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Abstract

Accuracy in cost estimating under conditions of uncertainty, as is typical of most construction projects, is an issue of immense concern for clients, project managers, contractors, and all other stakeholders in construction works. It is an issue of continuing interest and has attracted a lot of scholarly attention from researchers and innovators. Accurate cost estimates are needed for planning and budgetary phases of road projects by highway agencies.

Highway projects have historically experienced significant cost overruns often rooted at the point of the decision to build. However the basis for assessing the level of cost overruns continues to elicit diverse opinions and has become a debatable issue in the literature, with some authors alluding to the estimate developed at the detailed design stage as opposed to the preliminary conceptual estimate as the true benchmark to be used in quantifying the level of cost overrun.

A survey of literature sources principally from scholarly articles and research programs undertaken by various highway agencies is carried out, with a view to identifying and defining the critical phase of development which should constitute the basis upon which investment estimates are to be predicated. This paper thus evaluates and synthesizes the theoretical basis of accuracy in estimating, outlines the nomenclature of the developmental phases of highway projects as evident in the literature and builds upon the argument raised by earlier authors: Wachs (1989); Simon (1991) and Flyvbjerg et al (2002).

Keywords:

Accuracy of Estimates, Conceptual Estimates, Cost Overruns, Development Phases, Highway Projects

1. Introduction

The development of accurate and reliable cost estimates in highway construction work has been a major focus for clients and contractors (Baccarani, 2004; Tan and Wakmasha, 2010; Asmar et al., 2011). The cost performance of construction projects is emphasized by Baccarani (2004) as a key success criterion for project sponsors against the background that construction projects are notorious for running over budget. A practical index used for evaluating the level of accuracy of estimates is cost overrun (Bordat et al., 2004; Cantarelli et al., 2010). Cost overrun is the excess amount of money expended at the conclusion of a project in excess of the initial projected cost figure. Tan and Makwasha (2010) stated that in the cost estimation of road infrastructure projects 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: Cost estimation scenarios

<table>
<thead>
<tr>
<th>Ex ante = Ex post</th>
<th>Ideal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ex ante &lt; Ex post</td>
<td>Under-estimation of funds leading to fund shortage</td>
</tr>
<tr>
<td>Ex ante &gt; Ex post</td>
<td>Over-estimation of funds leading to fund surplus</td>
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</table>

(Source: Tan and Makwasha, 2010)

Inaccurate estimates have been established in the literature to be a major source of cost overruns for highway projects which can lead to delays and even total project abandonment (Steven and Oberlender, 2003; Donell, 2005; Asmar et al., 2011). Other authors have convergently stated that bridging the gap between *Ex ante* and *Ex post* estimates is a major challenge for most highway agencies (Ogunlana, 1989; Phaubunjong, 2002; Mahamid, 2011).

Evans and Peck (2008) graphically illustrated 3 project scenarios of project performance:

- An ideal project;
- An acceptable project;
- An unacceptable project.

The ideal project was defined as one in which the final cost coincides with the conceptual cost without reliance on contingency allowance. The acceptable project was defined as a project whose final outturn cost does not exceed the sum of the initial projected cost and contingency allowance.

An unacceptable project was defined as to be a project whose final cost far exceeds the initial cost plus the contingency allowance as shown in figure 1. They noted regretfully that this last project scenario was however the common trend in highway projects.
2. Literature Review

2.1. Accuracy of Estimates in Highway Projects: Scale of the Problem

Empirical studies show that time and costs are often exceeded (Flyvberg et al., 2002; Bordat et al., 2004; Baccarini, 2004). The widely referenced research by Flyvberg et al (2002) revealed a non improvement in the practice of cost estimation globally over the last century, with cost overruns remaining consistently on the high side for major transportation infrastructure projects. The authors revealed based on analysis of 258 projects infrastructure project costs sampled worldwide worth $90 billion, that 90% of projects were underestimated. Actual costs were on average 20% higher for road projects.

Several notable projects have been shown in the literature to have experienced cost overruns of huge proportions. Creedy (2006) reported that in the United States, a central artery tunnel located in Boston and popularly referred to as the ‘Big Dig’ was publicized to have incurred a monumental cost overrun of over 600% and attracted critical media exposure. The initial estimated figure of 2.6 billion US dollars in 1982 was shown to have escalated to above 14 billion dollars by 2002. Creedy (2006) also reported that in Australia, based on the Queensland Government’s Road Implementation Program, most projects estimated at more than one million dollars had significantly exceeded their decision-to-build estimates.

The UK Transport and Road Research Laboratory (TRRL, 1999) in investigating the phenomena of cost overruns revealed an equally large range of cost overruns above 50% for six out of 21 projects carried out in developing countries. Two of these projects were in an upper range from 100 to 500%. Three and four projects respectively experienced overruns in a lower range of 20 to 50% and 10 to 20%. Also, the African Infrastructural Country Diagnostic (AICD, 2008) study of the performance of road infrastructure investment budgets focused on 24 countries in sub-Saharan Africa. The AICD findings corroborate those carried out by Flyvberg et al (2002) and also revealed that on the average, cost overruns were substantially higher in developing countries than in other developed countries with ranges of up to 700% evidenced in some of the analyzed contracts.

The ideal scenario of equality in ex-ante and ex-post (Tan and Makwasha, 2010) is what every project should strive to achieve. However this is rarely the case as most times project costs tends to overshoot initial budgets leading to delays and other issues. For Transportation Agencies, Alavi and Tavares (2009) posited that cost overruns can lead to adverse consequences, including:

- Disruption of plans, postponement, or cancellation scheduled projects to satisfy budgetary constraints;
- Reduction in project scope, resulting in projects that do not fully provide the service initially intended;
- Extension in construction duration until additional funds become available;

They thus concluded that an eventual misallocation of design resources creates false expectations with the public and other stakeholders. This is because any upward increment in budgeted figure set aside for a project means a corresponding deduction from funds voted for other projects. They reported that in 2002 the Virginia Department of Transportation (VDOT) had to postpone or cancel 166 projects due to lack of funding occasioned by cost overruns.

The occurrence of cost underestimation has been shown in the literature to be a pervasive trend in highway agencies. Inaccuracy of estimates expressed as cost overruns for infrastructure
projects have therefore become a common global problem for Transportation Agencies with Federal, State, Regional, and local transportation agencies grappling with the discrepancy between budgeted costs and actual costs of projects they sponsor (Turouchy et al., 2001; Flyvberg et al., 2002; Tan and Wakmasha, 2010).

2.2. Cost Estimation in the Project Phases

Cost estimates are projected throughout the various phases of a project development. These development phases have been outlined in the literature to portray how projects advance from inception to completion and how various cost estimation inputs vary (Phaobunjong, 2002; Chou, 2005; Tan and Wakmasha, 2010; Asmar et al., 2011). It has however being noted by the researcher that in the literature various terminologies abound for labeling the development phases of projects, often leading to ambiguity as to which phase of development is being referred to as the initial phase. The following section summarizes the nomenclature of these phases as described by various authors.

Phaobunjong (2002) categorized the project development phases into: The Conceptual Phase; Design/Engineering Phase; Execution Phase. Figure 2 below is a flowchart representation of the estimation basis used for cost planning and control activity as depicted by Phaobunjong (2002).

![Figure 2. Cost estimates in project planning (Source: Phaobunjong, 2002)](image)

He discussed the estimation of complimentary estimates for each phase as the key element of cost control and management required in project development and noted that the principal costing activity in the conceptual phase constitutes the basis of planning and control of later estimates at the design and engineering phases. At this later point more elements become defined and the increased availability of project information leads to a revision of cost estimates which becomes the basis of procurement and construction.

Sabol (2008) used a similar 3 phase development configuration to graphically convey the degree of project detailing typical in projects as shown in figure 3. Though this was carried in respect of building projects and estimate types typically associated with different phases, an analogy can be drawn for highway projects.
Preliminary estimates as explained by Sabol (2008) are made from high level generic data pertaining to projects and are of particular importance during project finance sourcing. More detailed estimates made at the point of more comprehensive design details of project features, referred to as fair-cost estimates are of higher accuracy and are typically used at the contractual phase of projects for bid evaluations. At this point, essential features of a proposed project are identifiable. Definitive estimates are made when all engineering project details as to plans and specifications are complete.

Project information and development phases, specific for highway projects, are also discussed in the literature (Chou, 2005; Tan and Wakmasha, 2010; Asmar et al., 2011). The identified phases as revealed in the literature are noted by the researcher as structured in recognition of the technical bureaucratic details and procedures requisite for obtaining funding approval often needed in public infrastructure projects.

Asmar et al (2011) outlined the following five stages in project development in the context of level of completeness of design details and the corresponding estimate type required at each phase of highway project development: Planning and scoping; Environmental process; Preliminary design; Final design; Advertise and bid. These phases as represented in figure 4, were outlined in relation to the typical project lifecycle for the Wisconsin Department of Transportation (WisDOT), to reflect the types of cost estimates produced and their typical ratios of design completion. The point at which approximately 30% of designs are complete is set to provide basic information to the agency on which to base approval and funding decisions; as well as to establish a project baseline cost required for budgeting in the proposed development.
Chou (2005) equally analyzed timeframes and the context of estimating for highway projects using a simplified illustration, as shown in figure 5, of the major stages of development of projects. He categorised the stages of project development in the context of the Texas Department of Transport (TxDOT).

The first stage of project development for the TxDOT is the investment stage. This is the crucial initial point where a project is introduced into the departments long range plans, which are prepared to span a period of twenty years. The estimate at this point is prepared to analyse the feasibility of a proposed scheme, with high feasibility projects given higher priority. The projects then proceeds to the next phase where alternative layouts are compared for their environmental impacts. Subsequent to this, schematic estimates are then prepared which determine the funding requirement of projects. This is the point at which a scheme can be definitively described as a project with responsibility passing from planners to designers at the Plan, Specifications and Estimate (PS & E) stage.

Evans and Peck (2008) in a report evaluating estimating practices of Highway agencies in Australia labelled project phases as shown in figure 6 according to the Australian Federal Infrastructure’s Notes on Administration: Project Identification; Project Scoping; Project Development; Project Delivery. This was done in the bid to create commonality in the phases of development used by all Australian highway agencies. At the Project Identification phase specific project cost data is unavailable and as such benchmark rates are used for the purpose of carrying out cost/benefit studies comparing project alternatives and not necessarily for budgeting purposes. An estimate which serves as a business case for the chosen alternative is subsequently produced at the Project Scoping phase.
The Project Development phase entails detailed planning, including; environmental approval; land, acquisition; community consultation; and design preparation processes. The Project Delivery phase covers construction and commissioning, requiring periodic estimates in reporting progress and ensuring cash flow until project completion.

2.3. Accuracy of Estimates in the Development Phases

Despite the different nomenclature used to identify phases of highway development as depicted in the literature, the starting point or basis of estimation for any project is the one projected early at the initial planning/budgeting stage during which a business case is identified and investment decisions have to be made. These very early estimates labeled as conceptual estimates in this paper, however exhibit the greatest amount of uncertainty (Schexnayder et al 2003; Oberlender, 1998). Figure 7 shows the distribution pattern of estimated costs around the final costs as projected by Schexnayder et al (2003).

![Diagram of project phases](image)

Figure. 6. Project phases in the Australian context (Source: Evans and Peck, 2008)

The plus or minus 40 percent confidence range typically associated with these estimates as illustrated by Schexnayder et al, (2003) in figure 7, reflects the lack of definite project information. Turochy et al, (2001) opined that each successive phase of the project life cycle is
more influential as the focus narrows on the amount each project will cost with a corresponding reduction in contingency allowance. Schexnayder et al., (2003) thus stated that subsequent estimates are made throughout project design as continuing checks on initial cost expectations. It was further opined that the later estimates that are added are necessarily assumed to be increasingly accurate cost predictors. The confidence intervals thus diminish to the final definitive estimate which is expected to be within an accuracy range of + or – 5% of actual project costs symmetrically distributed around the actual costs.

Oberlender (1998) equally described that the accuracy range for a typical project usually shows a trumpet shape which is narrower as the project evolves, depicting the typical assumption that estimates tend on average to equal actual project cost with the level of uncertainty declining monotonically over the duration of project development.

Several standards of best practice are also evident in the literature which define the level of accuracy achievable for estimates, based on the level of detail available at the various stages of project development: The Department of Energy (DOE) Guide (2011); The GAO Cost Estimating and Assessment Guide, (2009); The Association for the Advancement of Cost Engineering (AACE, 1997). These standards serve to provide uniform guidance and best practices prescribing methods and procedures of estimating that can be used for varying levels of scope definition and detail.

Typically, the Association for the Advancement of Cost Engineering (AACE, 1997) developed a cost classification system, shown in table 2, based on the purpose and level of project definition in the preparation of cost estimates.
Table 2: AACE Generic Cost Estimating Classification Matrix.

<table>
<thead>
<tr>
<th>Estimate Class</th>
<th>Level of Project definition</th>
<th>Typical purpose of estimate</th>
<th>Expected Accuracy range (variation in low and high ranges)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 5</td>
<td>0 – 2%</td>
<td>Screening or Feasibility</td>
<td>L:20% to -50%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>H: +30% to +100%</td>
</tr>
<tr>
<td>Class 4</td>
<td>1to 15%</td>
<td>Concept Study or Feasibility</td>
<td>L: -15% to -30%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>H: +20% to +50%</td>
</tr>
<tr>
<td>Class 3</td>
<td>10 to 40%</td>
<td>Budgetary, Authorization</td>
<td>L: -10% to -20%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>H: +10% to +30%</td>
</tr>
<tr>
<td>Class 2</td>
<td>30 to 70%</td>
<td>Control or Bid/Tender</td>
<td>L: -5% to -15%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>H: +5% to +20%</td>
</tr>
<tr>
<td>Class 1</td>
<td>50 to 100%</td>
<td>Check Estimate or Bid/Tender</td>
<td>L:3% to -10%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>H: +3% to +15%</td>
</tr>
</tbody>
</table>

(Source: AACE Recommended Practice No. 17R-97, 1997)

From the guide typical conceptual estimates useful for budget authorization fall between class 4 and 3 on the scale of 1 to 5 with class 1 bid/tender estimates being the most accurate. The expected range of accuracy for such class 4 and 3 estimates is within a lower limit of -20% and an upper limit of +50% at a 10 to 40% level of project definition as shown in figure 9.

![Figure 9: Degree of Variability in Accuracy of AACE Estimate Classes as Portrayed by the Department of Energy (DOE, 2010)](image)

Class 2 and 1 estimates on the other hand, often generated after detailed designs (70 to 100% project definition) used in bids/tenders, have a higher level of accuracy implied by the lower level of variability (+/- 3 to 15%) of estimates from the final cost.
2.4. **Accuracy of Cost Estimates: Critical Cost Overrun Phase for Highway Projects**

Cost overrun is measured as actual out-turn costs minus estimated costs as a percentage of estimated costs (Creedy, 2006). Actual costs are defined as real, accounted construction costs determined as being expended from the point of contract award to the time of project completion (Flyberg et al., 2002). “Estimated costs are defined as budgeted or forecasted construction costs determined at the time of the decision to build” (Cantarelli et al., 2010). The authors equally affirmed that the estimate designated by highway authority based upon which the decision whether or not to implement the project becomes increasingly changed to the estimate based on which a formal contract is awarded and up to point of project completion.

The literature shows a strong and still on-going debate on the basis to be used for estimating the level of cost overruns. Principally, project promoters are adverse to the adoption of the initial phase of highway project development which represents the time-of-decision-to-build as a benchmark on the premise that it constitutes an unfair basis for such assessment (Simon, 1991). Odeck (2004) was of a similar view and supported this stance stating that the estimate generated at the detailed design and specification should be the basis on which planning approval and funding for projects ought to be sought. This argument was raised in concordance with of the practice of parliament in the Norwegian context. The author recognized the highly challenging situation often resulting from project cost underestimation at the planning stages and outline proposal phases presented to the decision makers. He asserted that decision makers in evaluating the viability of projects are misled and will therefore base funding approval on this deceptive basis. His argument was thus that at the detailed design, the actual viability of a project will be known, and noted early enough by the decision makers who can then resolve to choose one of the following three alternatives:

- Not to implement the project at all;
- To implement the project in another form;
- To implement other project or projects.

He thus concluded that the detailed design stage should in effect be considered as the critical estimate phase to be logically used for assessing the level of cost overruns.

Several other authors have however argued otherwise, stating that the initial conceptual estimate is the most crucial estimate which should serve as a benchmark for assessing the level of cost overrun (Chou, 2005; Anderson et al., 2006; Creedy, 2006; Cantarelli et al., 2010, Tan and Wakmasha, 2010). Asmar et al (2011) states that an estimate at this stage is ideally needed to provide information to highway agencies on which to base approval and funding decisions as well as to establish a project baseline cost and budget. It was also noted by Sabol (2008) that the conceptual estimate represents the first point of effort made at assessing the potential cost of a project necessary to align decision-making.

Along similar lines of argument, key authors, Flyvbjerg et al (2002) in furtherance of the assertions of Wachs (1989) almost three decades ago, provided a strong justification in defense of this stance stating that:

> “When the focus is on decision making, and hence on the accuracy of the information available to decision makers, then it is exactly the cost estimate at the time of making the decision to build that is of primary interest. Estimates made after the decision to build are by definition irrelevant to this decision” (p 4).

The argument of these authors was rationalized on the following grounds:
- The impossibility of assessing how informed the basis for decisions are and the uncertainty associated with budgets.
- The deliberate concealment of project details and facts likely to reflect the true financial implications of a proposed project termed as ‘Salami tactics’.
- The need to have a uniform platform for consistent comparisons of projects.

The authors noted that this preliminary phase was also used for computing cost overruns as the international standard. In line with these assertions, Evans and Peck (2008) further went on to state that:

“The cost estimate produced at the preliminary phase is the first cost estimate in the life of a project that should be able to be relied upon for program purposes and taken forward through future phases” (p.18).

This was stated against the background that for government funded projects budgetary allocation has to be voted out for a project after the identification of the proposed scheme from annual development budget. Other authors also reiterated that:

“Initial cost estimates are more useful in determining funding levels needed for long-range capital programs. This quantification of cost is the initial figure that allows the project to proceed to the next phases for final design and construction” (Schexnayder et al., 2003. p.8).

Turochy et al (2001) thus stated that it is often thought of as the first estimate used for budgeting purposes and allocation of funds by highway agencies. Chou (2008) emphasized that the conceptual phase of cost estimation should be conceived as the most significant starting process to influence the fate of a new transportation project.

2.5. Implications of Inaccurate Conceptual Estimates for Highway Project Delivery

Very high conceptual estimates above the likely costs would mean insufficient funds for sponsoring other development schemes (Donnell, 2005; Tan and Wakmasha, 2010). This scenario where budgeted figures are greater than the actual project costs would imply an under-expenditure resulting in fund carry-overs between financial years and consequently funds not being efficiently utilized by the agencies. (Belli et al, 2001). The Freiman curve in figure 10 below describes the scenario of over-estimation as self-fulfilling prophecies.

![Figure 10. Freiman Curve Showing Estimating Scenarios (Source: Phaobunjong, 2002)](image-url)
Conversely, very low estimates would imply that adequate funding is not voted out for a scheme and the progress of works would be stalled due this shortfall. Jameson (2007) was of the opinion that the bureaucratic challenge associated with gaining further approval of funds which is a consequence of the ‘functional nature of public service institutions’ will therefore slow down pace of project completion. CusWorth (1993) outlined the various phases that budgetary shortfalls emanating from inaccurate conceptual estimates have to go through before it can be accommodated in future budgets in figure 11.

![Budgetary Implementation Phases](source: CusWorth, 1993)

As such the bureaucracy associated with gaining further budgetary approval requisite to accommodate such cost overruns, can lead to lengthy delays. One of the earlier authors in the literature, Hall (1980) in congruence with the Freiman curve asserted that:

“Most of the planning disasters experienced in highway projects seem to be rooted with under-estimates at the preliminary phase” (p. 34.)

The general consensus in the literature is that in practice, it is essential that estimates be reasonably high to have adequate funds to cover for any project cost but not to the detriment of other schemes (CusWorth, 1993; Evans and Peck, 2008; Tan and Wakmasha, 2010; Asmar et al, 2011). The collective views of theses authors emphasize striking the right balance between these two extremities for achieving accuracy in initial estimates for planning purposes.

3. Summary of Findings and Conclusion

The study has discussed the theoretical basis of accuracy in estimating. Accuracy of cost estimates has being shown to be defined relative to the phase of project development at which the estimate is being projected. The literature review however shows that there is no uniform nomenclature in the literature for labeling the phases of development and therefore different terminologies are evident. The level of accuracy increases correspondingly as projects mature through the developmental phases with the estimates produced at the earlier phase the most variable. Highway agencies thus place emphasis on this phase due to the ‘Chain reaction’ effect that this phase has been shown to have on the successful completion of highway projects. The spill-over consequence of this effect has thus being shown in the literature to manifest as ‘cost overruns’ in varying degrees of magnitude and impact for highway projects.

Most of the studies in scholarly literature as summarized in table 2, adopt this initial estimate as the basis of cost overrun evaluation, convergently emphasizing the need for accuracy and supporting their stance with very sound and logical arguments.
Table 3: Perspectives on critical cost overrun estimate phase

<table>
<thead>
<tr>
<th>Authors</th>
<th>Adopted Stance</th>
<th>Conceptual Phase</th>
<th>Design Phase</th>
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<tbody>
<tr>
<td>Hall (1980)</td>
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<td>Simon (1991)</td>
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<td>Turochy et al (2001)</td>
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<td>Schexnayder et al (2003)</td>
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<td>Odeck (2004)</td>
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<td>Asmar et al (2011)</td>
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Source: Literature Survey

Having critically analyzed the arguments raised in the literature, the authors of this paper, conclude that it is the ‘time of the decision to build estimate’ useful in budgeting for proposed schemes that should determine the degree to which the final project cost has ‘run-over budget’ and not the latter phase estimates. However, the researchers note that the stage at which this estimate is made is dependent on the configuration of the development phases which are specific to highway agencies. Therefore in line with the objective of the study, this phase has being logically identified as the critical benchmark in estimating, requisite for assessing the level of cost overrun for highway projects. The study tags it as the ‘conceptual phase’ for uniformity and specifically refers to the point of planning when the initial feasibility study has being concluded, and an estimate is needed based on a schematic outline design of the concepts of the project for budgetary authorization. The proper planning of highway development programs, as repeatedly emphasized in the literature, necessitates the accurate estimation of funds at the initial phase for projects to circumvent the occurrence of cost overruns.

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