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'Best practice' cost estimation in land transport infrastructure projects

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Abstract

In the road transport sector, some projects, especially large scale or complex infrastructure projects run over budget. The cost overrun is mainly because cost computations do not consider uncertainty and risk elements inherent in the projects. This paper introduces the element of risk in the cost estimation of land transport infrastructure projects. The paper is structured on the recommendations from the Evans and Peck (2008a) report on 'Best Practice Cost Estimation for Publicly Funded Road and Rail Construction' undertaken and adopted by the Department of Infrastructure, Transport, Regional Development and Local Government (DITRDLG). The essentials of risk analysis are provided, including several issues encountered by practitioners. A comparison of the P50 versus P90 cost estimation, including discussions on how to deal with the current practice of pricing contingencies in project cost estimation is undertaken. With the use of a generic project example, an empirical application of the P50 and P90 cost estimation is demonstrated. This paper is intended to draw the attention of transport agencies to the Best Practice Cost Estimation ('the Standard') in the preparation of cost estimates for any proposed project(s) that require funding from the Australian Government.

1. Introduction

Transport planners and managers in Australia often undertake benefit-cost analysis (BCA) for road transport projects, where the costs are a precursor to BCA. These costs figures are applied across a project's development life cycle and submitted to State Treasury Departments where Federal Government funding is sought. A project's life stream covers the four stages from project identification to scoping, development and delivery. Typically, costs are estimated prior to project commencement based on predictions about the future rather than actual observations. There would be an element of risk and uncertainty as the future values of a project's costs are not known. Whilst uncertainty refers to a range of values for a certain quantity where probabilities are unknown, risk refers to the possibility of loss or gain as a result of uncertainty. In project cost estimation, risk results from inaccuracies in the assumptions or technical data used as inputs to cost estimating relationships, cost overruns, overestimated benefits, technological change and failure to meet datelines. Uncertainties are a result of inaccuracies in the cost estimation methodologies (Flyvbjerg 2006 and Anderson and Cherwonik 1997). To assume that all costs included in a cash flow are estimated with certainty would be unrealistic.

This paper seeks to account for risk in estimating the project outturn costs for road transport projects. The analysis follows on the findings of Evans and Peck (2008a) where the concept of the *Best Practice Cost Estimation* ('*the Standard*') is introduced. Risk analysis is a small but critical part of project cost estimation. Risk assessment and analysis (qualitative versus quantitative), modelling techniques used, and the relationship of risk analysis with sensitivity analysis in project evaluation are all discussed. Several issues on risk estimation are highlighted for practitioners' consideration, in order to improve the alignment between *ex* *ante* and *ex post* cost figures[1]. These issues are that probability based risk analysis methods are not usually applied in project appraisal, contingencies adopted are often set too low, and the concepts of P50 and P90 values are not universally understood. Quantitative risk analysis is demonstrated in this paper with the use of a generic project example, which is employed to address these issues and to better illustrate the importance of risk in cost estimation. In particular, a comparative assessment followed by recommendations on the P50 and P90 cost estimation is provided.

2. Best practice cost estimation

2.1. *Ex ante* and *ex post* cost estimation

In the cost estimation of road infrastructure projects that are to be submitted to State Treasury Departments for funding, there are three possible scenarios where *ex ante* (budgeted) cost figures either match or do not match with *ex post* (actual) cost figures as shown in Table 1.

Table 1: Ex ante versus ex post costs for road projects

Situation	Remarks
Ex ante = Ex post	Ideal
Ex ante < Ex post	Under-estimation of funds leading to fund shortage
Ex ante > Ex post	Over-estimation of funds leading to fund surplus

Source: ARRB (2010).

The ideal situation, from a planning and budgeting perspective, is when the *ex ante* costs equate with the *ex post* cost figures and there is no need for the agency to seek additional funding[2]. Where the *ex ante* figures are less than the *ex post* figures, there is under-estimation of the budgeted costs. As the budgeted amount is less than the actual expenditure, this leads to a shortage of funds. Several reasons account for such a situation, including rising labour or materials cost pressures, increased scope of the project, under-budgeting of the project outturn cost estimate, changing economic conditions and technology changes (Flyvbjerg, 2006). This leads to a situation where additional funding needs to be sought from State Treasury Departments.

The situation when *ex ante* figures exceed the *ex post* figures reflects an over-estimation of project funds. As the budgeted figures are greater than the actual project costs, there is under-expenditure resulting in fund carry-overs between financial years. Whilst this implies that funds are not efficiently utilised by the agency, it can also mean that funds cannot be spent owing to unavoidable administrative requirements such as the time taken to obtain a clearing permit or delays resulting from a lack of labour and equipment availability, and administrative and procedural constraints (ARRB 2010).

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[1] Ex ante cost figures are estimated prior to project commencement. Ex post figures are the actual costs incurred.

[2] This situation is ideal from a planning and budgeting perspective. It does not necessarily mean that the project represents value-for-money as it could be under-budgeted, but at the risk of cutting corners or having poor quality control.

2.2. Evans and Peck findings

Road transport agencies are encouraged to adopt the *Best Practice Cost Estimation for Publicly Funded Road and Rail Construction* (‘the Standard’) developed by Evans & Peck in June 2008 (Commonwealth Department of Infrastructure 2009). The Standard should be used in preparing cost estimates for projects for which Australian Government funding is sought. It is important to adopt the Standard in the early stages of a project when there is a higher degree of uncertainty on the scope, course, implementation and outturn costs. A Concise Guide explaining ‘the Standard’ is developed for the practitioners’ reference (see Appendix 10 in Evans and Peck 2008a for more detail).

Whilst transport planners and managers can adopt their own documentation and governance processes, they should estimate costs in a way consistent with this Standard. The Commonwealth Department of Infrastructure requires that all project outturn cost estimates are reviewed and approved in accordance with the respective agency’s documented process.

Evans and Peck (2008a) state that application of the Standard will improve the alignment between *ex ante* and *ex post* figures, especially in their call for adopting the P90 method in cost estimation. The inclusion of risk in the project outturn cost estimation is regarded as an essential ingredient in project management. Sections 3 and 4 below introduce risk analysis and approaches used in estimating risk related to infrastructure investment.

3. Risks in cost estimation

The delivery of major capital projects especially those of long duration and external exposure[3], involves complex transactions with considerable uncertainty. Imperfect information exists in long-term projects and this could lead to under- or over-investment (Bebchuk and Stole 1993). Risk analysis deals with this type of uncertainty. To measure the potential overall cost of a project, it is necessary to understand the potential risks and opportunities, how these are managed, the potential financial exposure after risk management and the potential cost implications (Evans and Peck 2008b). This section describes the ways of analysing risk and how risk is incorporated in a project’s outturn cost estimation.

3.1. Qualitative and quantitative risk

There are two broad ways in assessing risk: qualitative assessment and quantitative analysis (Modarrs 2006). The former identifies the risks and opportunities, and assesses the potential consequences and treatment measures. Qualitative assessment is used as a first step in the early stages of the development of projects to guide organisational decisions on whether the projects should be carried out as illustrated in Figure 1. At this stage, the hard financial data are not yet estimated.

Having identified the qualitative risks, the portfolio of projects is presented. The outcomes of the qualitative assessment are used as inputs to the quantitative analysis. Once projects are shortlisted, the base estimates are calculated. From the base estimates, risks are modelled into each project. This forms the quantitative aspect of risk assessment.

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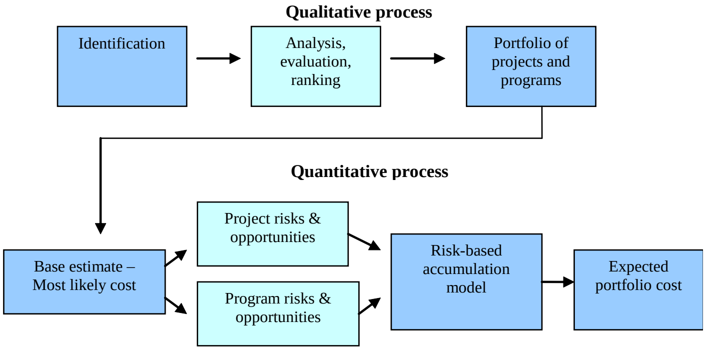
[3] Some examples of external exposure include changing economic climate, financial crisis, involvement of external vendors for the project etc.

Figure 1: Qualitative versus quantitative risk assessment

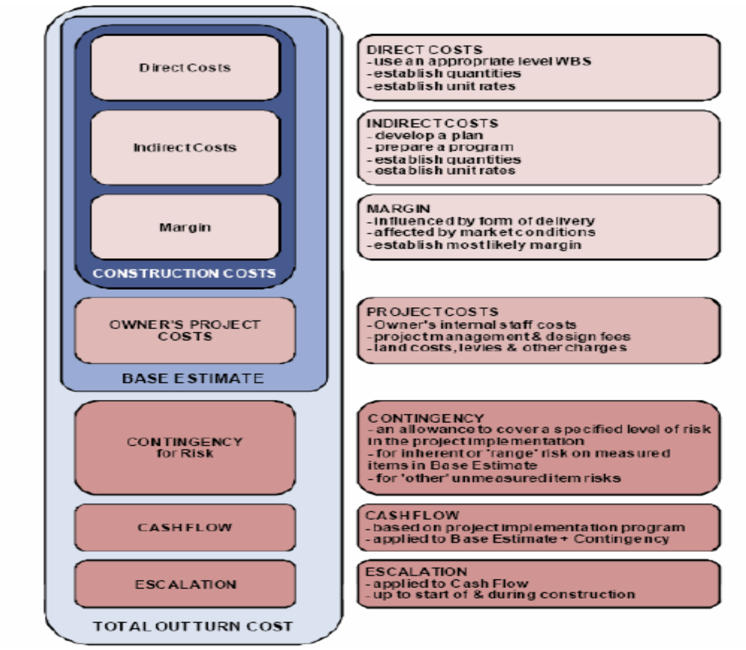


Source: Evans and Peck (2008b).

3.2. Risks in project outturn cost

As presented in Evans and Peck (2008a), the project outturn cost consists of the base estimate, contingency allowance, cash flow determination and cost escalation (see Figure 2). The base estimate consists of construction costs (direct costs, indirect costs and margin) and project costs (labour, project management and design fees, land costs, review and other charges). Contingency is understood to be an add-on to a project cost estimate to cover some element of risk or uncertainty. Risk estimation mostly reflects the calculation of the contingency allowance of the cost estimate.

Figure 2: Project outturn cost estimation



Source: Evans and Peck (2008a).

3.3. Inherent risk and contingent risks

There are two potential sources of risk namely, inherent risk and contingent risk (Evans and Peck 2008a). Both types of risk should be included in risk estimation.

Inherent (or planned) risk represents uncertainty in the scope of work and its pricing, quantities or unit rates for items in the base estimate, or variance in the construction method.

Contingent risk is due to unmeasured items outside the base estimate, which mostly correspond to the estimation of the contingent allowance. Unforeseen circumstances, such as weather impacts, industrial issues, safety, planning approval conditions, design development, owner requirements, geotechnical investigations and potential claims from contractors, are some examples.

4. Common approaches to incorporating risk

The two approaches that can be used to analyse risk in the estimation of project outturn costs are sensitivity analysis and probabilistic risk analysis.

4.1. Sensitivity analysis

Sensitivity analysis is one way of considering uncertainty by gauging the broad consequences of uncertain inputs. It is the simplest type of risk analysis and for this reason is universally used (Austroads 2005). Sensitivity analysis can be used to test if ‘designed’ changes in key inputs (variables) have considerable impact on project cost.

The main drawback of sensitivity analysis lies in the need for individuals to apply subjectivity in determining the degree of variability. Often the analyst relies on a subjective estimate of risk. If, for example, geotechnical investigation costs are believed to vary by about 20% based on a ‘ballpark’ estimate, varying values at 20% (below) and 20% (above) of the estimated cost will enter the calculations to gauge the effects on the overall cost of the project. Another drawback lies in the absence of estimation of the likelihood of the cost being higher or lower. There is an added limitation in the number of input variables tested, as even a small number of variables would result in numerous combinations, which are confusing for a decision-maker. This is not discounting the fact that some input variables may be closely correlated (e.g. road usage and maintenance costs), which may produce meaningless results (Campbell and Brown 2003).

Nonetheless, sensitivity analysis is a useful first step in determining the sensitivity of key variables and whether they should be included in a more elaborate investigation.

4.2. Probabilistic risk analysis

Probabilistic risk analysis allows for a range of possible values of input variables (including the simple case of low, most likely, or high values as in a sensitivity analysis), but goes beyond by introducing the probability factor of the project cost being higher or lower (Austroads 2005). It is sometimes referred to as part of the quantitative risk assessment (Bedford and Cooke 2001).

4.2.1. Discrete versus continuous probability function

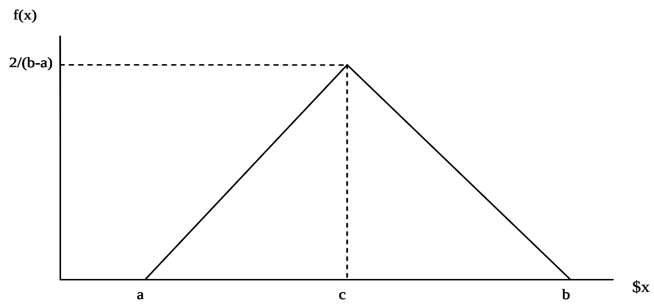
A discrete probability function applies when a finite number of values can occur. For example for the low, medium or high values, the probability of occurrence can be 20%, 30% and 50% respectively.

A continuous probability distribution applies when any value within the range can occur. Characteristics of the probability distribution include the linear distribution where each value within the specified range is equally likely.

The triangular distribution illustrated in Figure 3, assigns higher probabilities to values near some chosen point within the range of the distribution and lower probabilities to values near the boundaries of the distribution. The distribution can be described in terms of high, low or most likely values, which represent the maximum value (b), minimum value (a) and modal value (c) respectively. The distribution f(x) with lower limit a, mode c and upper limit b, can be represented in Equation (1) as:

$$f(x) = \begin{cases} \dfrac{2(x-a)}{(b-a)(c-a)} & \text{for } a \le x \le c \\ \dfrac{2(b-x)}{(b-a)(b-c)} & \text{for } c \le x \le b \\ 0 & \end{cases} \qquad (1)$$

Figure 3: Triangular probability distribution

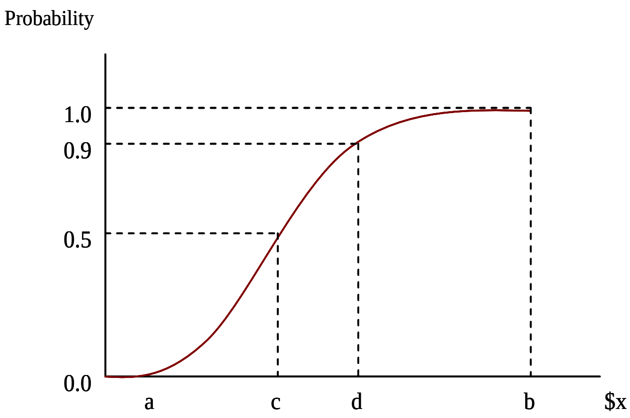


Source: ARRB (2010).

Alternatively, the information can be presented as a cumulative probability distribution curve where the vertical axis is scaled from 0 to 1. Graphically, this is represented by the ‘S’ curve shown in Figure 4. The cumulative probability curve indicates what the probability of the cost will be below (or above) a certain value.

Monte Carlo simulation is a computerised mathematical technique that allows practitioners to assess risk in quantitative analysis and decision making. Simulation techniques in Monte Carlo are useful in analysing distributions (Belli et al 2001). The simulations involve including the range of potential cost outcomes for each item based on the project cost estimates and assessing potential combinations of the costs to develop a likely range of costs for the overall project. Monte Carlo simulation runs thousands of iterations using randomly selected values in probability distribution functions as model inputs to produce numerous possibilities instead of a few discrete scenarios (Mun 2006). The results of Monte Carlo simulations essentially take into account all uncertainties and risks associated with each project. These output distributions provide a range of all possible costs and an understanding of which outcomes are more probable. In addition, the model results can provide an understanding of which cost items or risk drivers should be focused on by practitioners to reduce the project’s risks.

Figure 4: Cumulative probability distribution



Source: ARRB (2010).

4.2.2. P50 and P90 cost estimation

From an organisational point of view, the expected cost of a portfolio of projects is of more interest than the costs of projects costed separately. Individual projects are considered at the mean of a simulated cost distribution, typically the P50 estimate. The P50 cost value is an estimate of the project cost based on a 50% probability that the cost will not be exceeded. In the context of Figure 4, the P50 cost is represented as ‘c’ dollars. The P50 estimate is one with equal chance of project overruns or underruns up till when the project scope can be finalised.

The P90 value is an estimate of the project cost based on a 90% probability that the cost will not be exceeded. Project proponents (and their management) often prefer to have less commercial (and political) exposure in respect of capital budgets and often look for a P90 figure (or equivalent if done deterministically), meaning the contingency allowance on top of the base estimate is sufficient to ensure that there is a 90% chance that the amount will not be exceeded (Evans and Peck 2008a). The P90 estimate, as illustrated in the cumulative distribution curve above, will be represented by ‘d’ dollars. That is, there is a 90% chance that the cost will be less than ‘d’ dollars and a 10% chance that it will be more than this value.

5. Issues for practitioners to consider in risk estimation

There is a common occurrence where the *ex ante* cost figures are less than the *ex post* figures for a project. As mentioned in Section 2, this leads to problems when the budgeted figures are submitted for approval. When actual project costs are incurred and additional funding needs are to be sought, this may result in delays in administering and approving the revised budget with State Treasury Departments. This delay could be minimised if risks were estimated and modelled more effectively.

Four issues relating to risk and contingency deserve closer attention by practitioners. They are as follows:

- probabilistic risk methods not usually applied;
- contingencies are often set too low;
- P90 value not universally understood; and

- treatment in P50 and P90 cost estimation in BCA.

In the course of the discussion, some guidance to practitioners will be provided on each of these issues.

5.1. Probabilistic risk not usually applied

Probabilistic risk methods are not usually applied across road transport agencies. Agencies usually apply sensitivity analysis rather than probabilistic methods to model for risk. Typically, risks are assessed in a deterministic fashion and the upper and lower ranges of measured input items. The limitations lie in the subjectivity of the cost estimate and inadequacy in examining effects of a combination of variables, as mentioned.

A better procedure would be to adopt probabilistic risk analysis as it is a more sophisticated means of risk assessment and accounts for an element of expectations in the event of a project overrun. This could be applied to all stages of a project from identification to scoping, development and delivery.

5.2. Contingencies are too low

Cost estimation is particularly difficult with construction projects (McMillan 1992). For such infrastructure projects, practitioners set a desired level of confidence to meet the base estimate and the contingency is set to absorb the impacts of project uncertainty. Low levels of contingency allowances are a common issue recognised by road transport agencies. If adequate contingency levels are not accounted for, this may lead to over-expenditure and funding requirements may not be met. Recent boom conditions leading to increased labour and materials costs for infrastructure projects have affected the costing of project in Australia. Over-expenditure problems will be exacerbated especially for long-term projects (Flyvbjerg, 2009).

A good procedure will be to describe the contingency range expected at each phase of the project, particularly at the identification phase. Whether an estimate has a percentage risk allowance or a probabilistic risk assessment at a particular stage, the result should fall in the expected range as suggested by the agency's estimating procedure. There is no specific formula or accurate correlation between a contingency allowance for risk exposure determined by a percentage or a probabilistic basis. Table 2 gives some guidance as on the percentage above the base estimate that would represent the P50 and P90 levels.

Table 2: Broad correlation proposed by Evans & Peck between percentage above base estimate and probabilistic contingency allowances

Phase	Type of estimate	P50	P90
Project identification	Strategic (strategic business case)	10% to 20%	40% to 60%
Project scoping	Concept (full business case)	10% to 15%	25% to 40%
Project development	Pre-tender	3% to 7%	5% to 15%
Project delivery	Construction	Actual cost	Actual cost

Source: Evans and Peck (2008a).

5.3. P90 value not universally understood

The P90 value is not usually adopted owing to reasons that it may not be well understood. In layman’s terms, this is the value that is unlikely to be exceeded, but is also not overly conservative. The P90 value is the upper limit value not to exceed with a 10% allowance for project overruns. It can be treated as a practical ‘worst case’ value during the identification stage of the project (AACE International 2009). It means that the upper limit will only be exceeded 1 time out of 10.

Contractors typically bid jobs around the P50 value (or equivalent if done deterministically) and submit these for funding approval (Evans and Peck 2008a). The P50 value is viewed as the ‘most likely’ value of a project cost estimate.

Federal Infrastructure requires that all estimates are expressed using the P90 value or equivalent (Evans and Peck 2008a). This is strongly recommended in order to avoid over-expenditure and fund shortage. Over-expenditure can be the result of poor financial and budget planning and setting low contingency allowances for projects (refer to Section 5.2). Fund shortage can occur as a result of project delays as funds are carried forward to the next financial year. In the unfortunate event of over-expenditure, funding agencies (either State or Federal Treasury Departments) may not have allocated sufficient resources to the transport agency to enable them to complete the project without having to forgo other projects which would have otherwise been funded.

In particular, the engineering appraisals of the Queensland Department of Transport and Main Roads (TMR) advocate the use of the P90 value. Table 3 provides the yardstick adopted by TMR in the P90 cost estimation. It is observed that the P90 ranges are close to the broad correlation measures shown in Table 2.

Table 3: P90 contingency range adopted by TMR

Project development cycle phase	P90 contingency range
Strategic (strategic business case)	40-70%
Proposal	40-70%
Options analysis	n.a.
Business case estimate	30-40%
Preliminary design	20-30%
Detailed design	10-20%

Source: TMR (2009).

5.4. Budgeting versus economic evaluation

In Australia, however, a P50, rather than a P90, value is often used in project evaluation. Adopting a P90 approach would render a lower benefit-cost ratio (BCR) for projects since the costs (inclusive of risk) will be higher. This would not affect the ranking or projects if all are estimated using P90 values. It will only affect the BCRs of projects (using P90 values) when they are compared to those estimated using P50 values.

Practitioners should bear in mind these implications when using a P50 approach when evaluating and prioritising their investments. Current practice tends to adopt the P50 measure in economic evaluation. Federal Infrastructure[4] recommends the use of the P90 cost estimate in financial budgeting.

Furthermore, this raises the issue of a smaller number of projects developed when the P90 method is applied. Given that total fund availability is fixed, it can be argued that the P50 method could lead to more projects being approved in the first place, as opposed to using the P90 estimation method. However, a P50 estimation may not be desirable especially if all or most of the projects end up being under-budgeted[5]. A situation like this is likely to lead to fund shortages and a need for seeking additional funding from State Treasury Departments. There is also the possibility of projects not being completed or delivered on time given these funding shortages. Consequently, a P90 estimation may be preferable as it ensures fund availability albeit at the expense of a smaller, but more realistic, portfolio of completed projects.

6. Empirical application of 'the Standard'

6.1. Project example

To guide agencies using a walk-through example, Table 4 shows a project where 'the Standard' can be applied[6]. The four phases of a project's life cycle, i.e. project identification, scoping, development and delivery, are illustrated in the example.

- **Project identification**. The project is identified as a road construction project for the agency. At this stage, the estimation structure and presentation in terms of inputs for the base estimate, risk and contingency, cash flow and escalation have to be catered for. The base estimate is $47.7 million, and increases to $66.7 million after including contingency using the P90 estimation. It is noted that the P90 value uses a contingency allowance of about 40% of the Base Estimate, based on the broad correlation measures as proposed by Evans and Peck (refer to Table 2).
- **Project scoping**. The scoping phase is where the business case is completed and the outturn cost is estimated. The base estimate has increased to $53 million with higher owner's cost and construction cost. The contingency value is lower (about 25% of the base estimate) using the broad correlation measures in Table 2 as a guide. The P90 value is $66 million after accounting for contingencies.
- **Project development**. This is the stage where Australian Government funding is sought. Prior to that, the design and documentation is completed and it must be submitted for review and approval by the appropriate Commonwealth government personnel. The agency is then ready to call tenders with the pre-tender estimate. Compared to the scoping stage, the base estimate is higher given the increased owner and construction costs at $60.2 million. The change management procedure is to adjust the P90 value downwards by scaling down the contingency allowance to 10% of the base estimate given the greater degree of certainty associated with project costing during the development stage.

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[4] In November 2007, Federal Infrastructure engaged Evans & Peck to develop a Best Practice Cost Estimation Standard for proposed construction projects on the National Land Transport Network that require Australian Government funding (refer to Evans and Peck 2008a)

[5] This does not preclude the possibility where some projects are over-spent and some are under-spent, in which case, funds for the road agency cancel out at the aggregate and fund shortage does not occur.

[6] A generic project example is used in this study to maintain the confidentiality of individual agencies' project information.

- **Project delivery.** Once funding is approved, the contract can be awarded. Actual works would have occurred and been completed. All claims would have been resolved and project accounts would be completed and closed. As such, there is no contingent allowance. The Base Estimate is slightly higher ($64.8 million) and it is within the range of the original budgeted figure of $66.7 million at the identification stage.

Table 4: Project estimate summary: history of estimates (example)

Project phase	Identification	Scoping	Development	Delivery
Base Date:	2010	2011	2012	2013
Concept Development				
Route/Concept/EIS	320,000	420,000	420,000	420,000
Project Management Services	200,000	250,000	250,000	250,000
Sponsor	150,000	120,000	120,000	120,000
Community Liaison	90,000	120,000	120,000	120,000
Subtotal Concept Development	**760,000**	**910,000**	**910,000**	**910,000**
Detail Design and Documentation				
Investigation and Design	2,600,000	2,700,000	2,700,000	2,700,000
Project Management Services	1,200,000	1,100,000	1,100,000	1,100,000
Sponsor	120,000	150,000	150,000	150,000
Community Liaison	180,000	220,000	220,000	220,000
Subtotal Detail Design and Documentation	**4,100,000**	**4,170,000**	**4,170,000**	**4,170,000**
Property Acquisition				
Acquire Property	3,750,000	4,000,000	4,200,000	4,800,000
Professional Services for Property	275,000	275,000	300,000	350,000
Project Management Services	170,000	140,000	140,000	170,000
Sponsor	100,000	110,000	120,000	150,000
Subtotal Propery Acquisition	**4,295,000**	**4,525,000**	**4,760,000**	**5,470,000**
Total Owner's Cost	**9,155,000**	**9,605,000**	**9,840,000**	**10,550,000**
Construction: *Contractor's Direct Costs*				
Utility Adjustments	3,100,000	3,250,000	3,300,000	3,400,000
Bulk Earthworks	5,500,000	5,500,000	6,000,000	6,000,000
Drainage	1,300,000	2,200,000	3,200,000	3,200,000
Retaining Walls	2,300,000	2,700,000	3,000,000	3,500,000
Bridges	3,000,000	2,700,000	2,800,000	3,300,000
Pavements	8,600,000	7,600,000	7,750,000	7,800,000
Noise Barriers	1,100,000	1,400,000	2,750,000	3,000,000
Road Lighting	750,000	1,000,000	1,100,000	1,300,000
Road Furniture and Safety Barriers	650,000	1,000,000	1,100,000	1,300,000
Road Markings and Signage	430,000	600,000	750,000	850,000
Traffic Signals	0	0	1,000,000	1,000,000
Traffic Information Systems	0	500,000	600,000	800,000
Environmental Works	375,000	1,850,000	1,850,000	2,300,000
Landscaping	300,000	500,000	500,000	750,000
Other	125,000	200,000	220,000	250,000
Subtotal Contractor's Direct Costs	**27,530,000**	**31,000,000**	**35,920,000**	**38,750,000**
Contractor's Indirect Costs				
Preliminaries (24%)	6,607,200	7,440,000	8,620,800	9,300,000
Directs - Subtotal	**34,137,200**	**38,440,000**	**44,540,800**	**48,050,000**
Contractor's Offsite Overhead and Margin (13%)	4,437,836	4,997,200	5,790,304	6,246,500
Total Construction Cost (TCC)	**38,575,036**	**43,437,200**	**50,331,104**	**54,296,500**
Base Estimate (Owner's Cost + Construction Cost)	**47,730,036**	**53,042,200**	**60,171,104**	**64,846,500**
Contingency - Inherent risk	11,000,000	7,500,000	4,000,000	0
Contingency- Contingent risk	8,000,000	5,500,000	2,000,000	0
Base Estimate + Contingency (Inherent + Contingent)	**66,730,036**	**66,042,200**	**66,171,104**	**64,846,500**
Escalation: 17.5% for Identification & Scoping, 12.5% for Development, 6.5% for Delivery	**11,677,756**	**11,557,385**	**4,301,122**	**4,215,023**
Total Outturn Cost	**78,407,792**	**77,599,585**	**70,472,226**	**69,061,523**

Source: Adapted from Evans and Peck (2008a).

6.2. P50 versus P90 cost estimation

Table 5 illustrates the difference between the P50 and P90 cost estimation and the importance of adopting a P90 estimate using the same project example as shown in Table 4[7].

At the project scoping stage, the Base Estimate (owner's cost plus construction cost) is $47.7 million. Under the P50 estimation, $5 million (about 10% of the Base Estimate) is catered as contingency, of which $3 million is set aside for inherent risk and $2 million for contingent risk. The Base Estimate plus contingency is $52.7 million. The total project outturn cost, inclusive of escalation is $62 million.

Under the P90 estimation, $19 million (about 40% of the Base Estimate) is reserved for contingency with $11 million reserved for inherent risk and $8 million for contingent risk. The Base Estimate plus contingency is $66.7 million. The outturn cost inclusive of escalation is $78.4 million.

The project example shows that the actual outturn cost during project delivery ($69 million in Table 4) is well under the original P90 outturn estimate of $78.4 million in the identification stage. This arises as the P90 cost estimation was adopted at the early stage during project scoping. Had the P50 cost estimate been adopted, there would have been a deviation of $7 million between the actual ($69 million) and budgeted P50 figure ($62 million). The project would have been under-budgeted.

Table 5: Project scoping: Example of probabilistic risk assessment using P50 and P90 values

Item	Base estimate	P50	P90
Base Estimate (Owner's Cost + Construction Cost)	**47,730,036**		
Contingency - Inherent risk		3,000,000	11,000,000
Contingency - Contingent risk		2,000,000	8,000,000
Base Estimate + Contingency		**52,730,036**	**66,730,036**
Escalation (applied to Base Estimate + Contingency)		**9,227,756**	**11,677,756**
Total Outturn Cost		**61,957,792**	**78,407,792**

Source: Adapted from Evans and Peck (2008).

6.3. Empirical application

6.3.1. Risk analysis application

In order to measure and estimate the levels of uncertainty associated with the project, a study of the risk levels is carried out. Different software packages can be used to run the Monte Carlo simulations e.g. @RISK, Risk Explorer, Risk Simulator. For the project example (as per Table 4), Risk Explorer, a proprietary tool developed by ARRB Group Ltd. for Austroads, was employed. The tool uses computer simulation to estimate the uncertainty levels and probability distributions. The distributions derived aid the practitioner in decision making and in determining the level of investment for each stage of the project.

[7] The base cost estimate remains the same regardless of whether the P50 or P90 cost estimate is undertaken.

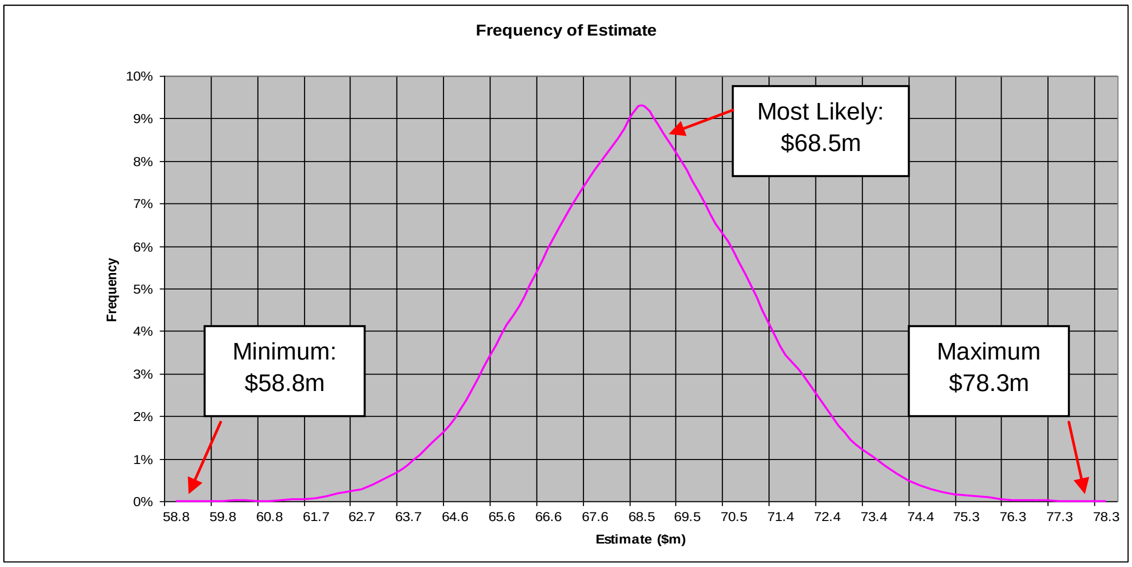
The project identification stage is selected for the empirical work as this is the phase where financial budgeting commences. The base estimate (plus contingency), cash flow and escalation have been estimated with the aid of the Risk Explorer. The input parameters and values were entered into the software using the data from the project example at project identification i.e. base period of 2010 (refer to Table 4). Monte Carlo simulations, embedded in the software, consisting of 50,000 iterations, were conducted.

6.3.2. Base Estimate (plus contingency allowance)

In the project example, the base estimate (plus contingency allowance) was $66.7 million, consisting of $47.7 million as the base estimate, $11 million as inherent risk and $8 million as contingent risk. These figures are based on a P90 estimate using the broad correlations between the percentage above the Base Estimate and probabilistic contingent allowance as shown in Table 2.

Instead of the broad correlation measure, a formal probabilistic risk analysis as described in Section 4.2 was adopted. A triangular distribution, which displays the lowest cost value, most likely value and highest value, is generated in Risk Explorer (Figure 6). The horizontal axis shows a range of values (possible values) and the vertical axis the frequency of the occurrence of a given number. From the Base Estimate, the minimum cost estimate is $58.8 million, the most likely is $68.5 million and the maximum value $78.3 million. This provides some form of guidance for practitioners, who should take into account these three values in the course of financial budgeting.

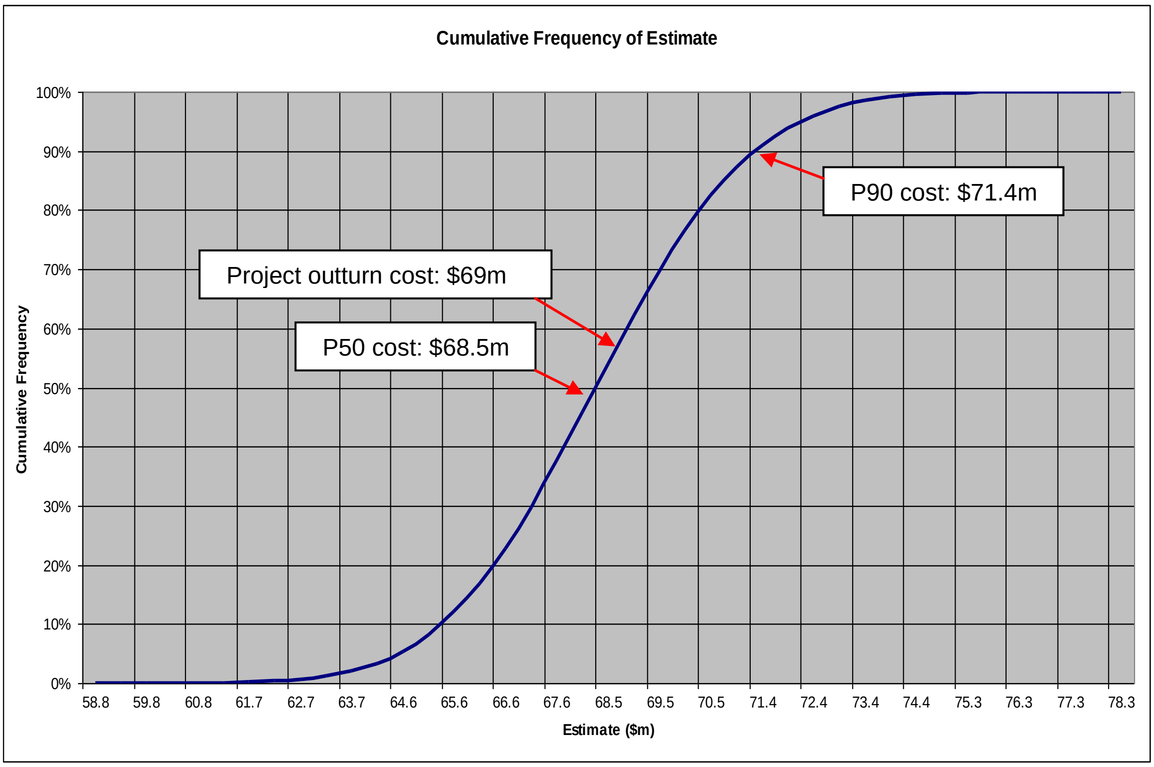
Figure 6: Triangular risk distribution



Source: Risk Explorer, ARRB Group Ltd.

The cumulative probability distribution, illustrated by the ‘S’ curve as described above, is produced in the Risk Explorer. Figure 7 illustrates that there is a 90 per cent probability that the total project costs will be below $71.4 million and a 50 per cent probability that the total project costs will be below $68.5 million. From Table 4, given that the actual project outturn cost was $69 million during project delivery, this falls under the $71.4 million (P90 mark on the ‘S’ curve). Had the P50 value been applied (i.e. $68.5 million), the outturn cost ($69 million) would have exceeded the P50 value. Therefore, the P90 value should be the commercial decision undertaken by practitioners.

Figure 7: Project cost probability distribution function



Source: Risk Explorer, ARRB Group Ltd.

7. Conclusion

This paper is intended to draw the attention of transport agencies to the Best Practice Cost Estimation ('the Standard') in the preparation of cost estimates for any proposed project(s) that require funding from the Australian Government. The application of 'the Standard' will assist the Government in their understanding and appraisal of project proposals, and improve the preparation of cost estimates that form part of the documentation to make them more transparent, reliable and consistent.

The incorporation of risk should be a necessary step in project cost estimation at all stages of a project, by applying the P90, rather than the P50, value. It is claimed that adoption of the P90 value will improve the alignment of cost estimates between the Australian Government and transport agencies.

It is envisaged that 'the Standard' applies to any project and leads to greater certainty in the outturn of cost estimates for the entire project development life cycle, and will have in place good governance to foster good estimation practices. Whilst not imposing a requirement, 'the Standard' may over time, influence agencies to redefine their own project phases and adopt the Best Practice Cost Estimation principle as developed in Evans and Peck (2008a).

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