PROJECT COMPLEXITY AS A MODERATOR OF PERFORMANCE BIAS TOWARDS OVERRUN

Li liu[1], Andrew Nguyen[2] and James Arvanitakis[1]

[1] School of Civil Engineering, University of Sydney
[2] Evans & Peck, Worley Parsons
Li.liu@sydney.edu.au

Abstract: Studies have shown that infrastructure projects have continued to experience significant delays and cost overrun over an extended period of time and no evidence of learning ever have happened [1] [2]. Various causes contribute to the bias towards overrun [3]. This study contributes to literature by developing and subsequently validating a set of hypothesized relationships between project complexity and project performance. The results show that project complexity is associated with both the magnitude and variance of overrun. Further, the extent and magnitude of the positive bias towards overrun are moderated by project complexity.

Keywords: project complexity, bias, overrun, optimism bias, strategic misrepresentation

Introduction

Studies have shown that infrastructure projects have continued to experience significant delays and cost overrun over an extended period of time and no evidence of learning appear to have happened [1] [2]. Various causes contribute to the bias towards overrun [3] [1].

Emerging evidence suggests that project complexity could also be a significant factor contributing to the overruns and bias towards overrun. No extant studies have investigated how complexity contributes to the project performance bias towards overrun.

Based on the performance data of 121 rail projects from an Australian state Rail Authority ('Rail Authority'), this study examines the relationship between project complexity and project performance and how the performance bias is affected by project complexity.

Below, literature is reviewed and hypotheses developed. Then research method is described and results analysed. Finally, implications are discussed and conclusions are drawn.

Literature Review

There have been a number of studies undertaken over the last thirty years that have attempted to analyse the performance of cost estimates against actual costs for infrastructure projects. Some studies have concluded that the cost performance are extremely poor and are characterised by consistent and significant overruns [4]. Other studies have found that cost performance are generally good with no abnormal discrepancy between estimated and actual construction costs [5] [6].

However, the statistical validity of many of these studies have been questioned, primarily due to the fact the majority are either single-case studies or cover a sample size of projects too small to allow a systematic comparative analysis [2] [7].

When looking at comparative studies with much larger sample sizes, a clear trend of significant cost overruns emerges. Based on a sample of 52 projects, a study performed by [8] found that severe cost overruns are the norm for construction projects across of wide spectrum of industries and sectors (chemical processing, energy and large public works). From his sample of 52 projects, the average overrun was observed to be 88% with 47 projects experiencing cost overruns. The study also found that smaller construction projects tended to have less severe cost overruns when compared to larger projects.

Merrow's findings are supported by a recent studies incorporating 258 transport infrastructure projects undertaken by Bent Flyvbjerg et al. [2]. According to the study, cost overruns (or cost escalations) occur in 86% of all transport infrastructure projects, with only 14% ending up equal or less than the estimated cost. The highest average overruns occur in rail projects (45%), followed by fixed links (34%) and roads (20%). Overall, the average cost overrun is 28%, which is much less than Merrow's finding. However, Flyvbjerg states that overruns of 50% to 100% are "common" and overruns of greater than 100% are "not uncommon" [9]. Another study on 1,015 World Bank projects found cost overruns to be an average of 22% above the original budgeted amount [10], which is consistent with levels of overruns observed in Flyvbjerg's study.

However a study of 650 "very small, small, medium and large" road projects in Norway found that the average cost overrun to be 7.88% [11], which is significantly less than the cost overruns observed for European road projects in Flyvbjerg's study (22.4%). However, the actual outcomes ranged anywhere from -59% to 183% of the estimated cost. It is also interesting to note that the study found that larger projects tended to perform better than smaller projects, contradicting the findings in Merrow's study [8]. Odeck suggested that this was a result of a concerted effort by the Norwegian government throughout the 1990s to better manage large projects and keep final costs within budget.

Specific to rail projects, Flyvbjerg et al. found that rail projects are by far the worst performing project type, with the sample of 58 rail projects experiencing an average overrun of 45%. Pickerell [4] and Auditor General of Sweden [12] are the two other studies examining performance of rail projects (8 and 15 rail projects, respectively).

Studies on causes for overruns classify causal factors broadly into three categories: technical, psychological and political-economic explanations. Proponents of the technical school believe that the poor cost performance can be attributed to imperfect estimating techniques, which are unable to accurately forecast the future. Furthermore, infrastructure projects are characterised by their complexity, risk and uncertain nature, which when combined inadequate data and errors by estimators, can contribute significantly to the overruns [13] [14] [15].

There are a number of well-known technical factors due to the planning and management of a project that could cause delays and cost escalation. For example, the merging effect when multiple project paths merge with the critical path has been shown to cause skewed distribution of project schedule and costs. Leach [3] shows that when the number of merged paths reaches 10, the path length increases by 60% more than the expected. In contrast, the early completion of a precedent path has little impact on whether subsequent task can start early as the task may need to wait until a number of precedent tasks have been completed. Therefore, the variance introduced from merging is always positive—little likelihood of being early.

Similarly, studies have shown that queuing—defined as "the build up of a line of work waiting to be performed by resources"—could lead to a very long waiting time and thus delay the task and increase costs significantly. The problem could be further exacerbated by organizational policies to maintain high "billability". Since there is no such thing as a negative queue, a positive schedule bias is introduced due to the sharing of common resources [3]. Multitasking is also known to introduce positive schedule bias because the wait for resources, task switching efficiency loss and the network delay of multitasking [3].

The opponents of the technical school argues that if the technical explanation hold true, then there should be as many projects going under budget as over budget and that there would be a more even distribution of errors around zero (on budget) [16] which is not supported by empirical studies [2] [11]. Further, if cost overruns could be explained by technical reasons, simple mistakes and inherent problems with predicting the future should have been identified and addressed through "the refinement of data collection, forecasting methods etc" [2]. However Flyvbjerg [16] found, within his sample of 258 transport infrastructure projects, that there is no evidence of an improvement of accuracy over time. This finding is consistent with the majority of current literature (summarized in

Figure 1). Evidence suggests that the performance of infrastructure projects, as a whole, has not improved over the past seventy years.

One alternative to the technical explanation is that the causes can be attributed to the cognitive bias exhibited by estimators and planners. The impact of cognitive bias on cost estimating in infrastructure projects was first looked at by Kahneman and Tversky [17] and developed in subsequent studies by Kahneman and Lovallo [18], Mackie & Preston [19] and Flyvbjerg et al. [1]. According to these studies there are two cognitive 'delusions' that are particularly applicable to the planning of infrastructure projects: the planning fallacy and anchoring and adjustment.

The planning fallacy, also known as optimism bias, refers to the systematic tendency for estimators and planners to be overly optimistic about the outcome of planned projects despite knowing that "the vast majority of similar tasks (in the past) have run late or have gone over budget" [18](Lovallo & Kahneman, 2003). In other words, where uncertainty exists, estimators and planners tend to disregard past experiences and favour optimistic options [20] [19] [18]. As estimates are typically performed during the feasibility stage, where there is a high degree of uncertainty surrounding the project, then the psychological explanation proposes that estimators exhibit planning fallacy by approaching this uncertainty with irrational optimism which then results in a consistent underestimation of costs.

The second cognitive delusion is known as anchoring and adjustment. According to Kahnerman and Lovallo [18], this refers to the situation where "the initial estimate serves as an anchor for later-stage estimates, which will never be sufficiently adjusted to the reality of the project's performance". In other words, estimators and senior management become irrationally fixated on the figures produced during an initial cost estimate, despite the fact that the estimates were produced during the initiation and feasibility stages of a project when full project specification had not been finalized.

Nevertheless, the psychological explanations has been criticized for failing to adequately account for the lack of improvement in cost estimation performance throughout the decades. Flyvbjerg [21] argues that it is human nature to learn, and it is unrealistic that the entire profession of cost estimators would continuously exhibit 'optimism bias' decade after decade, resulting in cost overruns, and not learn from past mistakes. This is supported by Bertisen & Davis [22] who stated that such irrational behaviour would have led managers to replace irrational estimators with rational ones.

Further, Flyvbjerg claims that upon closer inspection, aspects of the optimism bias argument are actually better described as deliberate misrepresentation. For example Lovallo & Kahneman refer to the organisational pressures forecasters face to exaggerate forecasts as a cause of optimism bias [18], Flyvbjerg argues that "this can hardly be called optimism...deliberate deception is a more accurate term". However, in more recent publications Flyvbjerg has admitted that the psychological explanation has "relative merit in situations where political and organizational pressures are absent or low" but have less merit in situations where these pressures are high [16]. In other words, the psychological explanation is most applicable in situations where there is no motivation for planners or estimators to deliberately underestimate costs. In situations when such motivations do exist, then the strength of the psychological explanation is much weaker. This leads to the final school of thought, the political-economic explanation.

The political-economic explanation proposes that the poor performance of cost estimates and the observed systematic bias towards cost overruns are caused by deliberate deception (strategic misrepresentation) by planners, estimators and/or project sponsors. Proponents of this school of thought believe that these 'players' purposely underestimate costs and over estimate benefits in order to serve their own self interest, resulting in cost overruns and benefit shortfalls [23] [16].

According to Flyvbjerg et al. [1], the problem of strategic misrepresentation stems from the agency problem. This problem arises whenever a principal appoints an agent to act on his or her behalf, but the motivations of the principal and their agents are not perfectly aligned. 'Mega' infrastructure projects are especially susceptible to P-A problems due to the existence of multi-tiered P-A relationships between tax-payers (P) and the government (A), between the government (P) and public organisations (A), and between public organisations (P) and estimators, planners and consultants (A).

In each of these relationships the principal provides the funding and the agent is supposed to assist the principal allocate these funds to the most efficient project (in terms of cost and benefits). However due to the existence of the 'agency' problem, agents may push for projects that serve their own self interest rather than the principals. They achieve this by deliberately underestimating costs and overestimating benefits for the projects they favour, which then makes these projects much more likely to get approval and funding [23] [4].

For example, public organisations naturally wish to undertake as many projects as possible, but are often constrained by the level of funding they can obtain from the Government's 'public purse' [4]. Governments have limited budgets to allocate to different public organisations and they determine how to allocate these funds typically based on benefit-cost evaluations. As public organisations are essentially competing against each other for funding, they have the motivation to understate costs and overstate benefits [4]. For governments they may be motivated by projects that increase their political popularity or profile [1] while estimators, planners and sponsors may be motivated by organisational pressures or to please their clients [23].

The information asymmetries between principals and agents provides fertile groups for agents opportunistic behaviours [22] [1]. Principals do not have access to the same level of information as their agents and therefore must rely on the accuracy of the estimates that those parties produce. This is the case at every 'tier' of P-A relationships. E.g. estimators would have more knowledge of project details then public organisations, who in turn have more knowledge then governments, who in turn have more knowledge then the general public. Therefore this information asymmetry provides agents with an opportunity to further their interests by strategic misrepresentation.

Some academic have suggested that principals are not completely ignorant of the incentives for producing the lowest possible cost. Therefore they may assume that cost estimates have been understated and factor this into their appraisal. This results in a circulatory effect, as it forces all estimators to also understate their projects in order to compete. In this way strategic misrepresentation has not only been tolerated in infrastructure cost estimates, it is accepted [4] [22].

To sum up, the above discussions reveal that the performance of infrastructure projects is biased towards overrun due to reasons that have typically been categorized into three groups. Given that projects vary in complexity, the question is how project complexity affect the extent of project overruns and the degree of bias towards overrun. The section below develops a set of hypotheses regarding the relationship between project complexity and project overrun which will be validated in the subsequent analysis section.

Task complexity and Hypotheses

Project complexity has been conceptualized in various ways such as system scope [24], size, and differentiation vs integration [25]. For the purpose of this paper, Baccarini's conceptualization of project complexity is adopted here. According to Baccarini, project complexity has two dimensions: organizational complexity and techonological complexity. The former includes two further sub-dimensions: the level of hierarchical levels, and the number of different organizational units involved and the number of specializations. The latter has two sub-dimensions: differentiation (diversity of inputs, outputs, tasks, trades) and interdependency between tasks.

As a project's complexity increases, the difficulty for coordination and planning should be expected to increase. As a result, the performance of high complexity projects is likely to be poorer than low complexity projects. For example, Merrow [8] found that smaller construction projects tended to have less severe cost overruns when compared to larger projects. Formally:

Hypothesis 1: High complexity projects perform significantly worse (higher mean of overrun) and less reliable (higher variance of overrun) than low complexity projects.

As discussed in the literature review section above, the performance of projects tends to be skewed towards overrun. Formally:

Hypothesis 2: Projects are more likely to exceed than below or equal it original budget.

As the complexity of a project decreases, it will become more transparent to define, estimate and coordinate tasks. As a result, the bias towards overrun could diminish with the decrease in complexity. Formally:

Hypothesis 2A: The likelihood of overrun is positively associated with project complexity—i.e. high complexity projects are more likely to overrun than low complexity projects.

Parallel to Hypotheses 2 and 2A above, the overrun bias should also be reflected by asymmetrical distribution of the magnitude of overrun. Formally:

Hypothesis 3: The magnitude of overruns is significantly greater than the magnitude of underrun.

Hypothesis 3A: The magnitude of difference between the magnitudes of overrun and underrun is positively associated with the level of project complexity, i.e. high complexity projects have higher difference while low complexity projects have lower difference.

Research Method

This study relies on data collected from a stated rail authority in Australia (for confidentiality reasons organization's identify has been disguised). The Authority is a major public rail authority which operates and maintains an expansive metropolitan and regional fixed-rail network.

The sample consisted of a portfolio of 121 projects (comprising of 68 major periodic maintenance (MPM) projects and 43 capital projects) undertaken by the Authority between 2006 and 2008. MPM projects are major maintenance projects undertaken to renew or maintain the function of existing Rail Authority assets; e.g. re-ballasting and track renewal. Capital projects, on the other hand, are projects undertaken to add a new function or capability to the Rail Authority; e.g. new rail line, extension of a station platform, diamond crossovers.

The project size (actual project cost) in the MPM sample ranges from A$546,670 to A$3,322,868. For the capital project sample, the actual project cost ranges from A$521,348--A$35,850,355. The cost data collected from the Rail Authority contained project's original budget, the final actual cost and variation details. The original budget is the client-allocated budget to deliver the project at its original scope and specification. It represents the best cost estimate available to decision makers and senior management at the project approval stage. The final actual cost is the real, accounted costs incurred by the client at the completion of the project. It reflects the money actually spent to deliver the project and includes any approved and spent variations on top of the original budget. The variation data outlines the value of the variation requested and approved, and is only available for the MPM project sample.

To ensure a 'like for like' comparison, data collected have been adjusted for inflation. The MPM data also had to be adjusted to account for inflation. The General Construction Index (available from the Australia Bureau of Statistics) was used to escalate all nominal figures to real dollars (2008 dollars). For capital projects, the data was already provided in real dollars and no adjustment against inflation is necessary.

Consistent with the majority of past studies on project cost performance, no adjustment for scope change have been made [2]. The argument against adjustment for scope change is that such adjustments would deny researchers to explore the possibility that estimators have engaged 'salami tactics'—a term referring to estimators purposely under or vaguely scope a project to lower the initial estimate and then add in variations later on, once the project has been approved.

Project (cost) performance is measured by capital cost ratio (CCR) [26] [22].

The CCR can be simply expressed as:

$$CCR = \frac{\text{Actual Final Costs}}{\text{Original Budget (adjusted for Inflation)}}$$

The CCR ratio normalises the actual final costs by the adjusted original budget, thus allowing for a meaningful comparison of projects with different values and budget amounts [22]. The CCR ratio was calculated for all 121 projects in the data set.

Analysis

A critical assumption has been made that the capital project sample represents high complexity projects. In contrast, the MPM project sample represents low complexity projects. For MPM projects, the complexity level is likely to be limited to a narrowly defined scope (e.g. re-ballasting and track renewal). The level of hierarchy, the number of different organizational units involved, the degree of differentiation and the degree of inter-dependencies amongst tasks are likely to be low. Therefore, according to Baccarini's definition [24], project complexity for the MPM projects, on average, is likely to be low (in comparison with the capital projects sample). In contrast, capital projects typically have much broader scope and relatively bigger in size. For example, developing a new line involves land acquisition, laying foundation and new tracks, managing the community affected and integration with existing lines—suggesting the need for more organizational units to be involved, the likelihood of higher hierarchy, more differentiation and higher task inter dependencies, thus high in complexity compared to MPM projects.

In this study sub-group analysis is adopted. Hypotheses 1 on the relative performance across the two samples, is tested by comparing CCR across the two samples using independent sample t-test. A significant difference in the two sample means indicate one is higher than the other. Similarly, a significant difference in variance from the associated Levene's test of equality of variance indicates the variances in the two samples are significantly different.

Hypotheses 2 & 3 are tested using a two-sided test using a binomial distribution. The test examines the hypothesis that the probability of cost overruns (p) and cost underruns (1-p) are equal. In other words, the null hypothesis (H0) that $p = 0.5$ was tested against the alternative hypothesis (H1) that $p \neq 0.5$ [27]. This test was used to determine whether or not the difference in the observed probability (% of projects that go over budget) of a project experiencing a cost overrun is the same as the observed probability of a project going under budget. A high P-value (e.g. $p>=0.05$) would suggest that the probability for cost overruns is similar to the probability for underruns and that any observed differences between the two can be attributed to chance. On the other hand a low P-value (e.g. $p<=0.05$) would suggest the difference is statistically significant and cannot be fully accounted by chance.

Table 1: Performance Results

Sample Description	Size of Sample	Average CCR	Standard Deviation	Percentage (%) of Projects Exceeding Original Budget
Capital Projects	43	1.3005	0.6031	67.4%
MPM Projects	78	1.0898	0.4177	55.1%
All Data (Entire Sample)	121	1.1647	0.4995	59.5%

Analysis results

Table 1 reports that 67.4% of high complexity (capital) projects experienced overruns as compared to 55.1% of low complexity (MPM) projects. On average, the high complexity projects experience cost overruns of 30.05% of the original budget compared to the average of 8.98% experienced by the low complexity sample.

Table 2: Results of Independent t-test comparing the means of Capital and MPM samples

Levene's Test for Equality of Variances		t-test for Equality of Means				
F	Sig	T	df	Sig (2-tailed)	Mean Difference	Std. Error Difference
9.350	.003	-2.037	64.681	0.046	-.210637	.103412

Hypothesis 1 is supported. Table 2 reports that the mean cost overrun in the high complexity project (capital projects) sample (30.05%) is significantly higher than that (8.98%) in the low complexity project (MPM) samples (P=0.05). The variance in the high complexity project sample (Std. Deviation of 0.60) is higher (p<=0.01) that that in the low complexity sample (Std. Deviation of 0.42).

Table 3: Results of Binomial Two-Sided Test on the samples

		Category b	N	Observed Prop.	Test Prop.	Asymp. Sig (2-tailed)
Capital	Group 1	<= 1	14	.33	.50	.032a
Sample	Group 2	> 1	29	.67		
	Total		43	1.00		
MPM	Group 1	<= 1	35	.45	.50	.428a
Sample	Group 2	> 1	43	.55		
	Total		78	1.00		

a. Based on Z approximation
b. Note: > 1 represents a cost overrun, <= 1 represents cost underrun or on budget

Hypotheses 2 and 2A are both supported. Table 3 shows that the null hypothesis that possibility of cost overruns is equal to cost underruns for the high complexity project (capital projects) sample has been rejected (P<=0.05)—indicating a strong positive bias. In contrast, the probability of overrun for the low complexity projects (MPM project) sample is not significantly different (P=0.428) from the possibility of underrun.

Table 4: Test results of magnitude of over/under run in both samples

Sample	Levene's Test for Equality of Variances		t-test for Equality of Means				
	F	Sig	T	df	Sig (2-tailed)	Mean Difference	Std. Error Difference
High complexity	31.059	.000	-2.938	33.67	0.006	-.337784	.114986
Low complexity	6.454	.013	-1.866	55.907	0.067	-.121698	.065203

Hypotheses 3 and 3A are both supported. Table 4 reports that the average (%) magnitude of cost overruns are significantly higher than the average (%) magnitude for cost underruns for the high complexity projects (Capital Projects) sample (p<=0.01). Further, Table 6 shows that average (%) magnitude of cost overruns is not significantly different from the average (%) magnitude of cost underruns for the low complexity projects (MPM projects).

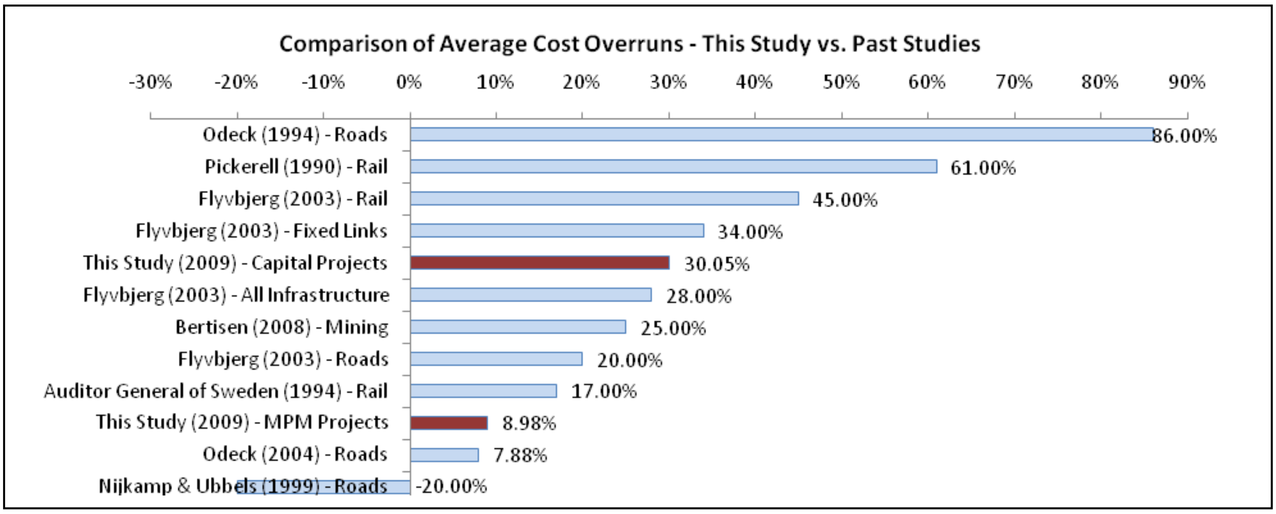
Discussions

The results discussed above supports all the five hypotheses. Specifically, on average, high complexity projects are found to have higher overruns than low complexity projects; and, the magnitude of average overrun for high complexity projects varies to a greater extent than that for low complexity projects. It was also found that high complexity projects are more likely to overrun its budget. In contrast, for low complexity projects, the result does not support a biased distribution of project outcome. Further, the results find that high complexity projects have a bias of higher magnitude of overrun than underrun which is marginally not statistically significant (p=0.07) for the low complexity sample.

The conclusions for the lack of evidence of bias in both the probability (H2) and the magnitude (H3) for low complexity projects should be interpreted with caution. Such conclusions are subject to the type II error due to limited sample size. As sample sizes increase, both null hypotheses could be rejected. However, the results still indicate that the bias towards overrun (if any) for low complexity projects is less pronounced and less severe.

To put the results from this study into context, Figure 1 plots the average overruns of the capital project sample and the MPM project sample, respectively, against results from past studies on similar projects. Figure 1 shows that the capital project sample performed relatively well amongst rail projects with lower overruns than Pickerell [4] and Flyvbjerg et al. [28] and only higher than Auditor general of Sweden [12].

Figure 1: Comparison of cost overruns - this study vs. past studies Implications



The findings from this study are consistent with previous findings on the distribution of cost overruns [3] [2]. Adding to literature, this study establishes and validates the relationships between project complexity, project performance and the extent of bias towards overrun. The validated relationships provide a foundation for the modelling of project management performance by aggregating the complexities of sub components/tasks of a project.

Understanding how complexity impacts on the distribution of project outcomes helps project managers to effectively manage project performance. For example, reduction of complexity could lead to reduction in the likelihood as well as the extent of overrun. Therefore, project managers can improve performance by minimizing the complexity level of the project. In doing so, the project managers should avoid focusing only on reduction of work package size because smaller work package sizes could lead to increased inter-dependencies among tasks and thus increase complexity. Instead, the managers should strike a balance between the size of work packages and the potential inter-dependencies among tasks that minimizes project complexity level.

Conclusion

The study contributes to literature by developing links between project complexity and project performance. The theoretical predictions have been validated using empirical data of rail projects in Australia.

The results report that the level of project complexity is associated with the level of performance—both magnitude of overrun and variance of overrun. Further, there is a bias towards overrun for high complexity projects and the extent of such bias appears to be moderated by project complexity—i.e. for low complexity projects, such bias is less pronounced or non-existent. The study also finds a positive bias for the magnitude of overrun (i.e. higher average overrun than underrun) for high complexity projects and the extent of such bias is also moderated by project complexity.

REFERENCES

[1] Flyvbjerg, B., Garbuio, M., & Lovallo, D. (2009). Delusion and Deception in Large Infrastructure Projects: Two Models for Explaining and Preventing Executive Disaster. California Management Review , 51 (2), 170-193.

[2] Flyvbjerg, B., Holm, M. S., & Buhl, S. (2002). Underestimating costs in public works projecs: Error or lie? Journal of the American Planning Association .

[3] Leach, L. (2003). Schedule and cost buffer sizing: How to account for the bias between project performance and your model. Project Management Journal, 34(2), 34-47.

[4] Pickrell, D. (1992). A Desire Named Streetcar: Fantasy and Fact in Rail Transit Planning. Journal of the American Planning Association , 58 (2), 158-176.

[5] Hufschmidt, M., & Gerin, J. (1970). Systematic errors in cost estimates for public investment projects. New York: The analysis of public output.

[6] Nijkamp, P., & Ubbels, B. (1998). How reliable are estimates of infrastructure costs? A comparative analysis. Research Memorandum .

[7] Wee, B. (2007). Large infrastructure projects: a review of the quality of demand forecasts and cost estimations. Environment and Planning B: Planning and Design , Volume 34, 611-625.

[8] Merrow, E. W. (1988). Understanding the outcomes of mega project: A quantitative analysis of very large civilian projects. Santa Monica, Carlifornia: The Rand Corporation.

[9] Flyvbjerg, B., Bruzekius, N., & Rothengatter, W. (2005). Megaprojects and Risk. Cambridge: Cambridge University Press.

[10] Pohl, G., & Mihaljek, D. (2002). Project Evaluation and uncertainty in practice: A statistical analysis of rate-of return divergences of 1,015 World Bank projects. World Bank Economic Review , 253-277.

[11] Odeck, J. (2004). Cost overruns in road construction - what are their sizes and determinants? Transport Policy , 11, 43-53.

[12] Auditor General of Sweden (1994). Infrastrukturinvesteringar - en kostnadsjämförelse mellan plan och utfall i 15 större projekt inom Vägverket och Banverket, RRV 1994:23. (Investments of infrastructure: A comparison of costs between plan and outcome in 15 larger projects within the National Swedish Road Administration and the National Rail Administration, RRV 1994:23).

[13] Reilly, J., & Brown, J. (2004). Management and control of cost and risk for tunneling and infrastructure projects. Proc. International Tunneling Conference. Singapore.

[14] Lee, J. (2008). Cost overrun and cause in Korean social overhead capital projects: Roads, rail, airports and ports. Journal of urban planning and development , 59-62.

[15] Venkataraman, R., & Pinto, J. (2008). Cost and Value Management. John Wiley and Sons.

[16] Flyvbjerg, B. (2007). Cost Overruns and Demand Shortfalls in Urban Rail and Other Infrastructure. Transportation Planning and Technology , 20 (1), 9-30.

[17] Kahneman, D. and Tversky, T. (1973). On the psychology of prediction. Psychological Review, 80, 237-251.

[18] Lovallo, D. & Kahneman, D. (2003). Delusions of success: How optimism undermines executives' decisions. Harvard Business Review , 56-63.

[19] Mackie, P., & Preston, J. (2000). Twenty-one sources of error and bias in transport project appraisal . Journal of Construction Engineering and Management , 130-136.

[20] Walmsley, D., & Pickett, M. (1992). The cost and patronage of rapid transit systems compared with forecasts. Crowthorne: Transport Research Laboratory .

[21] Flyvbjerg, B. (2006). From Nobel Prize to project management: Getting risks right. Project Management Journal , 5-15.

[22] Bertisen, J., & Davis, G. (2008). Bias and error in mine project capital cost estimation. The Engineering Economist, 118-139.

[23] Wachs, M. (1989). When planners lie with numbers. Journal of the American Planning Association (10 (4)), 476-479.

[24] Shenhar, A. J. (2001). One Size Does Not Fit All Projects: Exploring Classical Contingency Domains. Management Science, 47(3), 394-414.

[25] Baccarini, D. (1996). The concept of project complexity--a review. International Journal of Project Management, 14(4), 201-204.

[26] Ostwald, P. (1992). Engineering cost estimating. Englewood Cliffs: Prentice-Hall.

[27] Phipps, M., & Quine, M. (1996). A Primer of Statistics. Erskineville: Prentice Hall.

[28] Flyvbjerg, B., Holm, M., & Buhl, S. (2003). How common and how large are cost overruns in transport infrastructure projects? Transport Reviews , 71-88.