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A Quantitative Analysis of the Performance of Transportation Projects in Developing Countries

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ABSTRACT *This paper presents the results of a detailed quantitative analysis of performance metrics of a sample consisting of 89 transportation projects sponsored by the World Bank. The sample and a subset consisting of 65 projects were evaluated using the performance metrics of project cost, schedule and scope. The effect of project size (dollar value) and project duration on performance metrics was investigated. Also, the achievement of project goals and potential improvement in planning and estimating over time (the learning effect) was studied. It was found that, in general, in transportation projects sponsored by the World Bank, costs are overestimated and schedules are optimistic. The outcome with respect to cost seems counter-intuitive because previous work by other researchers had shown a systematic underestimation of project costs. There is significant evidence that there are no efficient controls in place to predict or prevent schedule delays. The study also showed that during the past 15 years, no improvement (learning effect) was evident in project cost and duration estimation as the level of accuracy has not changed significantly. Further, it is observed that project duration did not affect the performance with respect to cost and delay.*

Unlike TANROADS

Like TANROADS

lagging indicators

Fishbone analysis
- methods, machines
- materials, manpower
- measurement, environment

Introduction

Analysing cost and schedule performance of construction projects in order to extrapolate and predict the outcome of future projects has been a subject of great interest to the construction industry. Roberds and McGrath (2006) noted that good project decisions require good information, not only from the project under consideration, but also historic data from performance of similar projects. However, project's ex-post documentation and evaluations of project performance are not always available; they are difficult to find, especially in developing countries.

The need for infrastructure worldwide is expanding rapidly especially in the transport sector, as the motor industry predicts accelerated growth. According to

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the World Bank (2007), over the next 20 years, more cars will be built than in the 110 years history of the industry, and over the next 35 years, another 2.5 billion people will be added to the current world population of 6.3 billion. Thus, evaluations of project performance characteristics to assist in more accurate forecasting will be of primary importance in the years to come. The future political climate may not allow gross inaccurate estimates like the ones seen in the past with examples such as the Panama Canal Project finishing 70–200% over the original budget, and most recently Boston's Central Artery/Tunnel Project (Big Dig) finishing 480% over budget (Sangrey *et al.*, 2003). Consequences of inaccurate estimates include: poor decisions in selecting the preferred alternatives, cost/schedule over-or-under runs, scope reduction, resource competition among projects, unfavourable media attention and ultimately public mistrust which can affect current and future funding (Roberds and McGrath, 2006).

In this paper, we have studied performance data from 89 transportation projects implemented in over 60 developing countries sponsored by the World Bank by comparing original budget, scope and schedule with actual values. A complete listing of these project and their performance characteristics is provided in Table A.1 (see Appendix). The objective is to develop a better understanding of the performance of these large infrastructure projects in developing countries. This is an area where there is a dearth of quantitative data and analysis. We have found very few reports in the literature that evaluate performance of transportation projects with significant amount of data. Only two important research studies have been identified as the pioneers to expose performance of infrastructure projects that dealt with a large number of projects. In the first study, the World Bank (2007) presented an evaluation of performance for ten years of project funding from 1995 to 2005; however, the evaluation is done from the point of view of the sponsor and its conclusions are based on the Bank's return on investment and effectiveness of their approach, and very little information is provided about the effectiveness of the management process in these projects. The second study was carried out by Flyvbjerg *et al.* (2002, 2003); they studied the cost data from 258 transportation projects and found that cost predictability is a major problem in infrastructure projects, with actual costs significantly larger than originally estimated. The study concentrated on cost performance, but is the most complete statistical analysis found on the subject; we have used Flyvbjerg's approach in statistical analysis to conduct our analysis. Many more studies have been conducted with rather small samples of transportation projects (Schumann, 1988; Pickrell, 1990; Faulkner and El-Sharafi, 2002). Many of these studies show that most large transportation projects suffer from cost overruns and schedule delays. Some of the reasons cited for cost overruns include: optimistic original estimates, leaving out sections of the scope in early estimates, scope creep (addition to the scope after the project budget is established due to public pressure and third party stakeholders), lack of sufficient contingency in the estimated budget and underestimation of escalation costs (Booz Allen Hamilton, 2005).

Data Collection and Methodology

Data collection is a major challenge that all research projects face. In this particular case, the data came from the World Bank records of highway projects from developing countries. The ex-post data in transportation infrastructure is rarely reported, especially in developing nations where reporting and documentation processes are not comprehensive and sophisticated. We found in the World Bank an entity that has a thorough process with a standardized set of documents that are developed through the life of a project, and more importantly is committed, since its creation in 1945, to fund infrastructure projects in developing nations. The World Bank is internally divided into geographic regions; in each region, there are ten sectors in which they fund projects. Transportation is the second largest sector the World Bank invests in, only after law and justice and public administration. Transportation funding represents 15% of the Bank's $23 600 million annual budget (World Bank, 2006).

Backgrd informtion

Once a project sponsored by the World Bank is completed, the Bank's supervising team generates a document called 'Implementation Completion Report' (ICR) within six months. This report summarizes the overall process starting at the project inception, original and modified objectives, achievements, sustainability and lessons learned. This document also provides data of original and actual investment and duration and the supervisory team from the Bank assigns a rating to the outcome of the project from the sponsor's viewpoint. The term 'sponsor' for these projects is used to designate the entity that principally contributes funding to the project and usually takes no part in the project implementation. As an example, the World Bank is a major sponsor in all the projects reported in this paper. Project implementation is the function of the host country (owner or owner agency).

There are multiple benefits for using this source of data:

1. The documents were consistent in format, terminology and criteria.
2. The spread of the data was broad coming from 60 developing countries in five continents.
3. The data dates ranged from 1991 to 2007 and accounted for $27 billion worth of work.
4. The evaluation process performed by the World Bank was consistent from project to project. About 60% of the projects in the sample also had a mid-term evaluation report. These documents were reviewed for this paper and overall, provided a comprehensive assessment of project performance using a consistent approach. This cannot be claimed about other databases consisting of projects that are evaluated by various agencies or firms.

The sample studied consists of the entire slate of highway projects from the World Bank web database, using the search criteria: *transport projects* and *implementation completion results reports*. From among these projects, all projects containing highway construction as principal component were collected and their documents were reviewed. As a result of this process, the ICR of 89 Transportation projects was carefully reviewed and relevant data were extracted.

In order to analyse the projects' performance, we were interested in the traditional three dimensions: *Cost*, *Schedule* and *Scope*. Every ICR provides detailed information for the total cost, and reports the World Bank and the counterpart's contributions. Typically, the Bank covers a portion of the investment and the host country, either with local funds or with additional sponsors, covers the balance. For the purposes of this research, we have used the total project cost. One important observation from this data is that all the original estimates and actual values were available from the original sources and they are free from bias. This bias has been a concern in the past when project data has been collected from questionnaires or surveys and not from their original sources (Flyvbjerg *et al.*, 2003).

For the analysis, we have defined 'cost performance' as actual cost of work divided by the budgeted cost of work in percentage points. Budgeted cost is defined as the original estimate or forecast at the time of decision to build a project and actual cost is defined as the real recorded cost at the time of project completion. Thus, a project with a percentage lower than 100% means that the project finished under budget.

$$\text{Cost performance }(\%) = \frac{\text{Actual cost}}{\text{Budgeted cost}} \times 100 \tag{1}$$

Also, we have defined 'schedule performance (delay)' as the difference of actual and estimated duration of the project in percentage points of estimated duration. Estimated duration is defined as the forecasted duration at the time of decision to build a project; actual duration is defined as the actual time it took to complete the project.

$$\text{Schedule performance (delay) }(\%) = \frac{(\text{Actual duration} - \text{Estimated duration})}{\text{Estimated duration}} \times 100 \tag{2}$$

For the statistical analysis, Kolmogorov–Smirnov test of Goodness of Fit (Ang and Tang, 1975) is used to verify if normal distributions can be assumed for the populations. The reason for this is that most statistical tests of hypotheses are based on the assumption of normality for the underlying populations. Binomial distribution test is used for comparing both sides of a distribution around a purposefully selected fixed value (i.e. 0% cost over/under run). This test is used to determine the proportion of the results obtained for a variable (cost or schedule over/under run). If the proportion is statistically similar to a 50%:50% chance, then we can say that the values of performance of the measured variable is random, otherwise it shows a tendency that is driven by something different than by chance. In general, the study contains analysis of variance (ANOVA) and regression analysis with the respective *F*- and *t*-tests (SPSS 16.0 for Windows, 2007). Additionally, tests of hypothesis are carried out and the respective *p*-values are reported for every case. Following Flyvbjerg *et al.*'s (2003) definition: p-value < 0.01 is considered highly significant, p-value < 0.05 significant and larger *p*-values assume that deviation could be due to chance.

Categorization of Data

The projects in the sample covered a total investment of $27 billion (actual cost) distributed in projects of different sizes. Table 1 shows a breakdown of number of projects per project size.

The duration of the projects ranged from 24 months to 92 months, with most common duration around 60 months (5 years). These durations are original estimated durations. Table 2 shows the statistical values of estimated durations for the sampled projects. Figure 1 shows a histogram of estimated durations.

Table 1. Number of projects per size

	Number of projects	Percent of the total
Projects < $100 million	32	36
$100 million < projects < $500 million	40	45
Projects > $500 million	17	19

Table 2. Statistics of estimated project durations in months

	Estimated duration of projects (months)
Mean	59
Standard deviation	12
Minimum	24
Maximum	92

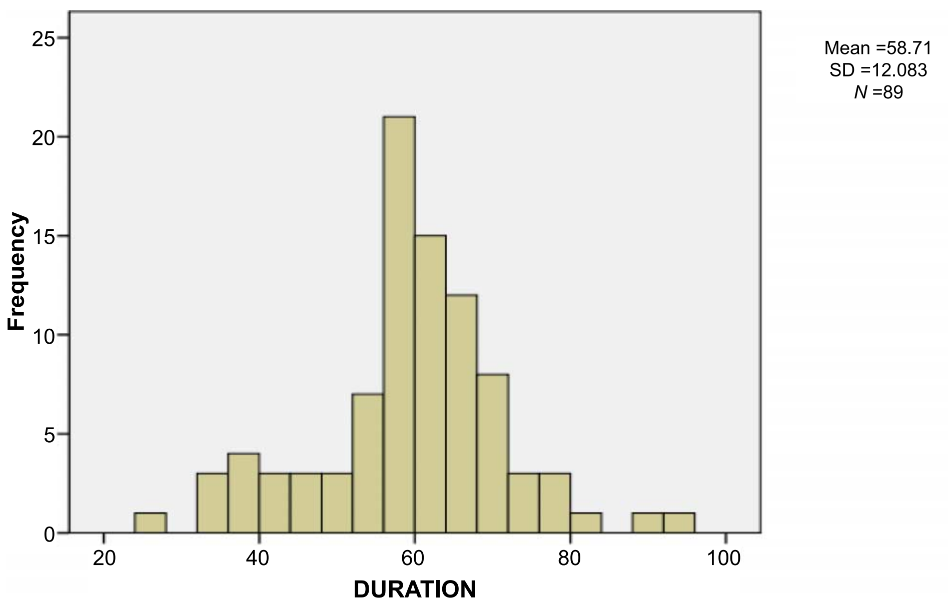

Figure 1. Frequency of estimated project

The projects in the study covered a period from 1991 to 2007, and the dates of actual completion ranged from 2002 to 2007. Figure 2 shows a histogram of the number of projects (frequency) versus year of completion. It can be seen that the number of projects finished per year is approximately uniformly distributed over this period.

Project Performance

This study analysed projects' performance along three dimensions: cost, schedule and scope. Therefore, the data extracted from the World Bank's ICRs were: *original*

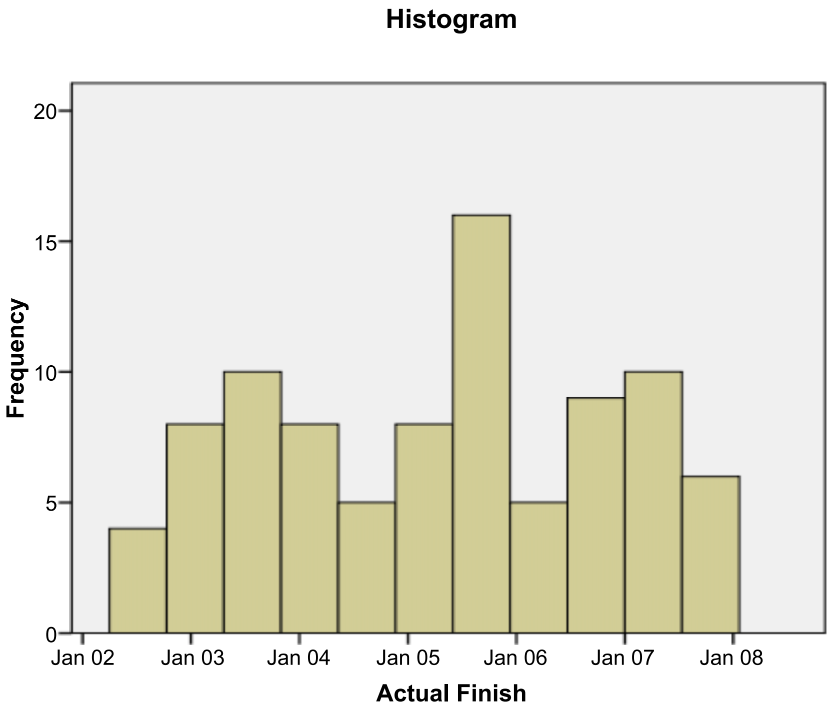

Figure 2. Project frequency per year of actual completion.

cost estimate, actual cost, original project start (the date the Bank loan becomes effective), estimated project finish, actual project finish and the rating of the outcome.

The ICRs clearly identified those projects that presented significant change in scope of work. And, it was observed that despite the fact that some projects experienced change in scope, the actual cost and schedule values were always compared with the originally estimated values.

Table 3 presents the Kolmogorov–Smirnov test of normality for values of cost performance and schedule performance (delay) tested for all cases and for cases with no change in scope. We have selected a level of significance of 0.025 for this test. In this two-tailed test, the data is assumed to follow a normal distribution, and *p*-values above 0.025 mean that the assumption of normality cannot be rejected. It can be observed that both delay and cost deviation follow a normal distribution; however, the cases with no scope change follow the theoretical

Table 3. Test of normality for cost performance and delay

Kolmogorov–Smirnov test of normality	Number of cases	Significance level (*p*-value)
Delay		
All cases	89	0.037
Projects with no scope change	65	0.331
Cost performance		
All cases	89	0.084
Projects with no scope change	65	0.760

Table 4. Cost performance statistics

	All projects	Projects with no change in scope
Cost performance		
Number of projects	89	65
Mean cost performance	97%	95%
Standard deviation	23.8	17.2
95% confidence interval for mean	91–102%	91–99%
Minimum	35%	48%
Maximum	221%	125%
Under-budget cases	56%	59%
Over-budget cases	40%	39%
On-budget cases	4%	2%

normal distribution model more closely, showing *p*-values much larger than the threshold of 0.025.

Since normality could not be rejected for any of the cases, we continue with the analysis assuming normality for the population. Table 4 presents the cost performance for all projects and for the subset of projects that did not report a significant change in scope.

Statistical testing showed that the mean cost performance of the sample with all projects is not statistically different with the mean of the subset of projects with no change in scope (*p*-value = 0.265). Also, it can be observed that the dispersion of the values show a reduction of the standard deviation from 23.8 to 17.2 for the subset of cases with no change in scope and a reduction of the range from 186 (221–35%) to 77 (125–48%). This means that projects with consistent scopes showed less variability in cost performance characteristics.

A similar analysis is presented in Table 5 for project delay. These results are used to assess if change in scope has an effect on delay.

It is observed that the mean values of delay do not show statistical difference (*p*-value = 0.105) when all projects are sampled versus the subset of projects with no scope change. Also, to a lesser extent than for cost performance, the dispersion seems to be reduced when the subset of projects with no scope change is

Table 5. Schedule performance

	All projects	Projects with no change in scope
Schedule performance		
Number of projects	89	65
Mean delay	37%	35%
Standard deviation	29	25
95% confidence interval	31–44%	29–41%
Minimum	0%	0%
Maximum	126%	100%
Probability of delay	87%	88%
Number of projects with 0% delay	12	8

evaluated versus the entire sample. It can be observed that the standard deviations are reduced from 29% to 25% for the subset; and the ranges reduced from 126 (126–0%) to 100 (100–0%).

An examination of the source documents show that even when there was substantial change in project scope, the actual were compared to the original estimates without correction for estimates. In order to be able to do a fair and meaningful assessment of project performance, the projects with substantial change in scope will be removed from the sample. This trimming of data will reduce the sample to 65 projects and will guarantee that our performance analysis is based on comparison of actual versus estimated values for the same scope. It is also worth noting that a significant change in scope is a qualitative adjective that was used in the ICRs by the World Bank personnel. In other words, sufficient information was not provided for the magnitude of the scope change. However, it may be inferred that a change of scope may comprise the elimination or shortening of a section of the roadway or a change in the route in order to achieve a desirable change in cost and/or schedule.

Cost Performance

The distribution of the cost performance values are presented in Figure 3 for projects with no significant change of scope. On the *X*-axis, 100% represents projects that finished on-budget, while the *Y*-axis gives the number of projects that finished with the same cost performance value.

Using the data from Table 4 and the histogram of Figure 3, the following observations can be made:

- The likelihood of a random project finishing under budget is 59% and the likelihood of cost overrun is 39%; 2% of projects finished on-budget.

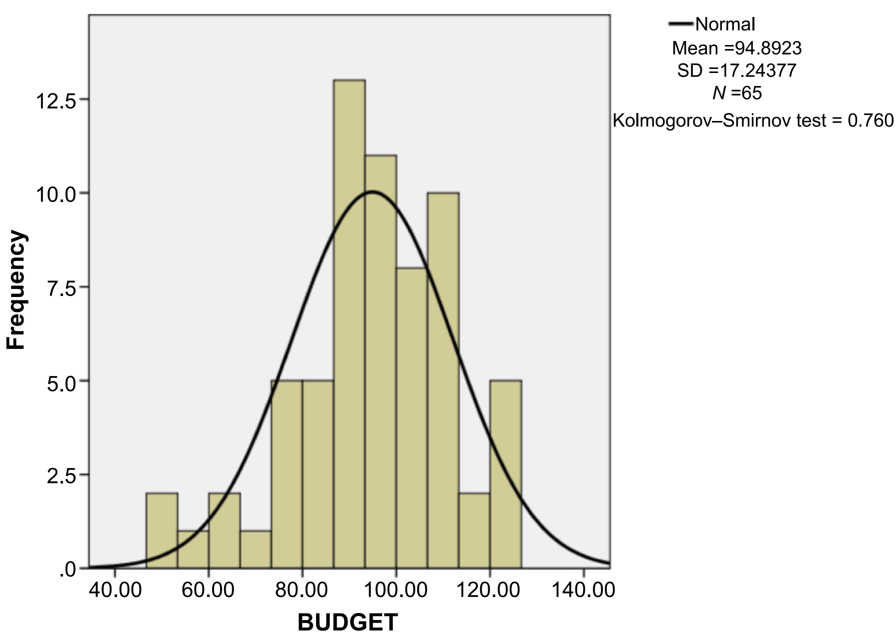

Figure 3. Histogram of cost performance.

- The mean of the actual cost is on average 3% less than the original estimate (SD = 17.2) and this is statistically significant (p-value = 0.020) when compared with an on-budget scenario.
- We cannot reject the hypothesis that underestimates are as common as overestimates (p-value = 0.130, binomial distribution test).

The results reported above present a somewhat unexpected finding. Most authors reporting on transportation project performance have observed a tendency of projects to finish significantly over budget. As an example, Flyvbjerg *et al*. (2002) reported that 86% of the transportation projects that they studied finished over budget, compared to only 39% computed from the data presented here. Furthermore, Flyvbjerg *et al.* (2002) reported significant evidence that cost deviation was not a result of chance or error, but instead due to a deliberate underestimation of costs, whereas the data analysed in this report does not present a significant trend other than random error for cost performance.

Flyvbjerg *et al.*'s (2002) analysis was done on projects that were mainly implemented in developed countries. Ninety-four per cent of the projects were in Europe and North America. Whereas 100% of the data used in our analysis comes from developing countries. Developing countries have different challenges to overcome: government and political instability, shortages of adequately trained manpower, limited resources (material, equipment), low productivity and financial limitations (Jaselskis and Talukhaba, 1998). These countries in general are less sophisticated in their forecasting and implementation expertise than developed nations. While underestimation seems to be the norm in developed nations (Flyvbjerg *et al.*, 2002), overestimation seems to be more frequent in developing countries, at least on international development transportation projects funded by the World Bank. While we can make this statement for sponsored projects, an equivalent study shall be undertaken for projects with domestic funds to reveal if this tendency to overestimate is widespread in all projects implemented in developing countries. This overestimation of cost performance is statistically significant (p-value = 0.020) with respect to an on-budget scenario, and it can potentially hurt project promoters to get projects approved by sponsors due to poor cost forecasting.

Achievement of scope. Table 6 shows statistical results for cost performance grouped by the classification of completion of scope. As defined by the World Bank's (n.d.) evaluation criteria: *Highly Satisfactory* (HS) are projects that achieved *all* the scope, *Satisfactory* (S) are projects that achieved *most* of *the scope* and *Unsatisfactory* (U) are projects that *did not* achieve their scope of work. This classification is assigned to each project by the supervisory team assigned by the World Bank and published in the ICRs. As an example of an unsatisfactory project, consider the 'Dhaka Urban Transport Project' in Bangladesh (P009524, Table A.1). Of the original budget of \$234 million, only \$125 million was spent. The World Bank supervisory team noted that the project failed to show satisfactory progress at a very early stage. Even though the project objectives were not revised, some components were removed at the mid-term review as they were not expected to be completed within the remaining duration of the project. It was observed that from 12 specific scope items, five were not completed with the major components being: Bus only lanes were not completed leaving \$2.7 million unused; road works adjacent to bus terminals left \$8.88 million worth of work

Table 6. Cost performance by scope completion (HS, S, U)

	Success		
	HS	S	U
Cost performance			
Number of projects	6	56	3
Mean	97%	94%	91%
Standard deviation	12.7	16.8	36.5
Minimum	77%	48%	51%
Maximum	111%	125%	122%

not performed; non-motorized traffic underpasses left $5.3 million of work not done and the Jatrabari Flyover left $27.88 million not executed. In addition, the implementation agency was changed at the bank's request at the mid-term review.

The following observations can be made from Table 6:

- Ninety-five per cent of the projects completed their original scope.
- The values of standard deviation and range are reduced by project success showing less variation as the projects are more successful with respect to scope completion. No statistical difference in the difference of mean values was found (ANOVA, p-value = 0.217, F-test).
- It is also noted that even though unsuccessful projects did not finish their scope, their mean cost performance was still 91% and do not show a statistically significant difference when compared to an on-budget scenario (p-value = 0.721).
- Sixty per cent of the projects that were completed (HS and S) finished under budget and 37% had cost overruns.

This data reveals that the developing economies still have cases where implementation cannot be completed even when the budgetary resources are there. More importantly, the projects that do not complete their scope do not show a significant decrease of the budget spent, showing that budgets were consumed in its entirety even though the scope was not achieved. In addition, 33% of the projects that did not complete their scope, spent more than their original estimated budgets. This observation translates in the inability of some owner agencies to implement projects regardless of the availability of budget. Lastly, it is observed that as implementation fails to deliver the forecasted scope, the cost performance becomes more disperse and very difficult to predict, leading us to conclude that the more successful implementations show a smaller dispersion in the values of project performance.

The effect of project size on cost performance. In this study, project size is defined by the total actual project cost at the time of project completion. Flyvbjerg *et al.* (2003) noted that the literature sometimes assume that smaller projects perform better (size determined by cost); the intent of this section is to evaluate if that assumption can be validated by the data. Table 7 presents statistics of cost performance by project size.

From Table 7, it can be observed:

Table 7. Cost performance by project size

	Project size		
	Project < $100 million	$100 million <project < $500 million	Project > $500 million
Cost performance			
Number of projects	25	28	12
Mean	101%	87%	102%
Standard deviation	14.2	17.7	14.8
Minimum	58%	48%	77%
Maximum	125%	122%	125%
Range	67	74	48
Unsatisfactory projects	1	2	0

- There is statistical evidence that cost performance varies by project size (ANOVA *p*-value = 0.003, *F*-test).
- For projects between $100 million and $500 million, the mean of actual costs is 13% under the original estimate (SD = 17.7), which is highly significant when compared to an on-budget scenario (*p*-value < 0.001).
- Additionally, projects between $100 million and $500 million present a highly significant evidence that project overestimation is different than project under-estimation (*p*-value < 0.001).
- For projects of less than $100 million and projects greater than $500 million, the estimates of the mean have been more reliable (mean = 101% and 102%); they do not show a significant difference of mean cost performance compared with an on-budget scenario (*p*-values=0.846 and 0.621, respectively).
- All projects above $500 million finished their scope.

There is strong evidence that projects between $100 million and $500 million are intentionally overestimated actual cost 13% below the original estimates (SD = 17.7). This conclusion is evident in the analysis by observing a combination of significant cost overestimation (compared to an on-budget scenario) and the fact that there are significantly more projects overestimated than underestimated (*p*-value < 0.001) in the sample.

There is statistical evidence that projects below $100 million and projects above $500 million are on average more predictable in terms of cost performance than the alternative (mean = 101% and 102%) and their variation is similar (SD = 14.2 and 14.8), with the only observation that all projects greater than $500 million finished the scope, while one of the projects below $100 million did not. It seems that cost control in these projects is more effective than in others. In summary, although different-sized projects behaved differently with respect to cost performance, it could not be said that there was a consistent (upward or downward) trend between project magnitude and cost performance.

Cost performance over time. In this section, the analysis is focused on the thesis that practitioners learn and cost performance improves over time. Flyvbjerg *et al.* (2003) stated that it is expected from project promoters, forecasters and decision-makers to learn from past experience and either improve their accuracy when setting expectations or improve their controls to achieve actual results closer to the forecasted; however, they couldn't find evidence of it in their data analysis. To evaluate the time variable, we will perform a similar analysis using both the date of original start and the actual completion date of the projects.

Figure 4 presents a scatter plot of cost performance versus original start date. Figure 5 shows a scatter plot of cost performance versus actual completion date. Neither figure seems to indicate learning or improvement of cost performance over time. This observation is further validated statistically, the null hypothesis being that project cost performance remains the same over time; using an ANOVA, the null hypothesis cannot be rejected (p-values = 0.110 and 0.080, respectively; F-test). In addition, a simple regression analysis was conducted for each case where the cost performance was regressed against start and completion dates. The results of these regression analyses did not indicate a linear trend (R^2 = 0.10 and 0.095, respectively). Although, the implementation period evaluated in the sample is not long enough to achieve definitive conclusions, we can observe that there is no evidence of improvement or deterioration of cost performance over time in the studied sample. It is understood that the length of study (1991–2007) is rather short for evaluating the learning that might occur for major projects. However, it was felt that inclusion of this analysis will provide an added perspective on the performance of these projects and their management.

Cost performance versus duration. In this part of analysis, the interest is in evaluating if longer duration projects have a tendency to be less predictable than shorter ones. We have used the *original duration* as the metric for measuring the project length. This selection is based on the fact that this is the value known by decision-makers at the time they approve a project.

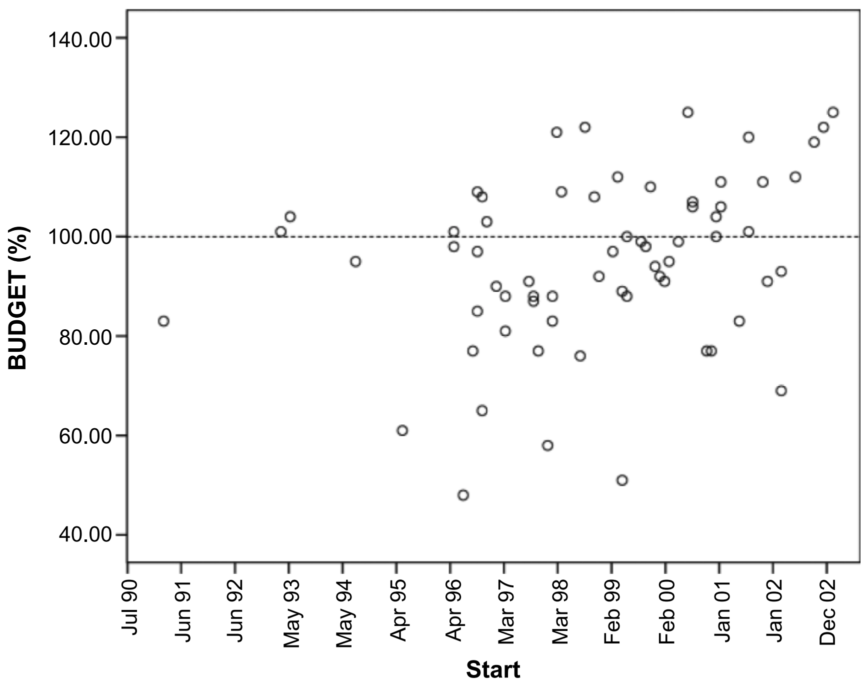

Figure 4. Cost performance versus original start.

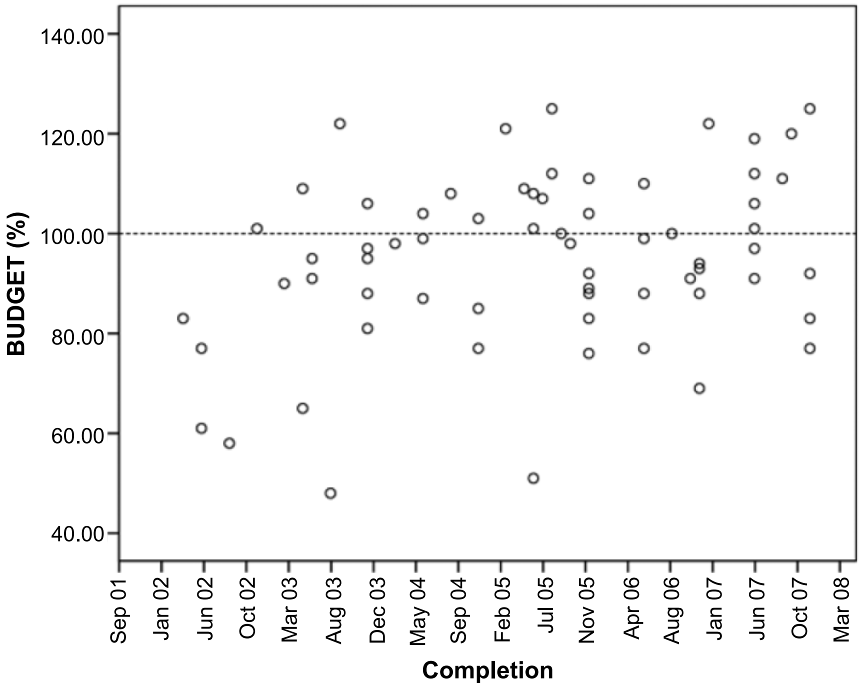

Figure 5. Cost performance versus actual completion date.

Figure 6 shows a scatter plot of cost performance versus project original duration in months. For each given duration in the plot, the mean of cost performance is given. It can be observed that there is no visual evidence that cost performance is affected by project duration. This observation is also statistically confirmed; a null test is designed by equating the mean of cost performance for all the project durations. After testing this statement using ANOVA, it was concluded that this hypothesis cannot be rejected (p-value = 0.641; F-test). Additionally, after testing linear correlation, no significant relationship is found (p-value = 0.102); the Pearson's correlation coefficient is $R = -0.160$. Therefore, it can be said that there is no statistical evidence that cost performance is more predictable for shorter projects.

Schedule Performance

Schedule delay, just like cost deviation, is widely used as an indicator of performance in construction projects. In this section, the analysis of predictability will be concentrated on schedule performance of the dataset, comparing actual durations at the project completion with those estimated before project start. As defined before, 'schedule performance' or 'delay' is defined as the difference of actual and estimated duration of the project in terms of percentage points of estimated duration. Figure 7 presents a histogram of the schedule performance for projects with no significant scope change, where 0% in the X-axis represents projects that finished on-schedule and the Y-axis displays the number of projects that finished with the same delay (frequency).

Using the data from Table 5 and the histogram presented in Figure 7, the following observations can be made:

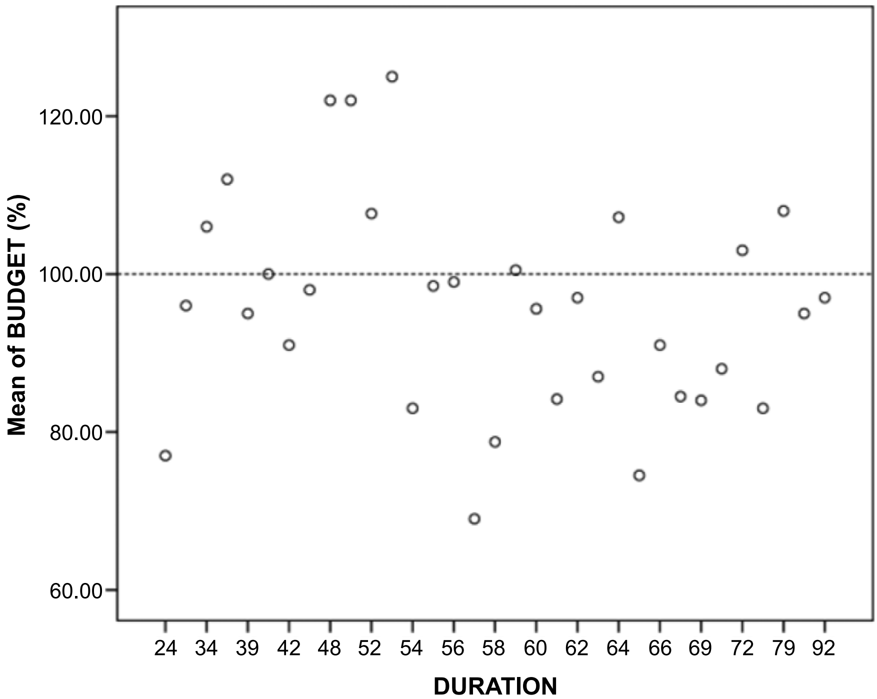

Figure 6. Cost performance versus original duration (months).

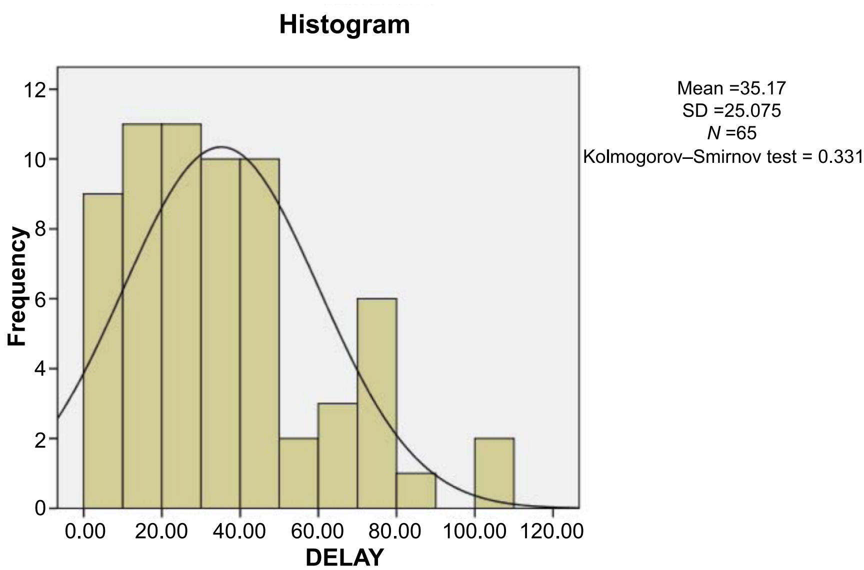

Figure 7. Histogram of schedule performance.

- The likelihood of a random project to finish late is 88%; while the likelihood of a project to finish on-schedule or ahead are 12%.
- The mean schedule delay is 35% of the original estimate (SD = 25%), and it is highly significant compared to an on-schedule scenario (p-value < 0.001).

- We reject with high significance the hypothesis that projects finishing with schedule delays are as common as projects meeting the schedule or finishing ahead of schedule (p-value < 0.001, binomial distribution test), meaning that the chances that a project is finished late is much higher than finishing on time.

These findings clearly indicate that schedule performance pose a larger challenge to these projects compared to cost performance. The underestimation of schedules is the rule rather than the exception and the magnitude of delay is significant.

Achievement of scope. Performance variables are largely affected by the completion of the scope of work. In order to address this distinction, the schedule delay will be analysed by projects that have completed the original scope to different degrees. Table 8 shows statistical measures for schedule performance grouped by the classification of scope completion: Highly Satisfactory (HS), Satisfactory (S) or Unsatisfactory (U).

The following observations can be made from Table 8:

- The values of schedule delay are less dispersed in highly satisfactory projects with respect to successful projects; range decreases from 100% to 44% and standard variation decreases from 25.8% to 17.9%.
- Unsuccessful projects presented smaller delay values, presumably due to an abrupt cancellation of the programme/project due to unsatisfactory implementation performance. This may happen when projects are not able to achieve the scope of work and present no indication that more time will help them to achieve it.
- The likelihood of a random project that finished its scope (HS and S) to finish late is 89%.

Based on these observations, it can be concluded that 89% of the time projects need more time than anticipated to complete their scope of work. It is also noted that there are some cases that do not achieve their scope regardless of the extra time given, although it happened in only three projects. Lastly, it is observed that better implementations show more controlled performance; this can be seen by observing smaller mean delay and smaller variation in highly satisfactory projects compared to successful projects.

Table 8. Schedule performance by scope completion (HS, S, U)

	Success		
	HS	S	U
Delay			
Number of projects	6	56	3
Mean	28%	37%	16%
Standard deviation	17.9	25.8	14.4
Minimum	0%	0%	0%
Maximum	44%	100%	28%
Chances of delay	83%	89%	67%

Table 9. Schedule performance by project size

	Project size		
	Project < $100 million	$100 million <project < $500 million	Project > $500 million
Delay			
Number of projects	25	28	12
Mean	27%	43%	33%
Standard deviation	26.5	22.6	23.6
Minimum	0%	0%	0%
Maximum	100%	100%	86%
Range	100	100	86
Probability of delay	76%	96%	92%

The effect of project size on schedule performance. Project size is defined by the actual cost of the project. Table 9 presents statistics of schedule performance by project size.

From Table 9, it can be concluded:

- There is a small statistical evidence that project delay values vary across project size (ANOVA p-value = 0.057, F-test).
- Projects between $100 million and $500 million present larger delays than the rest, with a mean value of 43% (SD = 22.6%), their delay is significantly larger than that of projects under $100 million ($p$-value = 0.020).

It is important to note that projects between $100 million and $500 million present the largest average delay of all groups. This performance by project size is consistent with the findings on cost performance for each group.

Schedule performance over time. In the same way that we evaluated if cost performance has improved over time, we examine schedule performance over time. Figure 8 presents a scatter plot of schedule performance and original start date and Figure 9 shows a scatter plot of schedule performance and actual completion date.

It can be observed visually from the scatter plots that no evidence of improvement or learning over time is present in the data. Thus, defining the null hypothesis for the case that the delay remains the same for various length projects, and using the ANOVA, no sufficient evidence is found to reject the hypothesis (p-value = 0.081 and 0.529, respectively; F-test). In addition, a simple regression analysis was designed for each case and the results do not indicate a linear trend (R^2 = 0.093 and 0.01, respectively). Therefore, no improvement on schedule performance over the years, or learning from past experience can be supported by this data. Again, it should be cautioned that the length of analysis (1991–2007) may not be sufficient to detect major improvements in learning from mistakes and errors.

Schedule performance versus duration. Lastly, schedule performance will be analysed versus project duration, defined by the original duration of projects in month.

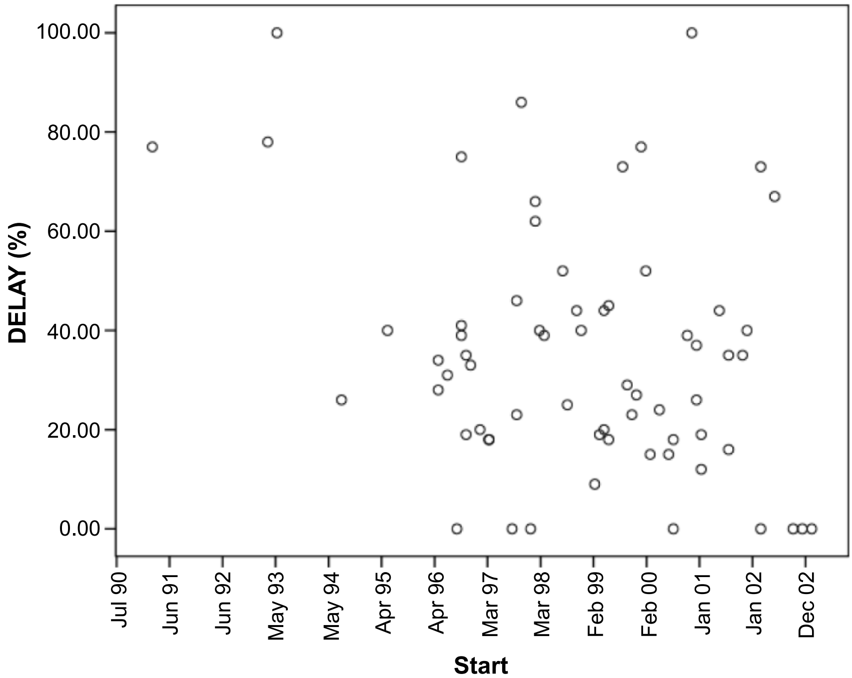

Figure 8. Schedule performance versus original start.

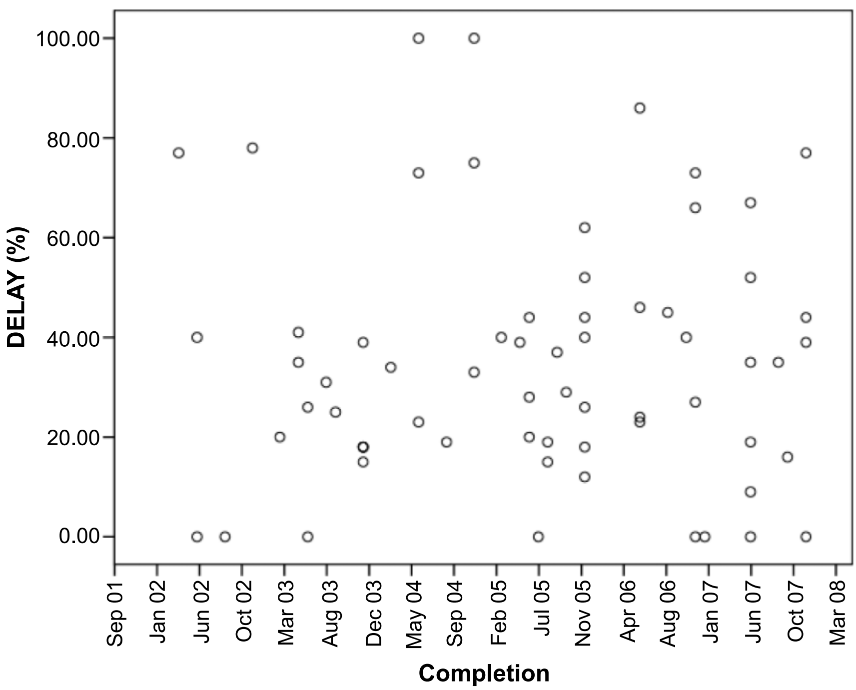

Figure 9. Schedule performance versus actual completion date.

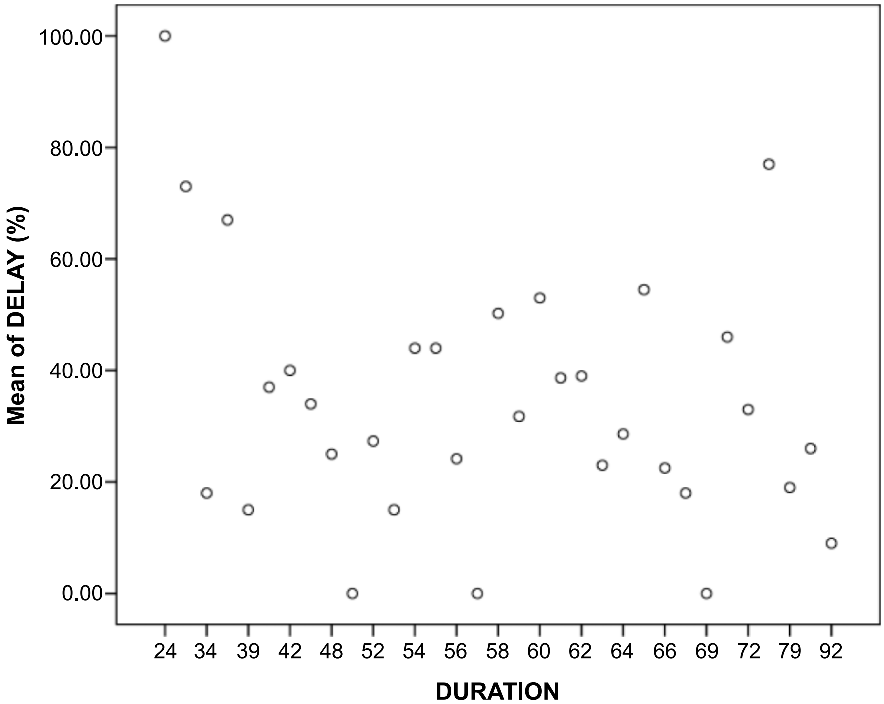

Figure 10. Schedule performance versus original duration (month).

Figure 10 presents a scatter plot of schedule delay plotted against original duration in month.

The scatter plot in Figure 10 seems to reveal that schedule delay does not correlate with project duration. In order to corroborate this statistically, an ANOVA was designed resulting in not sufficient evidence to reject the hypothesis that schedule performance is similar for projects of different durations (p-value = 0.212; F-test). In addition, testing the linear correlation showed a small significance (p-value = 0.028); however, the Pearson's correlation coefficient is very small (R = –0.273). Therefore, the conclusion is that no significant difference in schedule performance is evident for projects of different durations.

Conclusions

There are very few studies that have analysed the performance of infrastructure projects with large sample sizes. The only significant study found was published by Flyvbjerg *et al.* (2002, 2003) and its focus was mainly on projects implemented in developed countries. The current paper used a similar analytical approach and provided an extensive study of project performance data for transportation projects funded by the World Bank and implemented in developing countries.

The analysis used the World Bank's ICR reports and project performance data pertaining to 89 transportation projects. The sample size was later reduced to 65 to take into consideration only the projects that presented no significant change in project scope. In general, we can summarize the conclusions from the statistical analysis of infrastructure projects in developing countries as follows:

- In 5% of the cases (three projects), projects were not completed regardless of the availability of budget.
- Project budgets had a tendency to be overestimated 59% of the time, finishing under budget with an average cost of 3% less than the original estimate (SD = 17.2%). This is counter-intuitive as the common belief assumes that most infrastructure projects end up with large overruns.
- While there is no evidence that project cost is intentionally overestimated, this error can reduce the owner's effectiveness in funding deserving projects due to tying up funds in overestimated projects. This is more evident in projects between $100 million and $500 million where the average overestimation is 13% of the estimated cost (SD = 17.7%). There was no indication on why projects within this price range performed worse.
- Projects of less than $100 million and above $500 million are more predictable in terms of cost and schedule, while projects between $100 million and $500 million show a significant tendency to be overestimated and overpromised, finishing on average 13% under budget and 43% over schedule, with a 96% chance of delay.
- There is no evidence that predictability has improved over time nor has learning in forecasting over the period evaluated in the sample. This is true for both cost and schedule performance.
- Neither cost performance nor schedule delay significantly correlated with project duration.
- Infrastructure projects have a significant tendency to incur schedule delays, 89% of the time. Average delay is 35% of the original duration (SD = 25%) and is highly significant compared to an on-schedule scenario (p-value < 0.001).
- It has been proven that 'implementation efficiency' is a driver of performance with the best cost and schedule performance in highly satisfactory projects.
- Lastly, it is evident that schedules are being significantly less controlled and more poorly predicted in developing countries than budgets.

Contrary to the results reported by Flyvbjerg *et al.* (2002) for projects implemented in developed nations, we observed that developing economies have less bias influencing the original cost estimates to promote projects. This at least seems to be true for projects sponsored by the World Bank. However, it was shown that schedule issues pose a larger challenge in these programmes compared to cost's. Overpromised schedules are the rule rather than the exception and the magnitudes of actual delay are significant. Consequently, whenever schedule is a constraint, there is a high risk of failing to finish the scope of work.

Although many may think that finishing a project below budget is desirable, this may not always be the case. Accuracy in project estimates is crucial for many owners in promoting their projects and using the available resources, especially in developing countries where resources are limited and efficiency is a requirement. The analysis shows that schedule performance is significantly different from the forecasts and there has not been any learning from the experiences of the past 15 years. Tighter controls are needed by owners of infrastructure projects to achieve the predictability needed to maximize the use of their resources; otherwise, the public's and the sponsors' mistrust may jeopardize the future project funding.

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Appendix

Table A.1. Project's database of cost and schedule

Number	Project ID no.	Country	Project name	Original start	Estimated finish	Actual finish	Project rating	Budgeted cost ($)	Actual cost ($)	WB estimate ($)[a]	WB actual ($)
1	P036060	Albania	National Roads Project	October 1996	June 2001	May 2003	S	66.00	72.00	25.00	22.95
2	P068853	Albania	Emergency Road Repair Project	March 2000	June 2003	December 2003	S	14.50	13.80	13.70	12.99
3	P066260	Albania	Road Maintenance Project	October 2002	June 2007	June 2007	S	37.07	40.92	30.00	33.75
4	P004907	Algeria	The Sixth Highway Project	June 1995	December 2002	December 2002	U	230.00	203.00	130.00	113.20
5	P052590	Argentine	National Highway Rehabilitation and Maintenance Project	December 1998	December 2003	December 2005	S	929.00	859.00	450.00	449.00
6	P005980	Argentine	Provincial Roads Project	November 1997	December 2002	June 2006	S	1 500.00	1 160.20	300.00	296.50
7	P035770	Azerbaijan	Pilot Reconstruction Project	November 1998	December 2001	September 2005	S	54.20	83.70	20.00	19.50
8	P037294	Bangladesh	Third Road Rehabilitation and Maintenance Project	May 1999	December 2003	December 2005	S	528.50	468.00	284.00	229.00
9	P009524	Bangladesh	Dhaka Urban Transport Program	May 1999	June 2004	June 2005	U	243.00	125.00	177.00	90.00
10	P009518	Bangladesh	Second Rural Roads and Maintenance Project	February 1997	March 2002	March 2003	S	217.95	196.41	153.00	141.90
11	P040150	Belize	Roads and Municipal Drainage Project	January 2001	June 2004	September 2005	S	18.39	18.41	13.00	12.40
12	P055230	Bolivia	Abapo–Camiri Highway Project	October 1999	June 2004	October 2005	S	120.00	118.00	88.00	89.20

Table A.1. (*Continued*)

Number	Project ID no.	Country	Project name	Original start	Estimated finish	Actual finish	Project rating	Budgeted cost ($)	Actual cost ($)	WB estimate ($)[a]	WB actual ($)
13	P071347	Bosnia & Herzegov.	Road Management and Safety Project	October 2002	June 2007	June 2007	S	41.53	49.45	30.00	34.67
14	P006532	Brazil	Federal Highway Decentralization Project	February 1998	December 2002	December 2005	S	375.00	311.00	300.00	245.30
15	P034578	Brazil	Rio Grande do Sul Highway Management Project	August 1998	June 2003	December 2005	S	136.00	104.00	70.00	70.00
16	P055954	Brazil	Goias State Highway Management Program	March 2002	December 2004	December 2006	S	130.00	120.50	65.00	63.20
17	P059481	Bhutan	Rural Access Project	May 2000	April 2005	June 2006	S	14.86	14.78	11.60	11.33
18	P000393	Cameroon	Transport Sector Project	April 1997	December 2002	December 2003	S	87.60	77.40	60.70	56.40
19	P004030	Cambodia	Road Rehabilitation Project	June 1999	June 2004	September 2006	S	47.60	47.41	45.31	44.47
20	P000435	Cape Verde	Transport and Infrastructure Project	June 1993	June 1998	June 2004	S	84.77	88.45	17.50	17.37
21	P006661	Chile	Third Road Sector Project	October 1995	June 1999	December 2002	S	2 075.30	4 589.00	120.00	118.90
22	P050036	China	Anhui Provincial Highway Project	April 1999	August 2004	August 2005	S	453.90	506.70	200.00	170.60
23	P003626	China	Fujian Provincial Highway Project	July 1994	June 2000	December 2003	S	528.80	465.00	140.00	117.50
24	P040513	China	Second Henan Provincial Highway Project	December 1996	December 2002	December 2004	S	605.60	621.30	210.00	180.70
25	P003652	China	Second Shaanxi Provincial Highway Project	July 1996	December 2001	December 2002	S	556.50	574.00	210.00	210.00

Table A.1. (*Continued*)

Number	Project ID no.	Country	Project name	Original start	Estimated finish	Actual finish	Project rating	Budgeted cost ($)	Actual cost ($)	WB estimate ($)[a]	WB actual ($)
26	P041890	China	Liaoning Urban Transport Project	June 1999	December 2004	December 2005	S	383.90	337.95	150.00	147.51
27	P003643	China	Second Xinjiang Highway Project	April 1997	December 2002	December 2003	S	658.00	532.00	300.00	240.00
28	P041268	China	Fourth National Highway Project	December 1999	June 2005	December 2006	S	952.10	890.80	350.00	312.40
29	P058843	China	Guangxi Highway Project	February 2001	June 2006	June 2007	S	566.82	602.38	200.00	180.30
30	P070441	China	Hubei Xiaogan–Xiangfan Highway Project.	February 2003	December 2007	December 2007	S	690.00	862.47	250.00	221.72
31	P051705	China	Second Fujian Highway Project	November 19999	June 2005	June 2007	S	595.60	616.59	200.00	195.98
32	P058845	China	Second Jiangxi Highway Project	March 2002	December 2006	December 2006	S	535.70	371.20	200.00	145.20
33	P058844	China	Third Henan Provincial Highway Project	March 2001	December 2005	December 2006	S	359.53	311.43	150.00	123.10
34	P045788	China	Tri-Provincial Highway Project	March 1999	June 2005	June 2007	S	658.70	649.27	230.00	225.00
35	P074006	Congo	Emergency Infrastructure Rehabilitation	December 2002	January 2007	January 2007	U	40.00	48.97	40.00	48.97
36	P069930	Djibouti	International Road Corridor Rehabilitation Project	July 2000	December 2004	August 2005	S	18.00	22.50	15.00	22.00
37	P035722	Dominican Rep.	National Highway Project	April 1997	December 2001	October 2003	S	122.50	180.90	75.00	75.00
38	P044674	Eritrea	Emergency Reconstruction Program	December 2000	December 2002	December 2004	S	287.70	220.60	105.00	105.00

Table A.1. (*Continued*)

Number	Project ID no.	Country	Project name	Original start	Estimated finish	Actual finish	Project rating	Budgeted cost ($)	Actual cost ($)	WB estimate ($)[a]	WB actual ($)
39	P035775	Estonia	Transport Project	September 2000	December 2005	December 2005	S	49.60	51.30	25.00	16.00
40	P000755	Ethiopia	Road Sector Development Program Support Project	April 1998	May 2003	May 2005	S	490.60	534.00	309.00	333.00
41	P000734	Ethiopia	Road Rehabilitation Project	April 1993	September 1998	December 2002	S	109.25	110.84	96.00	90.60
42	P040556	Georgia	Roads Project	January 2001	December 2004	December 2005	S	55.00	57.00	40.00	40.70
43	P057538	Honduras	Road Reconstruction and Improvement Project	November 2001	March 2006	September 2007	S	106.80	118.20	66.50	73.20
44	P009995	India	Andhra Pradesh state Highway Project	October 1997	January 2003	June 2004	S	485.50	424.70	350.00	333.00
45	P010566	India	Gujarat State Highway Project	November 2000	December 2005	December 2007	HS	533.00	408.34	381.00	280.00
46	P070421	India	Karnataka State Highway Improvement Project	August 2001	December 2006	October 2007	S	447.00	538.38	360.00	360.00
47	P003993	Indonesia	Sumatra Region Roads Project	July 1998	December 2003	December 2005	S	369.00	219.00	234.00	178.90
48	P004016	Indonesia	Strategic Urban Roads Infrastructure Project	November 1996	September 2001	May 2003	S	168.00	109.00	86.90	86.40
49	P008499	Kazakhstan	Road Transport Sector Restructuring Project	January 2000	December 2004	December 2007	S	143.80	131.91	100.00	95.60
50	P035691	Kenya	Nairobi–Mombasa Road Rehabilitation Project	May 1996	March 2002	March 2004	S	122.00	120.00	50.00	41.90
51	P001319	Kenya	Urban Transport Infrastructure Project	May 1996	June 2003	June 2005	U	155.00	156.80	115.00	78.35

Table A.1. (*Continued*)

Number	Project ID no.	Country	Project name	Original start	Estimated finish	Actual finish	Project rating	Budgeted cost ($)	Actual cost ($)	WB estimate ($)[a]	WB actual ($)
52	P004175	Korea	Pusan Urban Transport Management Project	June 1995	June 2000	June 2002	S	332.00	202.00	100.00	92.00
53	P070295	Kosovo	Urgent Road Project	August 2000	June 2003	December 2003	S	12.00	12.76	5.00	12.00
54	P004210	Lao	Third Highway Improvement Project	September 1997	June 2003	June 2003	HS	69.90	63.80	48.00	45.00
55	P042237	Lao	Provincial Infrastructure Project	March 1999	November 2006	June 2007	S	31.10	30.18	27.80	27.94
56	P038674	Lebanon	National Roads Project	November 1996	June 2003	September 2004	S	67.80	73.00	42.00	40.90
57	P001403	Lesotho	Road Rehabilitation and Maintenance Project	October 1996	December 2001	December 2003	S	129.00	124.60	40.00	22.90
58	P050589	Macedonia	Transport Sector Project	May 1999	June 2002	September 2004	S	41.70	46.30	31.70	31.00
59	P052208	Madagascar	Transport Sector Reform and Rehabilitation Project	August 2000	July 2005	July 2005	S	66.00	70.30	63.50	64.70
60	P001666	Malawi	Road Maintenance and Rehabilitation Project	November 1999	March 2005	June 2006	S	34.90	38.37	30.00	31.64
61	P041723	Mali	National Rural Infrastructure Project	June 2001	December 2005	December 2007	S	139.30	115.10	115.10	114.10
62	P005524	Morocco	Fes Medina Rehabilitation Project	March 1999	December 2003	November 2005	U	27.60	14.30	14.00	9.00
63	P001804	Mozambiq.	Second Roads and Coastal Shipping Project	August 1994	June 2001	June 2003	S	814.60	776.26	188.26	186.26
64	P001785	Mozambiq.	Roads and Bridges Management Project	June 2002	June 2005	June 2007	S	703.60	789.60	162.00	187.00

Table A.1. (*Continued*)

Number	Project ID no.	Country	Project name	Original start	Estimated finish	Actual finish	Project rating	Budgeted cost ($)	Actual cost ($)	WB estimate ($)[a]	WB actual ($)
65	P045052	Nepal	Road Manintenance and Development Project	February 2000	December 2004	June 2007	S	65.90	59.74	54.50	53.47
66	P053705	Nicaragua	Second Road Rehabilitation and Maintenance Project	November 1998	June 2003	June 2005	HS	54.50	59.00	47.40	48.00
67	P068673	Nicaragua	Third Road Rehabilitation and Maintenance Project	August 2001	December 2005	June 2007	HS	87.40	88.70	75.00	83.10
68	P035608	Niger	Transport Infrastructure Rehabilitation Project	May 1998	January 2003	May 2003	U	30.50	29.00	28.00	26.90
69	P007844	Panama	Roads Rehabilitation Project	April 1994	September 2000	September 2003	S	409.90	476.00	60.00	55.50
70	P044601	Peru	Second Rural Roads Project	December 2001	June 2005	November 2006	HS	151.00	137.43	50.00	48.19
71	P039019	Philippines	First National Roads Improvement Project	July 2000	June 2004	March 2007	S	305.43	306.56	150.00	133.30
72	P008593	Poland	Roads II project	February 1998	June 2003	December 2006	S	540.00	473.00	300.00	300.00
73	P039250	Romania	Roads Two Project	October 1997	September 2003	June 2006	S	553.45	486.31	150.00	150.00
74	P008806	Russia	Urban Transport Project	September 1995	June 2001	December 2002	S	391.00	309.00	329.00	247.60
75	P035764	Russia	A Bridge Rehabilitation Project	July 1996	December 2001	August 2003	S	466.00	224.00	350.00	150.11
76	P002238	Rwanda	Transport Sector Project	March 1991	June 1997	April 2002	S	149.00	124.00	40.00	85.70
77	P057996	Senegal	National Rural Infrastructure Project	February 2001	June 2005	December 2005	HS	42.90	47.47	28.50	28.02
78	P002420	Sierra Leone	Transport Sector Project	October 1996	June 2001	December 2004	S	41.00	35.00	35.00	32.00

Table A.1. (*Continued*)

Number	Project ID no.	Country	Project name	Original start	Estimated finish	Actual finish	Project rating	Budgeted cost ($)	Actual cost ($)	WB estimate ($)[a]	WB actual ($)
79	P052293	Samoa	Infrastructure Asset Management Project	May 1999	December 2002	March 2004	HS	18.80	19.80	14.40	13.70
80	P002770	Tanzania	Second Integrated Roads Project	February 1995	December 2000	December 2006	S	650.20	669.82	170.20	90.77
81	P002875	Togo	Road Transport Project	January 1998	September 2002	September 2002	S	55.00	32.00	50.00	32.00
82	P038091	Turkey	Road Improvement and Traffic Safety Project	September 1996	March 2003	February 2003	S	389.00	308.00	250.00	202.00
83	P059223	Uganda	Nakivubo Channel Rehabilitation Project	September 19999	June 2002	June 2004	S	24.92	24.68	22.38	22.17
84	P049267	Uruguay	Second Transport Project	September 1998	September 2002	September 2003	S	137.00	167.00	64.50	64.50
85	P039203	Uruguay	Forest Products Transport Project	December 1997	December 2001	April 2006	S	152.00	142.00	76.00	71.00
86	P008223	Venezuela	Highway Maintenance Project	March 1993	June 1998	December 2002	S	840.00	291.00	150.00	83.00
87	P004842	Viet Nam	Second Highway Rehabilitation Project	July 1997	June 2002	June 2003	S	236.70	201.70	195.60	173.60
88	P041267	Yemen	Transport Rehabilitation Project	September 1996	June 2002	June 2002	S	51.80	40.00	34.50	29.00
89	P003236	Zambia	Road Sector Program and Support Project	March 1998	March 2003	March 2005	S	384.00	466.00	70.00	69.00

[a]WB estimate refers to the estimated share of WB at the project conception. WB actual refers to the actual contribution of WB to the project.

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