2003). In some areas of the public sector there is a tendency to remove contingency provisions in budget submission, as contingencies are often seen as facts — leaving no allowance for anticipating project risk (Yeo 1990).

There has been little research undertaken that relates owner risks in highway construction to actual completed costs (Williams 2003), and it is expected that relationships in construction cost data can be found that may be usefully and simply applied to estimating processes. Models have been derived from simple linear regression, for example, that can be used to predict the completed cost of competitively bid highway construction projects using only the low bid as input (Williams et al. 1999), but little has been done to identify the risk factors of specific highway project types and their relationship to budget cost overrun (Williams 2003). In addition, there is a lack of studies relating the incidence of highway project types and owner project risks to the cost overruns of actual completed projects. An understanding of the reasons for consistent cost overruns will allow owners to focus on problem areas and implement systems into program budgeting procedures as a means of developing more realistic project budget estimates. As pointed out by Flyvbjerg et al. (2003), the change in project cost, or cost growth, occurs as a result of many related factors, all of which are associated with some form of risk. Analysis of the reasons for the cost overrun of construction projects is a necessary step for the improvement of any given cost estimating system and can be used to pinpoint areas where the greatest improvements can be obtained.

With the limitations and deficiencies of the current research in mind, the purpose of this paper is to investigate the risk factors leading to substantial cost overruns of highway projects. The paper also aims to develop a more definitive risk contingency allocation regime for overall highway projects to supersede the arbitrary models currently present. The objectives are twofold. First, to undertake an analysis of historic project cost overrun factors and project parameters to ascertain if this will lead to more accurate owner budget estimates in the future through more realistic allowances for identified cost overrun factors. Second, to develop model relationships between the percentage of cost overrun in highway construction projects and a number of variables, including construction risks such as types of highway construction projects, delivery methods, location and project size. Only highway construction projects are considered in this paper.

LITERATURE REVIEW

Risk and uncertainty characterize situations where the actual outcome of a particular event or activity is likely to deviate from the estimate or forecast value (Raftery 1994). Construction is particularly prone to this for, as Leu et al. (2001) note, there are many uncertain variables during project implementation that dynamically affect project duration and cost (del Cano and de la Cruz 2002). In fact, all construction projects are, by their very nature, economically risky undertakings and projects let on the basis of competitive bids can add to such risks. Most highway infrastructure projects in Australia, Canada, New Zealand, Sweden, the UK and the US adopt a common delivery model known as the 'traditional model', or Design-Bid-Build (DBB) (Pakkala 2002). This means that the design/engineering services are produced first, and then another procurement contract is tendered for the actual construction or physical works based upon the design/engineering portion of the contract. However, the main criticisms of the traditional DBB method are the lack of innovation, delayed completion periods and cost overruns that are sometimes encountered. Since the owner bears most of the risks of both the design and construction aspects, there needs to be better practices to ensure the owner's needs are being met and that quicker project completion times and cost effective solutions are provided (Pakkala 2002).

A wide variety of factors influence construction costs of highway projects. In a study conducted in Newfoundland, Hegazy and Ayed (1998) found that season, location, type of project, contract duration and contract size had a significant impact on individual contract costs. Similarly, Herbsman (1986) found that in addition to input costs of materials; labor, equipment and the total volume of contracts bid each year (the so-called bid volume) all influence project costs. Yeo (1990) and Minato & Ashley (1998) suggest that cost overrun arises primarily because of four factors: external risk (due to modifications in the scope of a project and changes in the legal, economic and technologic environments); technical complexity of the project; inadequate project management (due to the control of internal resources, poor labor relations and low productivity) and unrealistic estimates (because of the uncertainties involved). Akinci and Fischer (1998), on the other hand, consider design and project-specific factors to be the key factors affecting the cost estimate of a project, including vagueness in scope, design complexity, and project size. Engineering designs have a high level of influence on project costs and sometimes unsatisfactory design performance can lead to cost overrun (Barrie and Paulson 1992). Anderson and Tucker (1994) report that their survey found about one-third of architectural/engineering projects miss cost and schedule targets. Chang (2002) notes that, as reported by Smith (1996), there have been few instances where an engineering design is so complete that a project could be built to the exact specifications contained in the original design documents. Many construction problems are due to design defects and can be traced back to the design process (Bramble and Cipollini 1998).

Furthermore, in their research study to quantify the impact that project changes have on engineering and construction project performance, Ibbs and Allen (1995) define change as any event which results in a modification of the original scope, execution time or cost of work. Because change may occur throughout all phases of a project, their research focuses on the quantitative impacts that change has on the detailed design and construction phase of projects. They found that project change has a large effect on the financial performance of a construction project. In addition, Thomas (1985) studied highway construction programs and reports on selected claims for project changes and cost/schedule overrun on these same projects. The study concludes that project change has a direct effect on costs and schedules of construction projects, primarily cost/schedule overrun.

While the reasons for cost overrun can be obvious, the problem still remains that an estimate is a forecast of a cost to be incurred sometime in the future — the problem being that the future is not always predictable. Kayode (1979) reports that project cost overruns are caused by rising costs largely due to inflation, inadequate analysis and inadequate information. Orji (1988) is of the opinion that the causes include certain government fiscal/monetary policies, poor costing of projects, inflation within the economy and some practices of project participants, especially those involving government projects. A further reason advanced for the incidence of project cost overrun is attributed to costing methods (Akpan and Igwe 2001).

In construction research, models have been developed showing cost influencing factors derived from past records of construction costs (Wilmot and Cheng 2003). Extrapolation of past trends has been used to forecast future overall construction costs (Koppula 1981; Hartgen et al. 1997), however such models are usually only used for short-term forecasting because of their reliance on the notion that past conditions and specifications do not always prevail in the future. Also, numerous factors affect project construction costs and most construction cost models developed in the past have used only a few of the many possible influential factors identified to date. Research of this type has also been hampered in the past because adequate data have not been available. The interrogation of in-house historical databases is probably the best source of data to assess risk occurrences or consequences of risk events and in many cases these databases are inadequate or disjointed, unavailable or supplemented with personal information bias (Al-Bahar and Crandall 1990). These databases are company and project specific and may not necessarily be able to be uniformly applied to new projects.

Research, such as that for the Washington State Department of Transportation, has identified risk factors that have strong association with project construction costs, indicating that cost overruns, expressed as a percentage of the original contract amount, tend to increase with the size of the project (Hinze and Walsh 1997). Williams (2003), in his research into highway contract overruns, identified the need to study further correlations between different highway project types and constructed project cost overruns. Despite these, there is little evidence in the research to date that has identified such correlations in highway projects in Australia. Furthermore, many research projects to date consider only the final outcome of contracts within the project and have not considered the owner's risks associated with the full project budget. That is, the failures that lead to cost overrun in the overall project — from the time the owner's decision-to-build is made until its completion. On the other hand, owners require different contingencies for different elements of projects (Eden et al. 2005). The establishment of a range of contingencies can require a considerable amount of work by estimators and so a simple contingency across the board is included in order to acknowledge the difficulty of identifying project uncertainty (Baccarini 2004). Therefore, this paper aims to address this issue by providing owners with a cost overrun model that correlates risk contingency with highway project attributes.

In general, the literature supports the notion that accurate early cost estimates for engineering and construction projects are extremely important to the sponsoring organization. Accurate cost estimates are vital for business unit decisions that include strategies for asset development, potential project screening, and resource commitments for further project development. Several research studies of highway construction projects attempt to predict the amount a construction contract might increase in cost while taking into account various factors that could be used for such predictions. While some research to date has generally revolved around the cost increase in contracts within projects, several research studies have also demonstrated that changes initiated during construction projects have a large effect on their financial performance. Research studies demonstrate that the estimating methodology and accuracy of cost estimates can be major reasons for cost increases. Research has also been conducted to predict the extent to which the cost of a construction contract might increase, taking into account various project prediction factors.

In conclusion, therefore, although many of the risk techniques are effective for the particular types of projects to which they are applied, these generally treat projects as independent entities with little attempt to categorize projects into specific sub-types from which detailed analyses can be undertaken. Also, little empirical research has determined owner risks - leading to cost overrun associated with certain types of highway projects and their delivery methods. In the past, highway cost estimating models have been established that describe construction risks as a function of factors believed to influence construction costs. Typically, the models established in this manner have been used to estimate the cost of individual contracts only, rather than project budgets. Therefore, empirical research is needed to assess whether certain highway projects' characteristics and delivery methods indicate a higher propensity to cost overrun. The research needs to be focused on the owner, not the contractor, and with a particular focus on overrun relating to the decision-to-build baseline budget.

RESEARCH METHODOLOGY

The overall objective of the research described in this paper was to identify the factors that influence significant project cost overruns for the owner and to propose an analytical model that correlates project attributes to the level of their cost overruns and owner project risks relating to decision-to-build budgets. In order to provide adequate answers to the research questions, the following five research stages were adopted:

1. Establishment of a data source for highway construction projects;
2. Identification of project work types and cost overrun factors from historic project data;
3. Utilization of principal component analysis and factor rotation on cost overrun factors in order to consolidate data;
4. Use of the nominal group technique with highway construction experts to elicit groupings of cost overrun factors and highway project types; and,
5. Use of multivariate linear regression analysis to investigate correlations between cost overrun risk factors and project attributes by using historic project data.

An historical analysis methodology was used as it provides an insight into the current research problem relating to cost overruns in highway project estimates through the examination of what had happened in the past, using analysis, analogy and trend extrapolation of historic data (Kirszner and Mandell 1992). The approach entails researching construction delivery practices to identify risk occurrences as well as risk constraints and processes to minimize owner risk exposure leading to cost overrun. It also provides a means for the development of a consensus of risk factors based on expert opinions and trend exploration in addition to the development of models of cost overrun based on historical project data and project attributes.

To establish a data source of highway construction projects, semi-structured interviews of construction industry representatives were first developed. This process also provided some opportunity to evaluate individual practitioners' tacit knowledge, based on their project management experience. The research stage required an appropriate sample of highway infrastructure projects. The data sample was required to be large enough to allow statistical analyses of cost overrun factors and project costs. The research focused on highway infrastructure projects from the Queensland Department of Main Roads (QDMR) that contained data on substantial project cost overruns. The highway project construction data was collected from the published Roads Implementation Program (RIP) Yearbooks of the QDMR over the period from 1995 to 2003 with a portfolio of projects in the sample worth approximately AUD $1 million. All projects subsequently analyzed were those delivered by the traditional design-bid-build method. For the purpose of the research, the total project cost estimate included the estimated costs of all component activities from the initiation of the project design to construction finalization. A data integrity process was also required to ensure that the data presented were true and factual representations of the highway organization's historic data. All the reported project expenditures were also standardized to 2003 project prices in order to enable the measurement of price changes over time. The Road Input Cost Index (RICI) by the Australian Bureau of Statistics (ABS) was used to index up the historical highway costs as it provided the only continuous highway focused price indices for the financial years for which the historic project data were available.

The second stage of the research involved the identification of project work types and cost overrun factors from the historic data. The available highway data contained individual descriptions of all the work types as well as the reasons for individual projects having exceeded the owner's programmed budget. The third stage of the research involved the development of consolidated groupings of high level project risk factors contributing to cost overrun in highway construction projects. The most common form of factor analysis is Principal Components Analysis (PCA). PCA seeks a linear combination of variables such that the maximum variance is extracted from the variables. It is a statistical procedure that is able to uncover relationships among numerous variables, variables limited in the context of this research to specific cost overrun reasons in highway construction projects. Several pre-tests, including Kaiser Meyer Olkins test (KMO) and Bartlett Test of Sphericity, are also used to measure the sample characteristics (i.e. sampling adequacy and test of identity matrix) necessary for successful factor analysis.

Stage four involved the elicitation of the grouping of cost overrun factors from experts. Elicitation from experts is a formal process for obtaining information or answers to specific questions where the information was highly subjective. The nominal group technique (NGT) was used as an alternative to the focus group and the Delphi techniques. The NGT is a consensus planning tool that helps prioritize issues (Delbecq et al. 1986). Participants in NGT are brought together for a discussion session led by a moderator. It presents more structure than the focus group, but still takes advantage of the synergy created by group participants. NGT provides a constructive, problem-solving approach that permits equal participation by all the group members, and avoids the disproportionate influence by vocal individuals who are often present in group processes (Gustafson et al. 1973). Potential candidates for the nominal group panel were considered from within professional organizations, project management consultants, contracting organizations and owner organizations. The selection of potential group members was based on their contract management experience in highway construction projects and their role of owner representative in infrastructure construction projects. At the end of this stage, the principal cost overrun risk groupings were developed and ranked in importance by the group by means of an importance index[4].

The final stage of the research process involved the identification of statistical models that can explain the correlation between the cause, effect and other relationships relating to cost overrun. Multivariate regression is the most common method of modelling construction costs (Koppula 1981; Blair et al. 1993; Williams 2003) and it was used here to manage the multiple project variables and relationships between projects, project risks and project cost overrun. The dependent variable adopted in the model was the continuous variable *percentage cost overrun* to denote the difference between the owner's actual project cost and programmed cost, expressed as a percentage of the programmed cost. This correlation between the following five project variables was analyzed:

1. Highway geographic project type (urban/rural projects)
2. Highway project construction type (project types 1 to 12)
3. Highway project delivery type (delivery code 1, 2 or 3)
4. Owner project high level risk grouping (HL/1 to 10 and HL/Q)
5. Indexed highway project programmed cost (Indexed program cost $m).

The null hypothesis was that there was no correlation between the size of cost overrun of location of projects, construction type, delivery process, project size or owner risk factors. Linear normal models were used (i.e. regression analysis with appropriate f-tests and t-tests). For each test, the p-value was reported as a measure for rareness if identity of groups was assumed. Forward, backward and stepwise selection regression methods were used in the

[4] The final ranking was determined by calculating the *Importance Index* for each group, using the formula: $100\Sigma(wf) / WF$, where w was the weighting, ranging from 1 to 10, given to each factor; W was the highest weight, i.e. 10; f was the frequency of the response; and F was the total number of NGT workshop participants.

analyses. The stepwise method delivered the most appropriate model after excluding outlier data and data transposition. Correlation analysis was undertaken to identify project variables that correlated with project cost overrun. This examined the performance of various models and the relationships between variables. *Pearson's* correlation coefficient (R) was used to examine the relationship between the data and for developing the rank order of regression models in terms of *goodness of fit*. The coefficients of multiple determinations – R^2 and adjusted R^2 statistics – were also used as they allowed the identification of the *best* model.

DATA COLLECTION AND ANALYSIS

Determination of cost overrun factors

The data were collected from 231 highway projects published in the RIP documents of the Queensland Department of Main Roads over the financial years from 1995–96 to 2002–03. These comprise of 140 (60.6 percent) projects categorized as open tender contracts and 91 (39.4 percent) sole invitee negotiated price contracts. As mentioned above, all the reported project expenditures were rebased to 2003 project prices. The average increase over the seven-year analysis period was 2.4 percent per year and the index data shows a 16.3 percent increase in highway costs over the period.

The next step involved the determination of project cost overrun factors. The focus of this analysis was the owner's exposure to project cost overrun. Where common cost overrun factors were identified across a number of projects, a common cost variable was recorded. This enabled the identification of 37 variables. These variables, their symbols and the number of times they occurred across projects are shown in Table 1. Nine variables were excluded from the factor analysis as they each related to only one incidence, leaving a total of 28 variables for factor analysis. The minimum sample size and ratio limits for the number of variables for factor analysis was 231 and 28 respectively. This gives an acceptable ratio of 8.3 (Guadagnoli and Velicer 1988).

<Insert Table 1>

Factor analysis (PCA) was then applied and factor rotation conducted on cost overrun variables to consolidate data. The KMO test that measured sampling adequacy gave a sampling adequacy of 0.460. This was much less than 0.6 that was sought in the literature (Kaiser 1958; Hutcheson and Sofroniou 1999) and threw initial doubt on the adequacy of the planned factor analysis technique in overcoming multicollinearity in the data. A further test using the Bartlett Test of Sphericity gave an approximate chi-square of 482.183 and 378 degrees of freedom. The associated significance level was small at $p = 0.000$. The results of factor analysis suggested that there were 13 principal factors with eigenvalues greater than one (1.000), however the results also reflected that the first 13 components collectively accounted for only 61.7 percent of the total variability, while the other 15 components together accounted for the remaining 38.3 percent. A further test using a scree plot also indicated a weak model comprising 13 factors. A review of the 13 groupings led to the conclusion that no common factor component names had been developed that could be allocated to the individual component groups to allow consistency in factor groupings. The results provided no evidence of strong correlations within any of the 13 groupings, even after rotation. Therefore, the 13 principal component factor model derived in the factor analysis process could not be used in any subsequent model development.

Elicitation and prioritization of principle cost overrun risk groupings

Since the factor analysis was unsuccessful, the Nominal Group Technique (NGT) was then used to obtain expert agreement on suitable groupings of overrun factors and ranking of importance of each in terms of cost overrun potential. The expert panel included an analyst from a consulting organization, two generalists and five specialists — the latter seven being from the QDMR. The ranking exercise required the workshop participants to provide numerical scores that expressed their individual opinions on the level of importance of each of the 10 principal cost overrun factors in terms of their cost impact on highway projects. A scale of 1 to 10 was adopted, with a score of 1 indicating the least impact, and 10 indicating the most impact. All the scores of the eight participants were recorded and an overall ranking of each of the groupings derived. The following summarizes the results of composition of the final groupings from the rank 1 (highest) to 10 (lowest) order of their cost impact as derived from the importance index (Table 2):

1. Design and project scope change (HL/1)
2. Insufficient investigation and latent conditions (HL/2)
3. Deficient documentation (specification and design) (HL/3)
4. Owner project management cost (HL/4)
5. Cost of services relocation (HL/5)
6. Constructability of highway projects (HL/6)
7. Price escalation of material components (HL/7)
8. Property acquisitions and adjustments to properties adjacent to highway projects (HL/8)
9. Contractor risks (HL/9)

10. Environment (HL/10)

<Insert Table 2>

Application of NGT workshop findings to project data

The high-level (HL) risk groupings that were developed by the experts and mapped to the initial 36 cost overrun factors were then mapped back to the initial projects. Table 3 shows a sample that was produced to map the associations of the low level cost overrun risks of D – Design/project scope change, DD – Design scope change for drainage and DE – Design scope change for environmental issues.

<Insert Table 3>

For the purpose of analysis, 1 was inserted in the master data file for each low level risk and its associated HL risk grouping for each project. In addition, a 0 was inserted in all low level risk columns when there was no association with a particular HL risk. This provided a visually complete 'picture' of the project mappings. An analysis was carried out to ascertain which HL groupings of cost overrun factors had the most occurrences across the projects analyzed. There were 42 HL risk combinations recorded across the project data. Table 4 shows the incidence of the HL groupings across the projects.

<Insert Table 4>

Column one and three of Table 4 shows the HL/1. A decimal format has been used to record when more than one HL risk grouping occurred in a particular project. Rows 1 to 10 of Column 2 and 4 of Table 4 display the incidences of single HL/1s. Whereas, Row 11 shows that there were five projects where both HL/1 and HL/2 occurred. HL/1 recorded the highest incidences with 92 projects. The next highest recorded 22 incidences recorded for HL/2. There were 19 recorded incidences where a combination of HL/1 and HL/5 occurred in projects. As a further explanation of Table 4 above, the last row shows that there was one project which had HL/1, HL/6, HL/ 8 and HL/10 risk groupings that collectively contributed to the cost overrun in the one recorded project. A significantly high number (92) of incidences were recorded for HL/1, when compared with the rest of the incidences recorded. The composition of HL/1 consisted of the following low-level risk factors determined by the previous expert elicitation process:

- Design/project scope change (23.6 percent of projects represented)
- Design scope change resulting from drainage, environmental issues, pavement materials/depth (8.2 percent of projects represented)
- Design scope change as a result of carrying out a safety audit on project (1.0 percent of projects represented)
- Quantity increase (7.7 percent of projects represented)
- Specification change (1.7 percent of projects represented).

There had been 31 incidences of quantity increase previously recorded against projects as shown in previous Table 1. As this amount comprised 34 percent of the HL/1 grouping, it was decided to extract the quantity increase incidences from the HL/1 risk group and create an 11th grouping of quantity increase (HL/Q) for incorporation in the model analysis.

Data analysis and statistical modelling

The final step was to analyze the historical project data to identify direct correlations between particular construction project types and project cost overrun. The dependent variable adopted in the model was the continuous variable percent cost overrun (the difference between the owner's actual project cost and the programmed cost), expressed as a percentage of the programmed cost for each project. This approach identified project variables that had relationships with projects reporting high cost overrun. The prediction variables were selected for model investigation and were based on the availability of historical project data, including (1) geographic project type (urban/rural projects); (2) project construction type (project types 1 to 12); (3) project delivery type (delivery code 1, 2 or 3); (4) indexed project programmed cost (*indexed program cost $m*); and (5) project high level risk grouping (HL/1 to 10 and HL/Q). Multivariate regression was used to analyze the correlation between these project variables and the dependent variable of cost overrun percentage. One of the interesting findings is in the correlation between indexed highway programmed cost and cost overrun after data translation. For the regression formula $y = bx + c$, the correlated model had the form of:

% project cost overrun = 14.519 x reciprocal of indexed programmed cost $m.+ 21.751 (Equation 1)

The regression results provided an R value of <0.2, indicating negligible correlation. The results further suggested that the variable reciprocal *indexed program cost $m* had a beta = 0.198 for the model which represents the change in the dependent variable *percent over cost* in units of its standard deviation. In general, the regression analysis demonstrated a weak correlation between the size of projects, as measured by the indexed programmed cost, and the size of cost overruns.

In effect, this model shows that, as the size of a project increases in budgeted programmed cost, then the percentage cost overrun reduces in value. It further suggests that to counter the potential cost overrun, the over-and-above additional contingency percent that should be factored into all types of highway projects by the owner to compensate for undefined (or under-defined) project risks can be varied depending on the project size. Such indicative over-and-above contingency percentages that have been derived from the model are shown in Table 5.

<Insert Table 5>

Details and summary of the multivariate linear regression analysis of the dependent variable of cost overrun and other project variables may be found in Creedy (2006). In general, both the forward and stepwise analyses produced three identical models, while the backwards mode produced 13 models. The R^2 values ranged overall from 0.019 (1.9 percent) up to 0.111 (11 percent) and with a very poor coefficient of variation. Also, the adjusted R^2 values ranged overall from 0.002 to 0.061, which again indicated very weak models. The values of the standard error of the regression estimate were consistently large and only showed a slight reduction in each of the models for the forward, backwards and stepwise procedures. This fact, combined with the low estimates of R^2 and adjusted R^2 values, indicated that the models had not fitted the data very well. Sensitivity testing was also carried out to ascertain whether additional outlier data still unduly influenced the models.

In summary, a wide spectrum of highway projects, delivery methods and owner risks were analyzed using three separate modes of variable selection in the regression analysis. There were 2 geographic location types, 12 project types, 3 project delivery methods, and 11 high level risk groupings that were hypothesized to have a correlation to the project overrun cost for the various analyzed projects. The null hypothesis adopted for Pearson's correlation tests was that there was no correlation between the size of cost overrun of projects and their geographic location, construction type, delivery process, project size, and owner project risks. Model testing was applied to confirm or otherwise that the given independent (prediction) variables in the model did not correlate against the dependent variable of project cost overrun to any significant level of accuracy. All models were tested statistically and practically to determine whether they were efficient in predicting real project cost overrun results. Based on the adopted statistical checks, all the regression models performed poorly in representing the project data. The correlation relationship of the multiple project variables was troublesome because the sought-after knowledge of cost overrun in highway projects was complex and had many different combinations of factors that had to be examined. The statistical modelling and analysis of the research data found no strong correlations between project types, work types and project risk factors in producing cost overrun. There was, however a weak model showing that as the size of a project increased in budgeted programmed cost, then the percentage cost overrun reduced in value.

DISCUSSION, CONTRIBUTION AND RECOMMENDATIONS

A number of important findings were obtained from the regression analyses. First, there is a lack of strong correlation between the geographic location of the projects and project cost overrun. This finding contrasts with Drew and Skitmore's (1992) finding that the density of population and the extent of geographic area were important factors for competitive bids in building projects. The difference may be due to highways being different to building projects. Also, the highway projects analyzed here are all located in one area - Queensland, Australia - and not a broader region as was the case for the Drew-Skitmore study. In addition, no strong correlation was found between highway project types and project cost overrun. However, projects involving the construction of six or eight lanes highways have excessive cost overruns when analyzed for discordance and were subsequently excluded as outliers. On a broader transportation research base of analyzing rail, fixed-line and road projects, Flyvbjerg, et al. (2002) found that the type of transportation project had a statistical effect on cost overrun. This difference may be attributed to Flyvbjerg's use of a much broader range of project types and that the research was conducted on an international scale.

In addition, the findings suggest that there is no strong correlation between the type of project delivery method and cost overrun. Projects that were delivered by open contract, as apposed to negotiated price, were no less susceptible to significant cost overrun. Likewise, no correlation was found between owner project risks and project cost overrun, although there is a correlation between indexed highway programmed cost and cost overrun (refer to Equation 2). This model indicates that as the size of a project increases in budgeted programmed cost, so the size of the percentage cost overrun reduces. In contrast, research carried out by the USA Transportation Research Board in 1992 evaluated construction cost overruns on 468 transport projects completed for the Washington State Department of Transportation indicated that cost overruns, expressed as a percentage of the original contract amount, *increased* with the size of the project (Hinze *et al* 1992). This finding is also inconsistent with Williams (2003), who analyzed transportation projects in both the UK and the US and found a (log.) linear relationship between contract size and cost overrun. The reason for the inconsistency appears to be that Williams analyzed only the contract elements of projects and also the size of projects. Williams (2003) also analyzed projects that included contract values below the equivalent of $1 million (AUD) in predominately highway rehabilitation schemes. In addition, he initially included dredging contracts in his data analysis in order to demonstrate linkages across project types in the USA. In contrast, only highway construction and rehabilitation projects in Queensland that were greater than AUD $1 million were used for the data analysis. Both sets of projects were based on the design-bid-build delivery model. Presumably the differing broad findings are due to the unique geography of highway construction projects in Australia as opposed to that of the USA.

The research indicated that the percentage of project cost overrun is linked to the economy of scale, such that smaller dollar projects can attract larger percentages of cost overruns, and larger dollar projects have the potential for smaller percentages of cost overruns. Of course, the actual dollar magnitude of the cost overrun for the large project may still be greater, even though its percentage change is less. For example, a five percent cost increase on a $1 million dollar project is $50,000, whereas a one percent cost increase on a $100 million dollar project is $1,000,000. The research also supports the assertion that additional contingency percentages can be derived from the model that can be applied to project sizes regarding decisions on the size of individual projects. These proportional contingency percentages to projects' decision-to-build budgets of particular sizes are shown in Table 5 in previous section.

A focus of research effort in the area of project cost overrun provides a more complete understanding of the linkages of risk to highway project delivery. The purpose of this research project is to undertake an empirical analysis in order to ascertain whether the data support the hypothesis that there is a statistical correlation between highway project cost overruns and project attributes. The research concentrates effort on the study of aggregate data about highway construction projects in order to identify common trends that occur. While the research finds a history of underestimation of costs and the over-optimistic assumptions about performance of a substantial number of project budget estimates, it also specifically contributes to the body of knowledge in project construction management and cost estimating in a number of ways. First, it combines risk assessment and expert elicitation techniques in investigating project management estimating and cost control issues when estimating highway projects. A quantitative and qualitative project assessment is also provided that will help highway project decision makers define unforeseeable disturbances more reliably ahead of time, so that corrective measures can be better taken into account. In addition, the in-depth *post mortem* analysis of owner risks that have led to significant project cost overrun strengthens the understanding of why highway projects can substantially overrun project decision-to-build budgets. Owner risk factors are also identified, aimed at providing a better understanding of the risk parameters and management contingency requirements in projects, thus validating better risk contingency weightings in budget estimates. The research found that design and scope changes are the highest contributing risk factor to project cost overrun in the analyzed highway projects. This finding is supported by Tilley et al. (2000) who found that the quality of project design and design documentation has fallen considerably over the past 15 to 20 years.

Several limitations of the study are worthy of mention. First, this research focuses on analyzing those highway projects with substantial project cost overrun, which is a starting point of understanding the cost overrun in this type of project. Therefore, this is a study of the pathology of cost deviance. Whilst it is accepted that a full understanding of cost over and underruns will necessarily involve the analysis of a more comprehensive set of data, further study will be extended to analyze highway projects with no or varying degrees of cost overrun problems in another study. Further study will also compare the highway data in different locations (i.e. US and Australia) and adopt a different form of analysis, to compare the findings. Second, studying the relationship of multiple variables is especially troublesome because the desired knowledge is complex in nature and many different combinations of factors need to be examined. The research was also confined to the study of highway projects in the state of Queensland, Australia. Since construction costs can be specific to geographical/economic areas and time periods, caution is required when comparing the data and results to other situations. The model developed could be refined by adding one or more important project variables (e.g. estimator) to the model, or using different type or market sector groupings such as toll roads. Further research could be undertaken by including a wider range of project sizes, such as those less than $1 million (AUD), to explore further the preferred size ranges at which projects are less susceptible to cost overrun. Similarly, other tests could be adopted to examine violations of the regression assumptions and other approaches to correct assumption violations. The Binary Probit and Logit models will be adopted in the further study to provide a binary representation and analysis. Further data transformations of project variables could be tested in the further study, and other regression approaches could be explored to modelling project cost overrun in project delivery. Further research could also be undertaken in testing the model by implementing two contingency allocation percentages on half the number of highway projects each, with differences in budget cost reporting observed and discussed. Also, the linkage between the risk assessment and determining the appropriate probability distributions for various highway project types should be researched for a more analytical connection, for example with the use of Analytical Hierarchy Process (AHP) or fuzzy set theory. Future research is needed to adequately identify and quantify the project cost overrun drivers as they relate to the construction of buildings and other infrastructure project types. Finally, there is a need for further studies into the storage and retrieval of historical project data. Historical data of finished projects have to be made more accessible. This will ultimately allow estimators to generate and deliver better project cost estimates. In this research, one major aim was to see if empirical models could be made – this main goal of this study *was* achieved in that they could be made. The fact that the R^2 result is low demonstrates the lack of correlation among the variables and hence there are several factors afoot. These factors are embodied in the small group of significant variables found.

CONCLUSION

The focus of this paper is on owners' exposure to project cost overruns. The analysis has produced important findings concerning the reasons highway projects have overrun and provided evidence of the most important risks on which highway agencies need to focus their efforts. Of particular concern are changes in project designs and scope changes during project development. The research process used the experience in highway construction and the professional judgment of the researcher to determine the listings of work types and reasons for cost overrun using the NGT process. The final stage of the research process involved the investigation into statistical models that can explain the correlation between the cause, effect and other relationships relating to cost overrun in highway construction projects. The regression analysis demonstrated a weak correlation between the size of highway projects, as measured in indexed programmed cost and the size of cost overruns. The correlation evolved after data transformation was carried out to improve the model. It can also be concluded from the research that the arbitrary application of a base contingency percentage figure, such as 10 percent, to accommodate project risk can lead to those projects reporting substantial budget overrun. Perhaps, cost overruns are primarily due to uncertainty (uncontrollable) than risk (controllable), and therefore, are more difficult to manage. The provision of more realistic contingency percentages across such projects will go a long way to providing better reporting of highway projects, program results and associated key project performance indicators.

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Reason for cost overrun	Code	Incidences across projects
Project acceleration requirement	A	5
Constructability difficulty costs	C	10
Constructability – under traffic	CT	17
Design/project scope change	D	95
Design scope change – drainage	DD	33
Design scope change – environmental issues	DE	19
Design scope change – design error	DF	2
Design scope change – pavement materials/depth	DM	23
Design preload requirement	DPL	1
Design change to sub grade	DSG	1
Design scope change – safety audit requirement	DSA	4
Extras unspecified	EU	6
Government initiative – employment continuity	G	1
Government initiative – contribution by developer	GCD	3
Government initiative – contribution by local government	GCLG	1
Government initiative – contribution by rail	GCR	1
Cultural heritage issues	H	4
Latent condition – requires design change	LD	4
Latent condition – rock encountered	LR	7
Latent condition – additional stabilizing	LSG	3
Latent condition – removal and replacement of unsuitable material	LUS	21
Material cost increase – asphalt	MA	1
Material cost increase – bitumen price	MB	1
Material cost increase – earthworks	ME	3
Material cost increase – pavement materials	MP	11
Material cost increase – owner supplied components/materials	MPS	4
Material/process quality issue	MQ	2
Contract failure – new contract establishment costs	N	1
Remote location costs	O	7
Project administration cost increase	P	8
Quantity increased measure	Q	31
Resumption/accommodation works	R	10
Services relocation costs	S	12
Specification change	SC	7
Contract tender price higher than original estimate	TH	35
Contract tender price increase due to inflation	TCI	1
Wet weather effects/rework	WW	8

Table 1: Project cost overrun factors derived from historic highway data

Rank	Principal Cost Overrun Factors
1	Design and scope change (HL/1)
2	Insufficient investigations and latent conditions (HL/2)
3	Deficient documentation (specification and design) (HL/3)
4	Owner project management costs (HL/4)
5	Services relocation (HL/5)
6	Constructability (HL/6)
7	Price escalation (HL/7)
8	Right-of-way costs (HL/8)
9	Contractor risks (HL/9)
10	Environment (HL/10)

Table 2: Ranking of the Principal Cost Overrun Factors

Project Number	Risk D[1]	HL/1[2]	Risk DD[3]	HL/1	Risk DE[4]	HL/1
A1	1*	1	0		0	
A2	0		0		0	
A3	0		0		0	
A4	1	1	0		0	
A5	1	1	0		0	
A6	1	1	1	1	0	
A7	0		1	1	0	
A8	0		0		0	
A9	1	1	0		0	
A10	1	1	0		1	1
A11	0		0		0	
A12	1	1	0		1	1
A13	1	1	0		1	1
A14	0		1	1	0	
A15	0		1	1	0	
A16	1	1	0		0	
A17	1	1	0		1	1
A18	0		0		0	
A19	1	1	0		0	
A20	1	1	0		0	
A21	1	1	0		0	

Notes:
[1] ***Risk D*** represents low level cost overrun risks due to design/project scope change,
[2] ***HL/1*** represents the high level risk due to design and scope change
[3] ***Risk DD*** represents low level cost overrun due to design scope change for drainage
[4] ***Risk DE*** represents low level cost overrun due to design scope change for environmental issues
* 1 was inserted for each low level risk and its associated high-level risk grouping for each project. A 0 was inserted in all low level risk columns when there was no association with a particular high-level risk.

Table 3: Sample of Low Level to High Level Cost Overrun Risk Group Mapping to Projects

Type*	HL/ risk grouping**	Incidence	Type*	HL/ risk grouping**	Incidence
1	HL/1	92	22	HL/5, HL/8	1
2	HL/2	1	23	HL/1, HL/10	10
3	HL/3	2	24	HL/1, HL/2, HL/5	1
4	HL/4	1	25	HL/1, HL/2 , HL/6	1
5	HL/5	6	26	HL/1, HL/2 , HL/7	1
6	HL/6	7	27	HL/1, HL/3 , HL/5	1
7	HL/7	1	28	HL/1, HL/5 , HL/6	3
8	HL/8	3	29	HL/1, HL/5 , HL/8	3
9	HL/9	1	30	HL/1, HL/6 , HL/8	1
10	HL/10	22	31	HL/3, HL/10	1
11	HL/1, HL/2	5	32	HL/5, HL/10	1
12	HL/1, HL/3	5	33	HL/6, HL/10	2
13	HL/1, HL/4	4	34	HL/7, HL/8 , HL/9	1
14	HL/1, HL/5	19	35	HL/9. , HL/10	3
15	HL/1, HL/6	5	36	HL/1, HL/3 , HL/6 , HL/9	1
16	HL/1, HL/7	1	37	HL/1, HL/8 , HL/10	2
17	HL/1, HL/8	1	38	HL/2. , HL/4, HL/10	1
18	HL/1, HL/9	2	39	HL/2, HL/9 , HL/10	1
19	HL/2, HL/4	2	40	HL/4, HL/5 , HL/10	1
20	HL/3, HL/8	2	41	HL/1, HL/4 , HL/9, HL/10	1
21	HL/5, HL/6	3	42	HL/1, HL/6 , HL/8 , HL/10	1

Notes: * represent 42 high level cost overrun risk combinations
** HL/1 represents high level cost overrun risk due to design and scope changes; HL/2 represents high level cost overrun risk due to insufficient investigations and latent conditions; HL/3 represents high level cost overrun risk due to deficient documentation (specification and design); HL/4 represents high level cost overrun risk due to owner project management costs; HL/5 represents high level cost overrun risk due to services relocation; HL/6 represents high level r cost overrun isk due to constructability; HL/7 represents high level cost overrun risk due to price escalation; HL/8 represents high level cost overrun risk due to right-of-way costs; HL/9 represents high level cost overrun risk due to contractor risks; HL/10 represents high level cost overrun risk due to environment;

Table 4: Incidences across projects for different high level cost overrun groups and group combinations

Project programmed cost	Over-and-above percentage
$1m	36.3%
$5m	24.7%
$10m	23.2%
$15m	22.7%
$25m	22.3%
$50m	22.0%

Table 5: Indicative over-and-above contingency percentages for project size