TRENDS IN U.S. RAIL TRANSIT PROJECT COST OVERRUN

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ABSTRACT

This paper compares the results of the Pickrell report to cost overruns of transit projects completed after 1990 to see if there has been any improvement in estimating the capital costs of rail transit projects in the past decade. The Pickrell's report, published in 1990, looked at 10 rail projects built in the 1980s and reported on the cost difference between the original cost estimates and the final costs of these projects. We have compared those statistics with data from 16 recent transit rail projects. The comparison focuses only on federally funded rail projects in the United States. The characteristics of the projects and data in the 1990 study and of the "recent" projects are presented followed by a statistical comparison. We conclude that there is evidence to suggest that cost overruns for projects completed before 1990 are different from that of projects completed after 1994 (*i.e.*, cost overruns have become smaller), but we do not have sufficient data to statistically prove this at a level of significance of 5%. In our opinion this is a positive trend. We suggest that we continue to pursue the current research by collecting data as more transit projects are completed and as more data becomes available.

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Nasiru A. Dantata[1] , Ali Touran [2], and Donald C. Schneck[3]

BACKGROUND

The results of the Pickrell's (1990) UMTA report on cost overruns in rail projects in the United States have been widely cited in several articles and research publications (Flyvbjerg *et al* 2002; Touran *et al* 1994). The report looked at 10 rail projects built in the 1980s. Many more rail projects have been built in the United States since 1990. The objective of this paper is to examine whether the results of Pickrell's report are still valid today or if the magnitude of cost overruns in rail transit projects have changed. Flyvbjerg *etal.* (2002, 2003) conducted a study for projects worldwide and concluded that cost estimating has not improved in the last two decades.

This paper compares the results of the Pickrell study to cost overruns of transit projects completed after 1990 to see if there is any improvement in estimating the capital costs of rail transit projects. It should be noted that this comparison is performed at a macro level and is not looking at causes of cost overrun in transit projects. Many factors have been suggested for the cause of cost overrun including but not limited to optimistic underestimation of costs at conceptual phase, the lengthy project approval and construction process, omission of project components during early phases, addition to project scope during project development, and unforeseen latent conditions that are difficult to predict. The study of these factors, although very important, is beyond the scope of this paper. The purpose here is to get an aggregate impression about the trend in cost overruns in transit projects in the past four decades. The current comparison focuses only on federally funded rail projects in the United States. The characteristics of the projects and data in the 1990 study and of the "recent" projects are presented followed by a statistical comparison.

PROJECT CHARACTERISTICS AND COST OVERRUNS

This analysis is limited to the ten (10) studies in the Pickrell (1990) report compared with data from sixteen (16) recently completed projects.

Projects Completed Prior to 1990

Pickrell examined 10 rail transit projects. Among them, two were automated guideway (AGT), four were heavy rail (HRT), and four were light rail transit (LRT) projects. Publication dates of AA/DEIS studies for these

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projects ranged from 1969 to 1981 and the projects were completed between 1986 and 1989. The average cost overrun was 50%. Nine out of the ten projects experienced cost overruns of 13% to 106% in 1988 dollars. One project experienced a cost underrun of 11%. Table 1 shows the capital costs and analysis of cost overruns of the projects in this study. The actual capital costs of the 10 projects range between $175 million to $7,968 million with an average of $1,551 million in 1988 dollars. The average actual cost for 9 projects excluding the Washington METRO HRT project is $838 million.

The main criteria used for selecting the 10 projects were the availability of detailed cost and ridership data and the amount of federal funding. The 10 projects also comprised "significant share of federally-financed investment in major transit capital improvements" from the late 1970s to the late 1990s (Pickrell 1990).

Projects Completed After 1994

We collected data for sixteen projects planned (DEIS published) after 1984 and completed after the publication of the Pickrell's report. These projects comprise 1 AGT, 7 HRT, and 8 LRT projects. Bus Transit projects are excluded because the Pickrell's report considered rail transit projects only. Publication dates of AA/DEIS studies for these projects ranged from 1984 to 1990 and the projects were completed between 1995 and 2004. The average cost overrun was 30%. Thirteen out of the sixteen projects experienced cost overruns of 3% to 78% in YOE dollars. The remaining three projects experienced cost underruns of 2% to 28%. Table 2 shows the capital costs and analysis of cost overruns for the recently completed projects.

The Pickrell's cost estimates are expressed in 1988 dollars while the costs of the recently completed projects are expressed in YOE dollars. These two formats can be used together in this analysis because they are both inflation adjusted. We adjusted project costs to the YOE dollars using the ENR's Construction Cost Index. In both cases the cost overruns measure the difference between the budget at the AA level and the actual costs adjusted for inflation.

The actual capital costs of the 16 projects range between $94 million to $1,625 million with an average of $486 million in 1988 dollars. The criteria for selecting these projects were the availability of the forecast and actual costs data and the time period from planning to completion. In general, collecting project data is a major undertaking; relevant reports are difficult to obtain and the information about the date of estimates is not readily available. In this paper, we were interested in rail projects of relatively large size with a DEIS report date of after 1982 (the latest date in Pickrell's report) and construction date of after 1994. This puts at least 5 years distance between the completion date of the projects and the completion of the UMTA (Pickrell) study.

Projects analyzed by Pickrell had an average cost of about 3 times the average cost of the 16 recent projects presented in this paper. This difference raises two questions: has the size of transit projects got smaller since 1990? Is cost overrun related to project size (total capital cost)? These questions are answered in the next section.

THE EFFECT OF PROJECT SIZE AND DATE ON COST OVERRUN

In evaluating the relationship between project size (cost) and cost overrun, we need to look at all available estimates and actual cost data on transit projects. Data was collected on 37 projects. These include the 10 projects in the 1990 Pickrell report, the 16 recently completed projects, and 11 other projects. The actual costs of the projects were converted to 1988 dollars to be consistent with the format of the 1990 Pickrell report. Table 3 shows the actual cost in 1988 dollars, the cost overrun, and the year of completion for the 37 projects. The actual capital costs of the 37 projects range between $94 million to $7,968 million with an average of $806 million in 1988 dollars.

Figure 1 shows the relationship between the total capital cost in 1988 dollars and the year of completion for the 37 projects. It shows that 30 projects cost below $1 billion while 7 projects cost above $1 billion. The projects under $1 billion were completed from 1988 to 2001 and show no clear pattern of increase or decrease with time. Among the 7 projects over $1 billion, four were completed before 1990 and the other 3 were completed after 2000. The figure shows that there is no clear trend of declining project size. The correlation coefficient between the actual capital cost and the year of completion is 0.38. This is a weak correlation and we conclude that the relationship between the project size and year of completion is weak, or there is no trend of declining project size. In general, a correlation coefficient of between 0 (minimum) and 0.5 is considered weak and between 0.8 and 1.0 (maximum) is considered strong (Devore 2004).

Figure 2 shows the relationship between the project size and cost overrun. The figure shows no clear pattern between the two variables. The correlation coefficient between the actual capital cost and the cost overrun is 0.37. This is again a weak correlation and we conclude that the relationship between the project size and cost overrun is weak.

STATISTICAL COMPARISON OF THE TWO SAMPLES

Table 4 summarizes the characteristics and summary statistics of the two samples being compared. Figure 3 shows the period between the publications of AA/DEIS reports and completion of projects for all projects in the two samples. It clearly shows that the recent projects being compared were executed in a period after that of the projects in the Pickrell's report. This is important because the goal of the comparison was to compare the two periods so we avoided projects in one sample that were executed in the time span of the other sample.

In comparing the average of cost overruns, we see that projects completed after 1990 experienced less cost overruns. However, the standard deviation of the cost overrun in this period is larger. Figure 4 shows the cost overrun versus year of completion for all sample projects. It shows that the range of cost overruns is about the same for projects completed before and after 1990.

In order to take into consideration data characteristics other than the means, we propose to conduct a statistical test of hypothesis. The hypothesis test that is relevant to our objective is called the 'two sample t-test.' The two sample t-test is used to compare the means of two normally distributed populations with unknown variances. The means and standard deviations of cost overruns shown in Table 4 are for the sample data and do not represent the true standard deviations of projects completed before or after 1990. Therefore the true means and true variances of cost overrun in transit projects are not known. That is why we have to use hypothesis test to check if the true means are the same or have changed; that is, whether the cost estimation has improved or not. Two assumptions are necessary to use the t-test. These are:

- Both populations (cost overruns in transit projects completed before and after 1990) are normally distributed, and
- The populations are independent; that is cost overruns for projects completed prior to 1990 are independent of cost overruns for projects completed after 1990.

These assumptions are reasonable for our population. The notations used in the hypothesis test are as follows:

- μ_1 represents the true mean of cost overruns for all projects completed before 1990
- μ_2 represents the true mean of cost overruns for all projects completed after 1994 (recent projects)

- y_1 represents the average cost overruns for our sample projects completed before 1990; this equals 0.5 from Table 4 (Sample mean for pre-1990 data)
- y_2 represents the average cost overruns for our sample projects completed after 1994; this equals 0.3 from Table 4 (Sample mean for post-1994 data)
- n_1 represents the size of the sample of projects completed before 1990; $n_1 = 10$
- n_2 represents the size of the sample of projects completed after 1994; $n_2 = 16$
- s_1^2 represents the variance of the sample of projects completed before 1990;
  $s_1^2 = 0.1089$
- s_2^2 represents the variance of the sample of projects completed after 1994;
  $s_2^2 = 0.1521$

The t-test used here is as suggested by Devore (2004).

The Null Hypothesis, H_0

The null hypothesis, denoted by H_0, is the basic question the test seeks to verify.
In our case it is H_0: $\mu_1 - \mu_2 = 0$ (or $\mu_1 = \mu_2$); that is cost overruns in transit projects have remained the same. The result of the t-test is to see if we can refute this hypothesis and therefore show that cost overruns have changed (improved.)

The Alternate Hypothesis, H_a

The alternative analysis, denoted by H_a, is the hypothesis to be put forth with the null hypothesis so that the null hypothesis can be rejected in support of the alternative analysis. We will examine two alternative hypotheses. The first will be that the mean cost overrun for projects completed after 1990 is different from the mean cost overrun for projects completed after 1994. This is shown as H_a: $\mu_1 \neq \mu_2$. The test for this H_a is called a two-tailed test because it considers the upper and lower ends of the distributions when checking if the means of the two populations are not equal.

The second H_a to test against H_0 is H_a: $\mu_1 > \mu_2$. That is the mean cost overrun for projects completed before 1990 is higher than that of projects completed after 1994 (as suggested by the sample means.) The test of this H_a is called a one-tailed test because it considers only one end of the distribution. This alternative hypothesis is important to use because we want to check if the improvement in cost forecasting shown by a lower average for projects completed after 1994 is statistically viable.

Test Results

The test statistic *t* is calculated from Eq. (1):

$$T = \frac{[(y_1 - y_2) - (\mu_1 - \mu_2)]}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} = 1.400 \qquad (1)$$

T has approximately a *t* distribution with υ degrees of freedom, where, degrees of freedom, is calculated from Eq. (2):

$$\nu = \frac{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)^2}{\frac{(s_1^2 / n_1)^2}{n_1 - 1} + \frac{(s_2^2 / n_2)^2}{n_2 - 1}} = 22 \qquad (2)$$

The p-value for the one-tailed test is 8.9% and for the two-tailed test is 17.8%. The p-value is the level of significance that will change the result of the test and reject the null hypothesis. It is the smallest α (level of significance) at which H_o would be rejected.

The results of the analysis suggest if we use a level of significance of 8.9% we can reject the hypothesis that cost increases have remained the same in favor of the cost overrun having decreased in recent years. In similar applications, level of significance values of between 1% to10% have been used, with α being 5% probably the most common assumption. At 5% level, the null hypothesis cannot be rejected, *i.e.,* there is insufficient evidence to prove statistically that cost overruns have changed in recent years.

CONCLUSION

We observe that there is evidence to suggest that cost overruns for projects completed before 1990 are different from that of projects completed after 1994 (*i.e.,* cost overruns have become smaller), but we do not have sufficient data to statistically prove this at a level of significance of 5%. This conclusion applies to both alternatives that cost overruns are different or that they have become smaller. We can reject the hypothesis that cost overruns have remained the same in favor of them being different at a significance level of 17.81% or more and can reject the hypothesis that cost overruns have remained the same in favor of them being improved at a significance level of 8.90% or more. In our opinion this is a positive trend. We suggest that we continue to pursue the current research by collecting data as more transit projects are completed and as more data becomes available.

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Table 1 - Data from Pickrell's 1990 Report

S/N	Forecast and Actual Capital Costs in millions of 1988 dollars: City	Project	Transit Mode	Forecast	Actual	% Cost Overrun	Year of Estimate	Year Completed
1	Miami	DPM Starter Line	DPM/AGT	84	175	106	1980	1988
2	Detroit	Central Automated Transit	DPM/AGT	144	215	50	1980	1988
3	Washington	METRO	HRT	4,352	7,968	83	1969	1986
4	Atlanta	Metropolitan Atlanta HRT	HRT	1,723	2,720	58	1971	1987
5	Baltimore	Phase I Rapid Transit	HRT	804	1,289	60	1972	1987
6	Miami	Dade County HRT	HRT	1,008	1,341	33	1978	1988
7	Buffalo	Minimum LR Rapid Transit	LRT	478	722	51	1977	1989
8	Pittsburgh	South Hills Reconstruction	LRT	699	622	-11	1976	1989
9	Portland	Banfield Line	LRT	172	266	55	1980	1988
10	Sacramento	Starter Line (Stage I LRT)	LRT	165	188	13	1981	1988
					Earliest year		1969	1986
					Latest year		1981	1989

	Number of Projects	Forecast	Actual	% Cost Overrun
Average for All	10	963	1,551	50
Average for AGT	2	114	195	78
Average for HR	4	1,972	3,330	59
Average for LRT	4	379	450	27
Standard Deviation All	10	1,295	2,390	33
Standard Deviation AGT	2	42	28	40
Standard Deviation HR	4	1,635	3,163	20
Standard Deviation LRT	4	259	262	32

Table 2 - Estimated Vs. Actual Cost Data Projects Completed after 1994

N	City	Project	Transit Mode	Capital Cost (in YOE Millions) Adjusted for Inflation AA/DEIS	As-Built	% Cost Overrun	Year of Estimate	Year Completed
	Miami	Omni &Brickell Ext.	AGT	221.20	228.00	3	1987	1995
	Atlanta	North Line Ext.	HRT	439.50	472.70	8	1990	2000
	Baltimore	Ext. to Johns Hopkins	HRT	313.70	353.00	13	1984	1995
	Boston	Old Colony Rehabilitation	HRT	447.00	565.00	26	1990	1997
	Los Angeles	Blue Line	HRT	561.00	877.00	56	1984	1990
	San Juan	Tren Urbano	HRT	965.00	2,250.00	113	1995	2004
	San Francisco	Airport Ext.	HRT	1,282.93	1,552.20	21	1992	2003
	San Francisco	Colma BART Station	HRT	112.50	179.90	60	1988	1996
	Baltimore	BWI, Hunt Valley, Penn Station Ext.	LRT	81.90	116.20	42	1990	1997
0	Dallas	South Oak Cliff	LRT	325.40	360.00	11	1990	1996
	Denver	Southwest	LRT	149.60	177.70	19	1995	2000
2	Northern NJ	Hudson-Bergen MOS-1	LRT	623.90	1,113.00	78	1993	2001
3	Minneapolis	Hiawatha Corridor	LRT	480.34	715.40	49	1985	2004
4	Salt Lake City	I-15/State Street	LRT	305.60	298.50	-2	1987	1999
5	San Jose	Tasman West	LRT	451.20	325.20	-28	1991	1997
6	St. Clair Co.	MetroLink Ext.	LRT	367.70	339.20	-8	1995	2001
						Earliest year	1984	1990
						Latest year	1995	2004

Cost estimates are reported in "midpoint of construction" dollars

Table 2 - Estimated Versus Actual Cost Data for Projects completed after 1994 (Continued)

	Number of Projects	Capital Cost (in YOE Millions) Adjusted for Inflation		Cost overrun (%)
		AA/DEIS	As-Built	
Average for All	16	445.53	620.19	30
Average for AGT	1	221.20	228.00	3
Average for HR	7	588.80	892.83	45
Average for LRT	8	348.21	430.65	20
Standard Deviation All	16	311.56	581.59	39
Standard Deviation AGT	1	-	-	-
Standard Deviation HR	7	401.88	748.40	44
Standard Deviation LRT	8	176.13	327.65	35

Table 3 - Capital costs, cost overrun, and year of completion

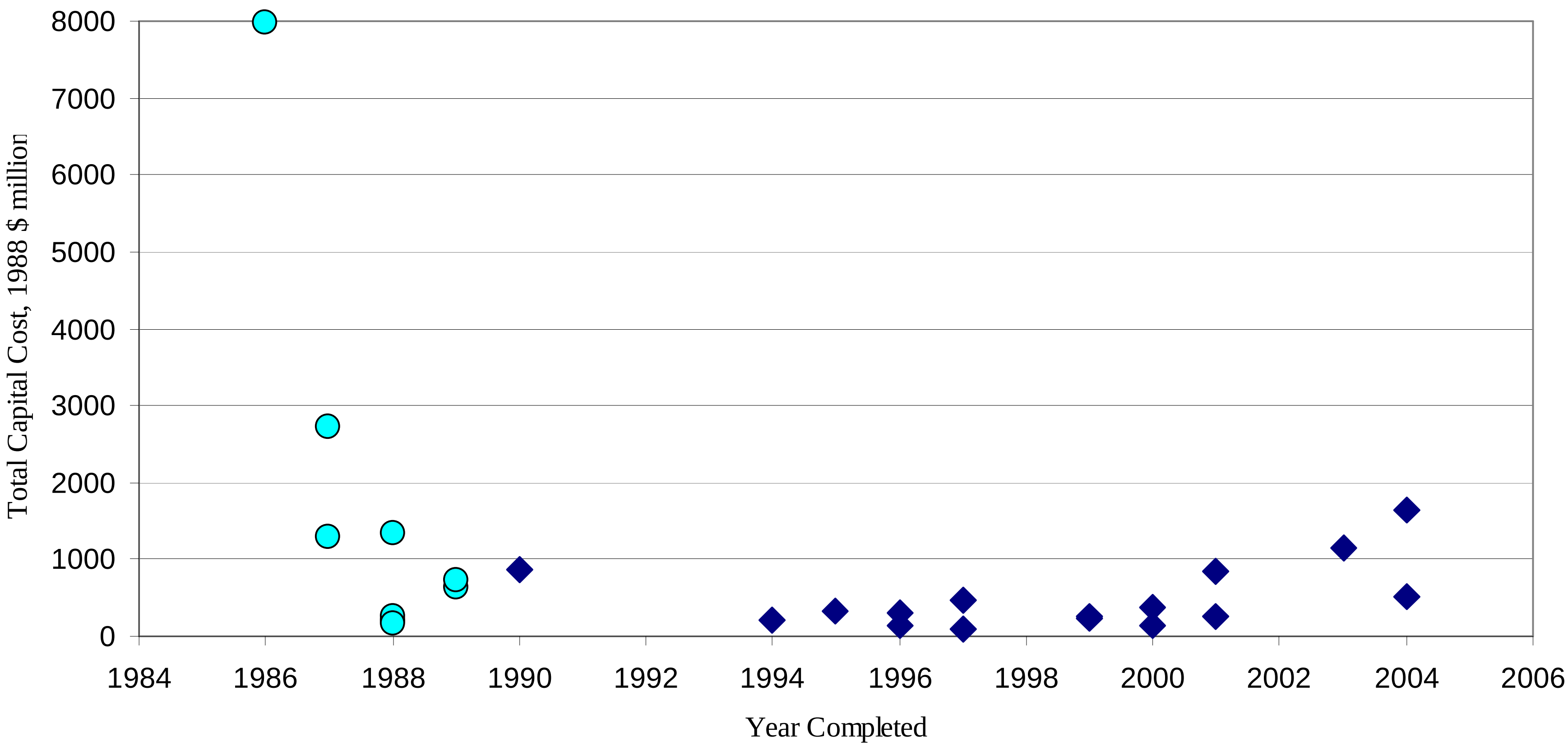
Project	Mode	Cost in 1988 $ millions	Cost Overrun	Year Completed
16 Recently planned and completed projects				
Miami Omni/Brickell	AGT	209.01	3.07%	1994
Atlanta North Line	HRT	365.06	7.55%	2000
Baltimore Johns Hopkins	HRT	323.60	12.52%	1995
Boston Old Colony Rehabilitation	HRT	458.28	26.40%	1997
Los Angeles Blue Line	HRT	865.01	56.33%	1990
San Francisco BART Airport Extension	HRT	1,139.48	20.99%	2003
San Francisco BART Colma Station	HRT	150.23	59.90%	1996
San Juan Tren Urbano	HRT	1,651.74	133.16%	2004
Baltimore BWI, H/Valley & P/Station Ext.	LRT	94.25	41.91%	1997
Dallas South Oak Cliff	LRT	300.64	10.63%	1996
Denver Southwest	LRT	130.45	18.80%	2000
Northern NJ Hudson-Bergen MOS-1	LRT	836.68	78.39%	2001
Minneapolis-St. Paul Hiawatha Corridor	LRT	513.00	48.94%	2004
Salt Lake City I-15/State Street	LRT	230.53	-2.32%	1999
San Jose Tasman West	LRT	249.15	-27.92%	1999
St. Louis St. Clair	LRT	254.99	-7.74%	2001
Pickrell 1990 Report Projects				
Pittsburgh LR	LRT	622.00	-11.02%	1989
Sacramento LR	LRT	188.00	13.94%	1988
Miami HR	HRT	1,341.00	33.04%	1988
Detroit DPM	AGT	215.00	49.31%	1988
Buffalo LR	LRT	722.00	51.05%	1989
Portland LR	LRT	266.00	54.65%	1988
Atlanta HR	HRT	2,720.00	57.86%	1987

Baltimore HR	HRT	1,289.00	60.32%	1987
Miami DPM	AGT	175.00	108.33%	1988
Washington HR	HRT	7,968.00	83.09%	1986
Other Projects				
Jacksonville ASE	AGT	106.04	59.98%	2000
Denver I-25 Busway	BRT	209.01	20.31%	1994
Houston SW Transitway	BRT	94.52	2.78%	1993
Pittsburgh Westside	BRT	236.24	17.26%	2000
Seattle Bus Tunnel	BRT	462.29	56.47%	1990
Chicago Southwest	HRT	501.91	-13.58%	1993
Los Angeles Red Line	HRT	3,281.23	47.45%	2002
Portland Westside/Hillsboro	LRT	781.91	72.37%	1998
San Diego El Cajon	LRT	102.70	-10.25%	1989
San Jose Guadalupe	LRT	380.30	47.60%	1991
St. Louis Initial LRT	LRT	387.49	22.20%	1993

Table 4 - Samples Data Comparison

	UMTA Study Sample (Projects completed before 1990)	Recent Projects Sample (Projects completed in 1994 and after)
Number of Projects	10	16
Number of AGT Projects	2	1
Number of HRT Projects	4	7
Number of LRT Projects	4	8
Cost Overruns		
Average	0.50	0.30
Standard deviation	0.33	0.39
Variance	0.1089	0.1521
Coefficient of variation	0.66	1.18

Figure 1 - Total Capital Cost vs Year Completed



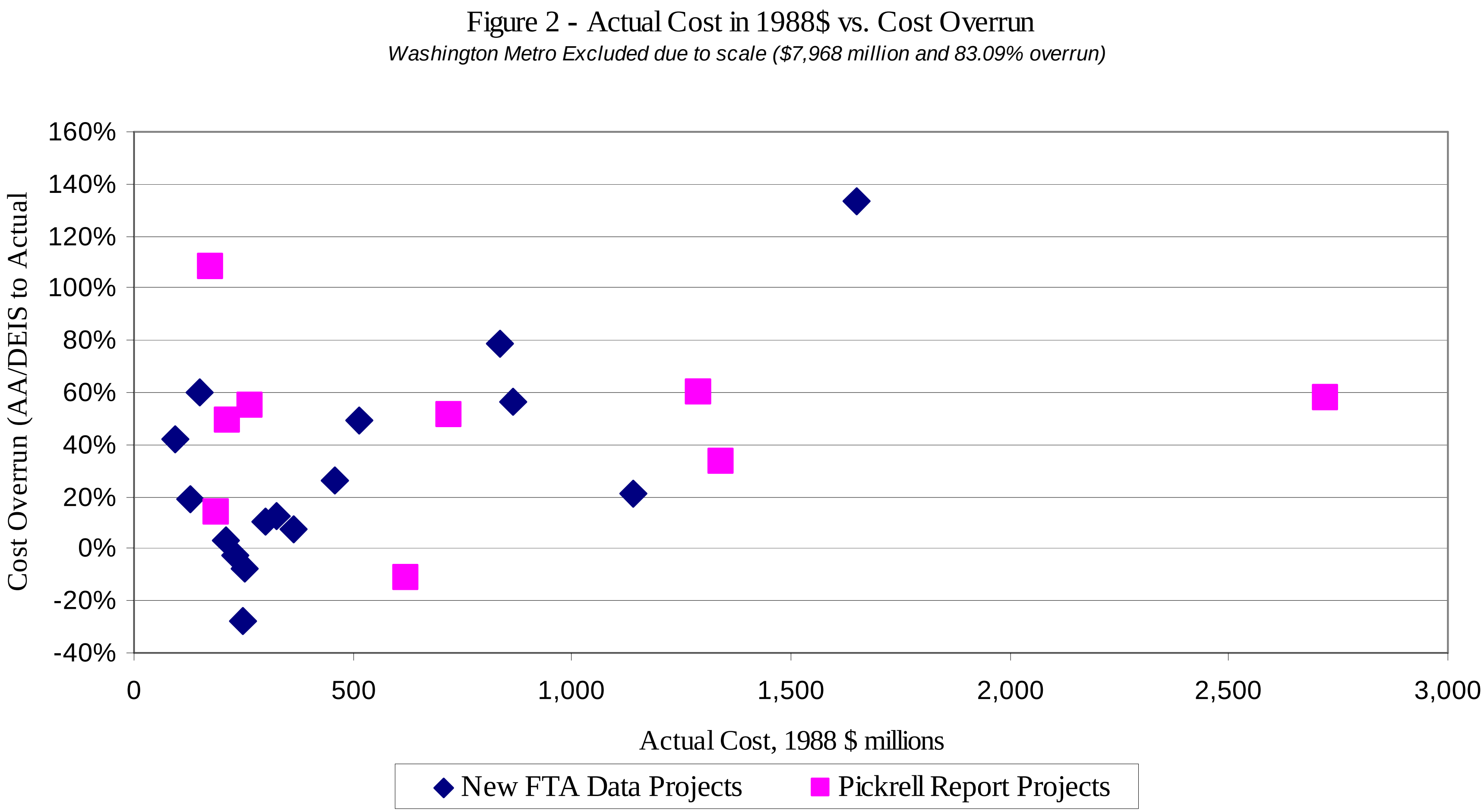


Figure 2 - Actual Cost in 1988$ vs. Cost Overrun
Washington Metro Excluded due to scale ($7,968 million and 83.09% overrun)
Cost Overrun (AA/DEIS to Actual
160%
140%
120%
100%
80%
60%
40%
20%
0%
-20%
-40%
0
500
1,000
1,500
2,000
2,500
3,000
Actual Cost, 1988 $ millions
New FTA Data Projects
Pickrell Report Projects

Figure 3 - Period between the Year of AA/DEIS Estimate to the Year of Completion/Operations

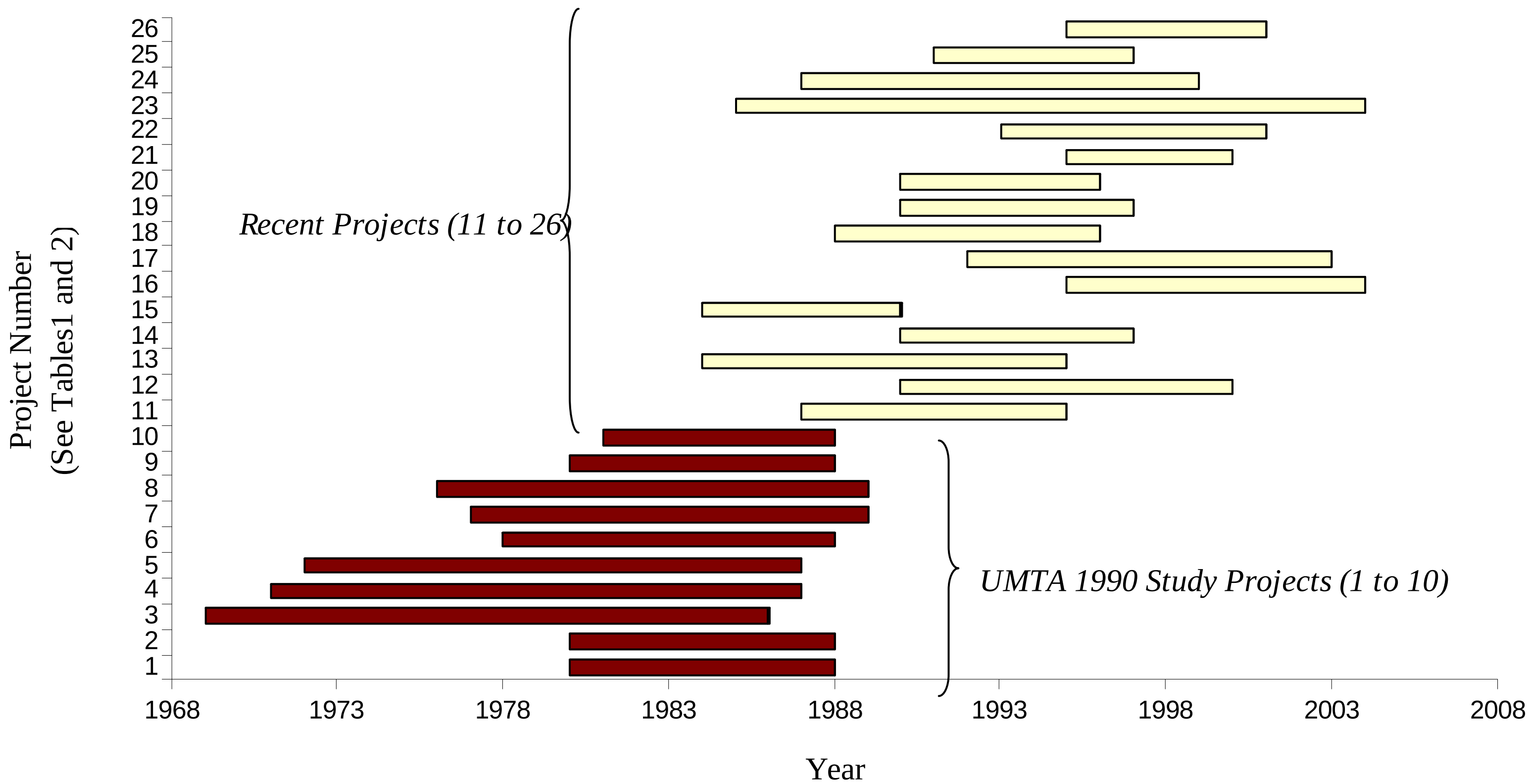


Figure 4 - Cost Overrun vs. Year of Completion