CLIENTS DRIVING INNOVATION

Case Study

RISK FACTORS LEADING TO COST OVER-RUN IN HIGHWAY CONSTRUCTION PROJECTS

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ABSTRACT

The change in project cost, or cost growth, occurs from many factors, some of which are related to each other, and all are associated with some form of risk. Determining the existence and influence of each of these cost overrun risk factors in projects may ultimately lead to better control on project cost estimates and assist in identifying possible solutions to avoid future estimate overruns.

This paper describes the PhD research project that is under way to study the risk factors related to cost growth in road construction projects and to evaluate influencing data from completed road projects. The paper details the literature research undertaken in the area of risks causing cost over-runs. It also identifies and describes historical cost factors which have contributed to excessive cost estimate overruns on 238 design-bid-build highway construction projects, each costing over $1m. in Queensland, Australia during the period 1995 to 2003.

1. Introduction

Accurate, early cost estimates for engineering and construction projects are extremely important to the sponsoring organization and the project team. For the sponsoring organization, early cost estimates are vital for business unit decisions that include strategies for asset development, potential project screening, and resource commitment for further project development. Early estimates are critical to the initial decision-making process for the construction of capital projects. As such, the importance of early estimates to owners and their project teams cannot be overemphasized. Early estimates are typically plagued by limited scope definition (and thus the high potential for scope change) and are often prepared under stiff time constraints. Furthermore, reliable cost data are often difficult to obtain during the conceptual stages of a project, particularly if basic design and geographic issues remain unresolved. Early estimates, even when grossly inaccurate, often have become the basis upon which all future estimates are judged. For the project team, performance and overall project success are often measured by how well the actual cost compares to the early cost estimate. Initial cost estimates are the basis on which all future estimates are compared. Future estimates are often expected to agree with (i.e., be equal to or less than) the initial estimates. However, final cost often exceeds the initial estimate.

As in any other business operation, the cost of estimating must be balanced against the quality of the estimates produced. Estimates will not be perfect no matter how much is spent on them. We must be satisfied with forecasts of the future which will cost as little as possible and be accurate enough for our immediate purpose. The analysis of accuracy is also necessary for the improvement of a given estimating system. It can be used to diagnose trouble spots, to pinpoint areas where the greatest improvement can be obtained at the lowest expense, and to measure the improvement which takes place when a system is changed.

The change in project cost, or cost growth, occurs due to many factors, some of which are related to each other, and all are associated with some form of risk. Determining the existence and influence of each of these cost overrun risk factors in a project may ultimately lead to better control on project cost and assist in identifying possible solutions to avoid future overruns.

1.2 The PhD Research Project

This PhD research project has been developed to study the risk factors related to cost growth in Queensland Department of Main Roads (QDMR) funded road construction projects and to evaluate data from completed design-bid-build road projects so as to
study the influence of those factors. The relationship between those risk factors and the project cost growth is also observed. A statistical model to predict the amount of certain cost contingency that is required to be incorporated into road project categories is then to be developed that will be based on the determination and analysis of these historical factors.

The objectives of the research are to:

- Ascertain the factors that may lead to variances between client cost estimates and the final cost at completion of road infrastructure projects.

- Rank different factors according to their influence and impact on different road project categories
- Develop project contingency profiles for identifying risks that may need to be incorporated in project cost estimating processes.
- Develop a numerical model, based on statistical theories and concepts that can allow the user to predict the amount of cost contingency that is required to balance cost growth in road infrastructure projects using information available at the time of the design estimate

To achieve the purpose and objectives of the research, information regarding the risk cost factors which can have an impact on the project construction costs was gathered by way of unstructured interviews and a detailed literature evaluation on construction risk and project cost estimating.

Following this important process, the research is being conducted in several phases. The first phase involved the analysis of historical project cost information in the period 1995 to 2003 that had been published as public documents to determine the risk factors for project cost over-runs. The second phase of the research involved the further analysis of the published information so as to categorize road project types. The third phase of the research involved the factor analysis of both the risk factors and project categories in order to distill the findings down into a useable population. The forth phase of the research proposes a statistical model to be developed to predict the amount of risk contingency to allow for as cost growth, based on the cost estimate at the design estimate time.

This paper details the literature research and the initial data analysis and its findings.

1.3 The Construction Project Process

Construction of a project may be performed by several delivery methods. For the purpose of this research a traditional method was assumed because it is by far the most generic construction process (Gould 1997) and it is this model that is usually applicable to infrastructure projects such as found in the great majority of road construction projects. The diagram in Figure 1 is presented as the traditional construction process that consists of the feasibility or preliminary design, design, construction and operation phases. Although cost control is applied in all project phases this research project focuses on cost estimating accuracy that begins in the feasibility phase and intensifies in the design phase.

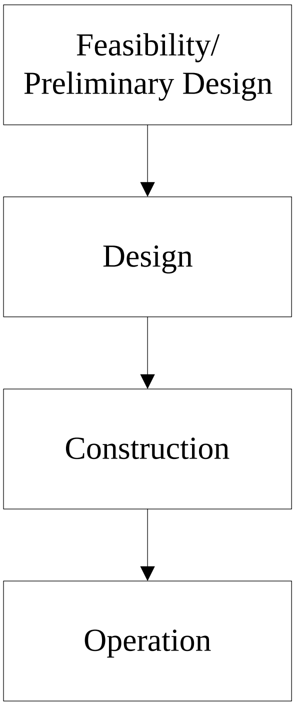

Figure 1. The Construction Project Process

Feasibility or Preliminary Design: Normally a project begins with a concept, where conceptual planning or a preliminary design will be performed and feasibility assessment will be made. During this feasibility phase conceptual drawings or a preliminary design is produced to help establish the feasibility of a project. The owner is also establishing requirements during this phase and therefore the concept's scope may fluctuate.
Design: If the project is feasible in terms of a sound business case, then a detailed design is performed. The design phase of a project will produce detailed drawings, specifications and quantity and cost schedules. During the design phase cost control is performed through scope control and value engineering. Value engineering is a team effort between designers, owners and builders to optimize the cost of a project. It is best applied in the design phase of a project and can result in savings of between 5-10% of construction costs (Mitten 1997).
Construction: During the construction phase the actual physical building of the project is accomplished. This stage is comprised of two parts, planning and execution. During the planning phase a detailed time schedule is developed and in the execution phase the actual project gets built.
Operation: The operation of a new facility begins once the construction is completed. This research project does not involve the risks or costs associated with a completed facility's operation.

For the purpose of this research project, the *total project cost estimate* includes the estimated costs of all component activities from the initiation of the project proposal to finalisation. These include the cost of:

- developing the concept design and business case,
- conducting investigations and developing the design,
- detailing the design,
- acquiring land,
- altering public utility plant,
- construction,

- project administration, and handover

Project cost over-runs create a significant financial risk to both contractors and owners; however, in spite of the risks involved, the history of the construction industry is full of projects that were completed with significant cost overruns. Sources of controllable and uncontrollable risks need to be proactively managed so as not to adversely affect a contractor's profitability (Akinci and Fischer 1998). Project performance is improved via systematic identification, appraisal and management of project-related risk (Chapman and Ward 1997).

Large-scale construction projects are exposed to uncertain environment because of such factors as planning, design and construction complexity, presence of various interest groups such as the project owner, consultants, contractors, stakeholders etc., resources such as materials, equipment, project funding, climatic environment, the economic and political environment and statutory regulations. Risk factors can also include the complexity of the project, the speed of its construction, the location of the project, and its degree of unfamiliarity. A highway or bridge construction project, for example is characterized by its linear complexity and limited design parameters in relation to certain design conditions such as ground or foundation conditions being exceeded. As well, the greatest risk lies below ground level due to the relatively larger footprint of a highway project, as compared with, say, a building structure.

1.4 Research into Construction Risk

Complexities of the project, location, type of contract, familiarity with the work and breakdown in communication are some of the significant contributors to risks in construction projects (Ahmed, Ahmed et al. 1999). Thompson and Perry (1992) state that evidence from projects worldwide show that project risks are not being adequately dealt with. Baker, Ponaniah et al. (1999) reports that in a survey of over 100 companies in both the oil and construction industries, most companies commonly respond to assessed risk, however the construction industry concentrated almost exclusively on the reduction of financial risk and less on managing technical risk. Perry and Hayes (1985) have suggested a checklist of risks that may occur throughout the life span of any project. Bent (1988), in introducing the concepts of control, said that: *the fundamental elements of control are the cost element and the project schedule* and are functions of the progress of technical performance. However, Might (1984) carried out a survey of the effectiveness of project control systems on high-risk US Department of Defence and NASA projects and his findings on control factors were unclear in respect of the effectiveness of specific control mechanisms. Uher (1994) identified thirty-four individual risks and categorised them into a single model, referring to some as “activity” risks that may affect individual activities, while other were “global” risks that were common to all activities. The majority of risks identified by Uher were global risks. Williams (1995) described various risk identification and analysis tools used by researchers and practitioners in project risk management. Tummala and Leung (1999) developed a methodology for risk management governing risk identification, measurement, assessment, evaluation and risk control and monitoring. They have applied it in managing cost risk for a transmission line project. Delphi technique has been used by Dey(1999) for identification of risk factors. Dey (2001) identified the following as the general benefits that can be achieved from the application of risk management in any type of project:

- The issues of the project are clarified and allowed for right from the start.
- Decisions are supported by thorough analysis of available data.
- The structure and definition of the project are continually and objectively monitored.
- Contingency planning allows controlled and pre-evaluated responses to risks that materialize.
- Clearer definitions of the specific risk associated with a project.
- Builds up a statistical profile of historical risk for modelling future projects.
- Encourages problem-solving innovative solutions to problems within a project.
- Provides a basis for project organization structure and appropriate responsibility matrices.

The literature has several case studies of construction risk management from general building construction (Baker, Graves et al. 1995), offshore construction (Curole 1995) or highway construction (Wang and Chou 2003). In the field of project management, risk management is a recognized practice to help managers deliver projects on schedule and within cost (Project Management Institute PMI 2000).

Studies from around the world have consistently highlighted the recurring frequency of claims for unforeseen ground conditions. In America, studies by Halligan, Hester et al. (1987) on Federal Highway Administration funded state highway construction projects indicated that, whereas claims for ground conditions accounted for only 20% of all claims when categorized by root cause, they were responsible for approximately 35% of the total dollar amount paid to contractors for claims. A study in Hong Kong by Kumaraswamy (1997), aimed at identifying root causes of claims for extension of time and extra payments on construction projects, found that unforeseen ground conditions were ranked fourth in the “top ten” common categories of construction claims as perceived by contractors, owners and consultants.

1.5 Estimating Project Costs

The project cost estimate is primarily concerned with the cost of resources needed to complete the project activities and include all the processes which are employed to maintain financial control over a project. Abbasi and Al-Mharmah (2000), Hutchings and Christofferson (2000) and White and Fortune (2002) examined various management tools and techniques with seven that have been adopted which are the most popular used in estimating and cost control. They are:

- Analogous analysis
- Parametric estimating
- Detailed estimating
- Best guess estimating
- Cash flow/S-curve
- Variances
- Earned value

The accuracy of conceptual cost estimates for capital projects has been a major concern and a subject of much scrutiny for almost 40 years. (Hackney

1986) published a checklist for establishing a detailed definition rating for capital projects. He proposed the use of the definition checklist for applying contingency to capital cost estimates and then validated the checklist by comparing the definition ratings of 30 projects to their respective levels of cost overrun. Later he revised the checklist to specifically address process projects and developed a separate checklist to apply the definition rating method specifically to hazardous waste remedial projects (Hackney 1986). In the late 1970s, the U.S. Department of Energy recognized the importance of accurate conceptual cost estimates and contracted with the Rand Corporation to study the capital cost estimation problems associated with pioneer energy and also process plants. The study determined that 74% of cost growth is caused by underestimation, that is, improper estimation (Merrow 1988).

In 1991, the Construction Industry Institute (CII) assembled a research team to study the impact of pre-project planning on overall project success for capital projects (Gibson and Hamilton 1995). The team sought to quantify the impact by establishing a success index value to rate project success. The success index value was computed and compared to a pre-project planning index value for a variety of projects (Gibson and Hamilton 1995).

Hegazy and Ayed (1998) used a neural network (NN) approach to effectively manage construction cost data and developed a parametric cost-estimating model for highway projects. Eighteen highway projects in Newfoundland, Canada were the source of the cost data and they used weightings that produced the best cost prediction for the historical case studies to find the optimum neural model.

Oberlender and Trost (2001), and again in Trost and Oberlender (2003)) reported on quantitative data they collected and analysed from completed construction projects in the process industry. The resulting model, known as the estimate score procedure, allowed a project team to score an estimate and then predict its accuracy based on the estimate score. They identified five main factors affecting estimate accuracy and, in order of significance, were:

- basic design,
- team experience and cost information,
- time allowed to prepare the estimate,
- site requirements, and
- bidding and labour climate

Engineering designs have a high level of influence on project costs (Barrie and Paulson 1992). However, design performance is usually not satisfactory. Anderson and Tucker (1994) reported their survey that found that about one third of architectural/engineering (A/E) projects miss cost and schedule targets. Chang (2002) notes that, as reported by Smith (1996), there have been few instances where an engineering design was 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).Chang (2002) reported that on four completed case study projects for environmental and engineering design services for roadway construction projects in California that were carried out on a cost-plus-fixed-fee basis, they experienced cost increases on average of 24.8%, based on the four sampled projects.

1.6 Cost Forecasting Models

The development of cost forecasting models has been summarized by Raftery and Ng (1993) as: first generation models –element cost planning in the U.K. and by bidding models in the USA; second generation models – by using the regression analysis; and third generation models – probabilistic estimates, frequently based on Monte Carlo techniques. Raftery (1994) suggests that 'range estimating' could be developed further to show the form/shape of project cost distributions. In 1996, Skitmore indicated this might be done parametrically for tender price forecasts, by fitting one of the standard probability density functions to the cumulative frequency of the tender price forecast/actual values (Skitmore 1996).

More recent research has attempted to apply artificial intelligence to the prediction of completed project costs. These efforts start with the *a priori* assumption that each project must be considered unique. Attempts have been made to develop extremely complex models that incorporate all of the many different factors and their interactions that can affect the cost of a construction project. Williams, Miles et al. (1999) described how simple linear regression models can be used to predict the completed cost of competitively bid highway construction projects in the USA using only the low bid as input. Touran (2003) proposed a probabilistic model for the calculation of project cost contingency to counter initial project cost estimates by considering the expected number of changes and the average cost of change. The model assumed a Poisson arrival pattern for change orders and independent random variables for various change orders and calculates the probability of cost overrun for a given contingency level.

1.7 Impacts of Project Changes

Ibbs and Allen (1995) defined project change as any event which results in a modification of the original scope, execution time or cost of work. Their research focused 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 a study by Hester, Kuprenas et al. (1991), it was found that most project owners assume routine changes in the work will affect only the work in the change area, whereas the effects can extend well beyond. Thomas (1985) studied highway construction programs and reported on selected claims for project changes and cost/schedule over-runs on those projects.

1.8 Common Project Procurement Types

Pakkala (2002) found that, in a global perspective, delivery of infrastructure services and products for capital investment projects varies in practice from country to country. He evaluated road infrastructure project delivery in Australia, Canada, England, New Zealand, Sweden and the USA and reported that all use a common practice for the main delivery model, known as the traditional model, or Design-Bid-Build. This means that 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.

Langford, Kennedy et al. (2003) investigated construction costs in 11 similar motorway project parcels in the UK between 1990 and 1995 where five projects were carried out by a traditional design, tender, construct method, and five were undertaken by a procurement system by which the contractor bid a lump sum for the work. As well, one project was done as a design and build project. The results of their analysis indicate that, in roadworks, the construction costs per kilometer were some 11% less expensive when lump sum contracts were used. Langford *et al* (2003) also reported that their research showed that lump sum projects were much more likely to be completed within budget and required less management by the client organisation, as well as delivering more harmonious working relationships between clients and contractors.

1.9 Literature Summary

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. The literature survey has revealed several research studies, particularly in highway construction projects, that have been conducted in an attempt to predict the amount of cost a construction contract might increase, taking into account various factors that could be used in such predictions. Research to date has generally revolved around contract cost increase data in a macroscopic way across many projects. Objective, quantitative measures for predicting the accuracy of early project estimates have been scarce. There is little research evidence that utilises a more intensive microscopic analysis of total project cost overruns using historical cost overrun data to develop cost contingency factors that can provide better estimated final project costs for project owners.

1.10 Research Project Data Analysis Methodology

The analytical procedure followed in this project entails disaggregation whereby parameters for any proposed cost overrun contingency model is based on individual projects and their data, rather than on generalization.

Microsoft Excel software is used to store and analyse the collected project data and is used to create the “base file” for the statistical analysis. The commercial statistical software package SPSS version12 for Windows is also planned to be used for the variety of statistical and mathematical analyses. SPSS has been tested extensively and provides specific operations and functionality such as factor analysis, creating indicator variables for a qualitative variable and multivariate statistical analysis. SPSS supports Excel data files and makes the transition from one to the other very convenient.

1.11 Road Project Cost Overrun Variables

The analysis of the cost over-run risk factors was carried out on 238 road construction projects throughout Queensland between 1995 and 2003 whose initial estimated project cost was more than A$1m and whose final cost exceeded the original estimate by greater than 10%. The total combined project value was A$1015b All road infrastructure data collected and analysed in this research is obtained from a single Government road source, namely the QDMR. It should also be noted that some of the initial research project findings may be strongly related to economic conditions and contracting climates that may vary from time to time.

The 238 road projects were analysed by means of a systematic review of each project and the reasons documented for each project and a list of 39 cost overrun variables was obtained. Table 1 below shows the 39 cost overrun variables derived from the published project data. As well, Table 1 also shows the occurrence of each of the cost overrun variables over the 238 projects.

Reason Code	**Reason for Variation**	**Occurrence**
D	Design/project scope change	95
TH	Contract tender price higher than original estimate	35
DD	Design scope change - Drainage	33
Q	Quantity increased measure	31
DM	Design Scope Change - pavement materials/depth	23
LUS	Latent Condition - Remove and replace unsuitable material	21
DE	Design Scope change - Environmental issues	19
CT	Constructability - under traffic	17
S	Services relocation costs	12
MP	Material cost increase – Pavement Materials	11
C	Constructability difficulty costs	10
R	Resumption/accommodation works	10
P	Project Administration Cost Increase	8
WW	Wet Weather Effects/Rework	8
LR	Latent Condition - Rock encountered	7
O	Remote location costs	7
SC	Specification Change	7
EU	Extras Unspecified	6
A	Project acceleration requirement	5
DSA	Design Scope Change - Safety Audit Requirement	4
H	Cultural heritage issues	4
LD	Latent Condition - requires design change	4
MPS	Material cost increase - Principal supplied components/materials	4
GCD	Government Initiative – Contribution by Developer	3
LSG	Latent Condition - Additional Stabilising	3
ME	Material cost increase - Earthworks	3
DF	Design Scope change - Design error	2
MQ	Material/Process Quality Issue	2
TL	Contract tender price lower than original estimate	2
DN	Design – Reduced scope change saving $	1
DPL	Design Preload Requirement	1
DSG	Design Change to Subgrade	1
G	Government Initiative - Employment continuity	1
GCLG	Government Initiative - Contribution by Local Government	1
GCR	Government Initiative - Contribution by Rail	1
MA	Material cost increase - Asphalt	1
MB	Material cost increase - Bitumen Price	1
N	Contract failure-New contract establishment costs	1
TCI	Contract Tender Price Increase due to inflation	1

Table 1: Cost Overrun Project Variables and Occurrences.

An analysis of the cost overrun which has 10 or more occurrences in the 238 projects is shown in Figure 2 below.

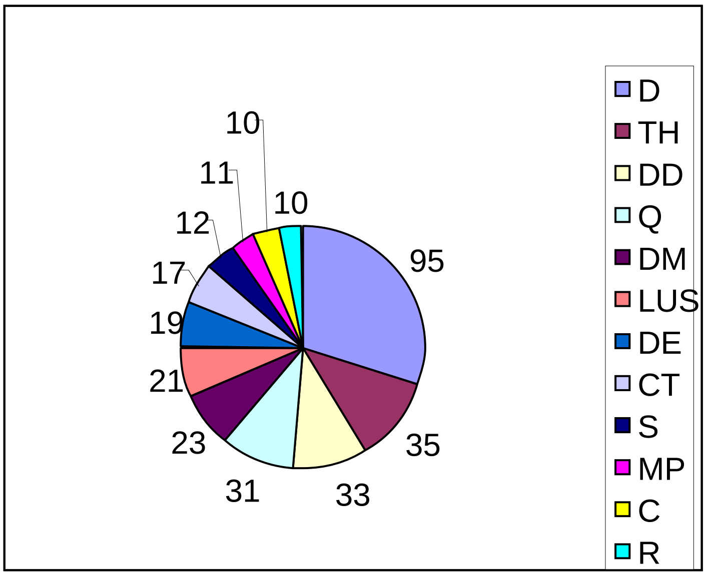

Figure 2: Major Cost Overrun Variables Occurrences

LEGEND

D	Design/project scope change
TH	Contract tender price higher than original estimate
DD	Design scope change - Drainage
Q	Quantity increased measure
DM	Design Scope Change - pavement materials/depth
LUS	Latent Condition - Remove and replace unsuitable material
DE	Design Scope change - Environmental issues
CT	Constructability - under traffic
S	Services relocation costs
MP	Material cost increase – Pavement Materials
C	Constructability difficulty costs
R	Resumption/accommodation works

The Design/project Scope Change (D) variable amounts to 31% of all the cost overruns in the 238 projects and is by far the variable that contributes to the highest incidence of overrun. Contract Tender Price Higher than Original Estimate (T) is the second highest variable occurrence and amounts to 11 of the measured factors. Design scope change – Drainage (DD) and Quantity Increased Measure are the third highest occurrences, both with 10%.

Figure 3 below shows the percentage occurrence of the 12 highest cost overrun variables.

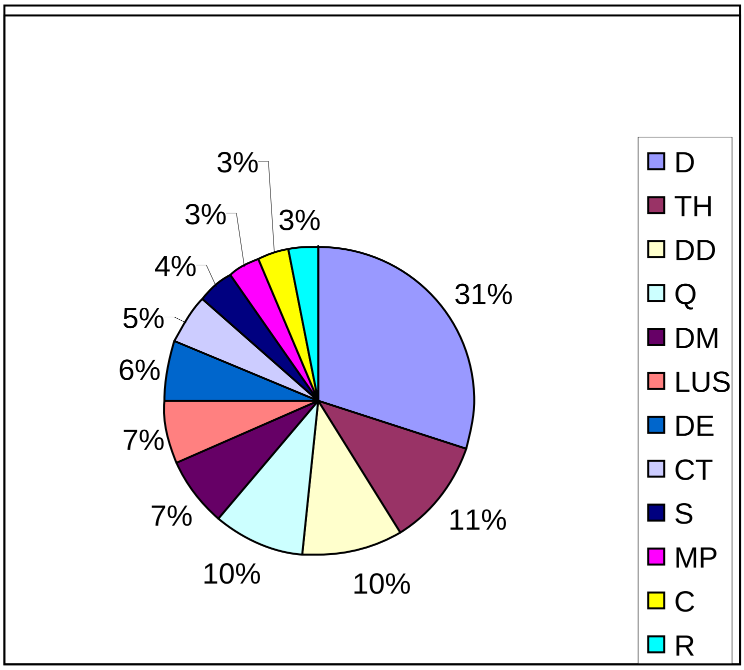

Figure 3: Percentage Distribution of Top Twelve Variables.

LEGEND

D	Design/project scope change
TH	Contract tender price higher than original estimate
DD	Design scope change - Drainage
Q	Quantity increased measure
DM	Design Scope Change - pavement materials/depth
LUS	Latent Condition - Remove and replace unsuitable material
DE	Design Scope change - Environmental issues
CT	Constructability - under traffic
S	Services relocation costs
MP	Material cost increase – Pavement Materials
C	Constructability difficulty costs
R	Resumption/accommodation works

Appendix A provides a description of the 12 cost overrun variables in the context of highway construction.

1.12 Planned Further Data Analysis

Because all the identified variables relate to the issue of cost overrun and estimate accuracy, and many were related to each other, multicollinearity is identified as a distinct problem. The next stage in the planned data analysis will utilise factor analysis on the data to overcome any multicollinearity problem. This analysis will provide a deterministic method to group variables into meaningful subdivisions, the number of which can be anywhere between one and the total number of variables.

2. Conclusion

The change in project cost, or cost growth, occurs due to many factors, some of which are related to each other, and all are associated with some form of risk. An analysis of the cost over-run risk factors was carried out on 238 road construction projects between 1995 and 2003 whose initial estimated project cost was more than A$1m and whose final cost exceeded the original estimate by greater than 10%. The road projects were analysed by means of a systematic review of each project and the reasons documented for each project and a list of 39 cost overrun variables was obtained. The Design/project Scope Change (D) variable amounted to 31% of all the cost overruns identified in the 238 projects. Contract Tender Price Higher than Original Estimate (T) was the second highest variable occurrence and amounted to 11% of the measured factors. Design Scope Change – Drainage (DD) and Quantity Increased Measure were the third highest occurrences, both with 10%.

Further planned data analysis will utilise factor analysis on the data to overcome any multicollinearity problem and should provide a deterministic method to group the cost overrun variables into meaningful subdivisions

Determining the existence and influence of these cost overrun risk factors in road construction projects may ultimately lead to better control on project cost and assist in identifying possible solutions to avoiding future overruns.

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APPENDIX A: Cost Overrun Variable Description

C **Constructability difficulty costs**

This project cost can occur where the tender rice is based on an approved construction process or sequence and this has to be varied by the Principal for certain reasons. The most prevalent cause of this cost might be that the foundation design criterion might not be achievable due to unforseen site conditions. Also, constructability difficulty costs might be incurred in a project where certain traffic arrangements must be maintained that severely restricts the economy of scale of certain construction processes such as paving runs, of concrete placement in drainage and bridge structures.

CT **Constructability - under traffic**

Increased project costs due to having to construct certain road construction processes under flowing traffic conditions can be substantial in highly trafficked areas. Whilst, generally all contracts for projects in such situations are specific in detailing the construction risks of process continuity and efficiency, there does arise situations in contracts when the contractor’s obligations are compromised by instructions and directions from the principal that would require the contractor to incur costs other than provided for in the contract provisions. Limiting a contractor’s work schedule to out of peak traffic times due to otherwise unforseen peak hour traffic congestion is one example where such additional project costs due to lower daily productivity might need to be borne by the principal. In urban areas, even say a traffic problem occurring on a nearby (arterial) road can force traffic through construction projects which normally would not have attracted such higher flows and subsequent congestion and safety issues.

Side tracking of traffic in some urban and rural projects is also a safe and efficient means of managing traffic during construction. Again, there are times when contingent emergencies or processes can occur that will disrupt this orderly traffic management strategy that results in construction processes having to be carried out under flowing traffic conditions. Again, this may be outside the control of the contractor and then could be deemed the cost responsibility of the principal.

D **Design/project scope change**

This is a general category into which all non-defined project scope changes that increase the cost are allocated. They exclude the specific areas of: drainage, environment, design error, pavement materials and pavement depth, earthworks preload, changes to pavement subgrade and changes as a result of physical site safety audits.

This variation category includes such design scope changes a vertical and horizontal alignment changes that can result in changes in quantities, as well as rework. It can include scope changes in traffic guardrail, traffic signage and kerb and channel and traffic island changes. Changes in this category are generally limited to one or a number of locations within the project and would not generally include a major design change such as the addition of further traffic lanes to the full length of the project.

DD **Design scope change - Drainage**

This category is for design scope changes specifically related to drainage and can include the addition of drainage structures where pre-existing structures are deemed to be inadequate upon detailed site inspection. In many cases, detailed site inspections cannot be adequately carried our without heavy excavation equipment. In some cases, especially where the design calls for the extension or addition to existing drainage structures, the condition of the existing drainage structure is not fully revealed until excavation work is carried out in the vicinity of the structure. Site investigation can then reveal substantial deteriation to the extent that the existing structure requires full replacement or substantial repairs. Where existing drainage structures have been constructed of corrugated helical steel pipes, it is often found that the inverts have rusted through, even resulting in scouring out of fill behind the structure. In most cases, this fact is not obvious at the time of site investigation for design because inverts can be permanently under water, or heavily silted.

Drainage design scope changes can occur when an increase is required in the flow capacity due to changes in hydraulic gradients due to conflicts with underground service installations or other expensive obstructions. In some urban and semi-urban areas, changes in zoning in upstream catchments can result in older drainage designs requiring redesign due to revised runoff coefficients as a result of planned land use. Sometimes, such design changes can be argued to be the cost to upstream developers if time permits, but in other cases, when the time horizon is sufficient far away that the additional costs would not be reimbursed from others.

A small factor that sometimes requires design consideration is when new metric drainage installations are required to join to old imperial drainage pipes and cells. The design modifications are small, but real.

DM Design Scope Change – pavement materials/depth

Pavement materials: This category occurs when there is a need to change the specified pavement materials to a different specification. This can happen for a number of reasons. Primarily, a change in material could be required where the excavated pavement box might have boor drainage and there is a possibility for moisture to build up due to difficulty in draining adequately. It may be deemed more economical to improve the specified material quality rather than install additional pavement drainage. This occurs sometimes in rock cutting subgrades where cement stabilisation might be ordered in lieu of drainage blankets or additional drainage lines. In some instances in urban construction, specified granular paving materials may be changed to asphaltic material where construction is required under traffic and there is the potential for the granular material to disperse under heavy turning traffic of create undue dust where the material cannot be kept wet due to the creation of then slippery road conditions that could cause traffic accidents. There also may be the need to install temporary traffic white lining for traffic directions and control, even overnight, which requires installation on a sound surface.

Pavement Depth: Changes in pavement depth predominantly occurs when the field measured strength of the pavement subgrade is weaker than the assumed strength for what the pavement design was based on. There is then a requirement for a revised pavement design, usually resulting in an increased pavement depth. In most cases, this also requires the raising of the grade line by the same amount that the pavement was increased. Minor regrading at bridges and new drainage culverts may be required if the pavement redesign extends over any substantial distance.

LUS Latent Condition - Removal and replacement of unsuitable material:
This process is used to overcome situations where foundation materials for pavement, drainage structures and structures are found to be inferior and the material is ordered to be removed to a specified depth and replaced with material of a certain quality. In some situations, the knowledge of the presence of unsuitable material can be ascertained by bore probes of other testing methods and adequate provision made in the schedule of quantities to cover such treatments. In cases where none or limited testing is carried out in the design stage, then it is appropriate to include only a nominal provision in the quantities to cover the risk of discovering and having to replace unsuitable material. Usually, contract provisions allow for such variations as a cost to the principal.

MP Material cost increase – Pavement Materials
Pavement design changes can substantially increase paving volumes which can lead to the risk of increased pavement materials and hence increased costs. In addition, for certain project locations, there may be no economically suitable source of paving materials and hence the material then has to be transported large distances from established quarries to the project. In some rural projects, there may be raw material suitable for paving gravel production close to a rural project but no suitable crushing equipment. It may then be a matter of establishing crushing facilities at the material source, if suitable equipment can be enticed there. In this case, the volume of paving material to be produced can be the important economic factor in determining the supply price of the paving material. Either supply option can be significantly more expensive than conventional quarries close to projects and so can have significant influence on the final cost of a project.

R Resumption/accommodation works:
Where private land is required on to which all or part of the project is to be built, the land can be purchased outright from the owner, or can be compulsively acquired under the powers of the Government. In the latter case, the land owner also has recourse to an appeal mechanism that can take a considerable period of time. The outcome of this appeal mechanism can in some circumstances increase the cost of acquiring the land for the project. In addition to compensation for the taking part land parcels, the Government is obliged to carry out accommodation works adjacent to the resumed land so as not to affect the amenity of that land. This can be costly and can increase project costs over that estimated at the time of commencement of any land procurement.

S Services relocation costs:
The road reserve is also used by services (utility) authorities under their various legislation heads. Whilst pre-approval is usually required for the service authority to install their particular facility, this approval usually obliges the road authority to pay for the cost of relocating such existing services where a new road project design conflicts. The physical relocation work is usually carried out on an actual cost basis and this can be substantially greater that preliminary estimated costs. These preliminary estimate costs are what are generally used when developing road project estimates. Actual cost figures

can be greater than estimated costs for a number of reasons, the most common is workplace safety provisions that are requires for workmen who are required to work sometimes under dangerous traffic conditions. This can lead to additional installation of temporary protective measures and/or the need to have the work carried out at night or on weekends when traffic conditions and the potential for congestion is lessened.

TH **Contract tender price higher than original estimate**:
The project estimated cost is based on the forecast tender cost of the construction component of the project delivery. Where the actual tender cost is higher than the original estimate, then there is an adjustment required to the project estimate.