US Department of Transportation
Federal Transit Administration

PREDICTED VERSUS ACTUAL IMPACTS OF CAPITAL INVESTMENT GRANTS PROJECTS - 2020

CAPITAL COST AND RIDERSHIP

Prepared by:

Federal Transit Administration
Office of Planning and Environment

Table of Contents

1. Introduction

As part of its ongoing commitment to learning from experience and improving technical practice in the administration of its programs, the Federal Transit Administration (FTA) periodically reviews the accuracy of the predicted capital costs and weekday ridership of transit projects funded by the FTA Capital Investment Grants (CIG) program. This study documents the results of the fourth Predicted versus Actual (PvA) study of the accuracy of the predicted outcomes of CIG projects that have been completed and opened for revenue service.

The study considers 29 transit projects (24 New Starts, three Small Starts, and two Very Small Starts[1]) that opened to revenue service between 2007 and 2015. The comparison of the predicted versus actual capital costs and ridership provides an assessment of the technical work done by project sponsors to develop the projects and the reliability of the information used by FTA and local government agencies to commit funds to the projects. Together with the results of the three earlier studies, the current PvA Study demonstrates the extent to which accumulated experience, better data, evolved technical disciplines, and improved project oversight have increased the accuracy of capital cost estimates and transit ridership forecasts.

All four studies have focused on predictions of capital costs and ridership because they are both key elements of FTA's evaluation and rating of CIG projects. The ratings for CIG projects are one factor FTA considers when making funding recommendations to Congress for the CIG program. However, the breadth of the PvA analysis necessarily extends to other aspects of the projects and their predictions. Capital cost estimates prepared during the planning and development of a project depend on the physical scope of the project and its construction schedule. Similarly, ridership outcomes and predictions depend on the performance characteristics of the project and its integration with other elements of the existing transit system. Consequently, the PvA analysis touches on a broad range of project outcomes and the accuracy of their predictions.

1.1. Previous Predicted versus Actual Studies

FTA and sponsors of CIG projects have applied many "lessons learned" from the previous PvA studies. The initial PvA study dates from the earliest days of the program, with the first 10 completed projects receiving Federal financial assistance from the Urban Mass Transit Administration (UMTA). The three previous studies were:

- Pickrell, Don; Urban Rail Transit Projects, Forecast versus Actual Ridership and Costs; USDOT, 1990.
- Lewis-Workman, Steve et al; Predicted and Actual Impacts of New Starts Projects; USDOT/FTA, 2003.
- Lewis-Workman, Steve et al; The Predicted and Actual Impacts of New Starts Projects -- 2007; USDOT/FTA, 2007.

[1] Very Small Start projects are no longer a project category in the Capital Investment Grants program.

Table 1.1-1 – Transit Modes of Project across the PvA Studies

Fixed-guideway Mode	Predicted versus Actual Study				
	1990	2003	2007	2020	All
Heavy Rail	4	5	4	1	14
Automated Guideway	2	2	0	0	4
Light Rail	4	10	12	17	43
Commuter Rail	0	0	4	5	9
Streetcar	0	0	0	1	1
Bus Rapid Transit	0	4	1	5	10
All	10	21	21	29	81

Table 1.1-2 –Category of Projects across the PvA Studies

Nature of the Project	Predicted versus Actual Study				
	1990	2003	2007	2020	All
First Fixed-guideway Project	10	10	2	9	31
Added Fixed-guideway Mode	0	0	3	4	7
Expansion into New Corridor	0	6	6	13	25
Extension of Existing Line	0	5	6	3	14
Upgrade of Existing Line	0	0	4	0	4
All	10	21	21	29	81

Table 1.1.1 describes the transit modes across the four PvA studies. The 1990 PvA study reviewed 10 projects, with four heavy rail systems, two automated guideway systems, and four light rail systems, which were the first fixed-guideway transit projects constructed with Federal financial assistance. There is a wider range of modes in the 2003, 2007, and 2020 PvA studies, including bus rapid transit, commuter rail, a streetcar, heavy rail, and light rail projects. Altogether, 81 CIG projects are assessed within the four PvA studies, 43 of which are light rail systems.

Table 1.1-2 shows the categories of projects assessed within the PvA studies. Within the 1990 PvA study, all 10 of the projects represented the "first" fixed-guideway project constructed within each respective city or region. Thus, at the time these projects were constructed the local project sponsors had no prior experience constructing a major capital fixed-guideway transit project. In the 2003, 2007, and 2020 PvA studies, 50 of the 71 projects benefited from prior experience constructing a fixed-guideway transit project.

The 1990 study considered 10 of the earliest Federally-funded major capital projects. Below is a summary:

- **Capital Costs:** At that time, the methods used for capital cost estimation were unreliable. Of the nine projects that prepared a capital cost estimate, the actual cost of only one project was within 20 percent of the original cost estimate, six of nine projects were between 30 and 100 percent above their original estimates, and two projects were more than double (over 100 percent of) their cost estimates. On average, the actual cost of projects exceeded their cost estimates by 77 percent.

- **Ridership:** During the early efforts for CIG project planning, the methods applied to predict ridership were generally unreliable. In 2007, FTA performed an update of the actual ridership for the projects included in the 1990 study. This analysis concluded that none of the 10 projects achieved, at the time of the analysis, ridership greater than 76 percent of their forecasts. Seven of the 10 projects had achieved less than 50 percent of their forecasts. On average, these projects achieved just 42 percent of their ridership forecasts.

The 2003 study examined 21 projects completed between 1990 and 2002, 19 of which had ridership predictions available. Below is a summary:

- **Capital Costs:** FTA found that the accuracy of the capital cost estimates had improved markedly since the 1990 PvA Study, but still systematically underestimated actual project costs. The actual capital cost of CIG projects were, on average, 21 percent greater than the inflation-adjusted predictions prepared during alternatives analysis, 14-percent greater than the predictions entering final design, and 7-percent greater than the predictions at execution of the FFGA (Full Funding Grant Agreement).

- **Ridership:** FTA found that ridership forecasts had also improved since the 1990 study. However, CIG project sponsors tended to overpredict the actual ridership achieved by their projects. The results indicate that, as of 2002, four projects exceeded their initial ridership forecasts and five projects exceeded 80 percent of their initial ridership forecasts. All told, nine of the 19 projects included in that study either achieved, or had a reasonable likelihood of coming within a reasonable range (±20 percent), of their ridership forecasts. On average, this group of projects achieved 67 percent of their forecasted ridership.

The 2007 study examined 21 CIG projects completed between 2003 and 2007, 18 of which had ridership predictions available. Below is a summary:

- **Capital costs:** On average, for the 21 projects, actual construction costs exceeded the predictions developed during the alternatives analysis phase by an average of 40 percent, exceeded the cost estimate predictions developed at the entry into final design phase by 12 percent, and exceeded the cost estimate predictions developed at execution of the FFGA by six percent. The sum of all the New Starts projects' actual capital costs exceeded the sum of their original inflation-adjusted FFGA amounts by $1.54 billion.

Over 60 percent ($948 million) of this amount was due to a single project (i.e., Tren Urbano). At the same time, 12 of the 21 projects had actual capital costs that were less than the FFGA inflation-adjusted estimate.

Due in part to the inclusion of the Tren Urbano project in the 2007 PvA study, the average error in cost estimates for the projects in the 2007 study is higher than the average error for the projects in the 2003 study. However, the cost estimates analyzed for the 2003 and 2007 studies combined are more accurate than the cost estimates analyzed in the 1990 PvA study.

- **Ridership:** FTA found that eight out of 18 projects for which ridership data was available had actual ridership exceeding 80 percent of the forecast ridership developed during the alternatives analysis phase. The same eight projects also exceeded 80 percent of the ridership forecasts developed when entering the final design phase. The projects in this study carried, on average, 75 percent of their alternatives analysis forecast ridership and 72 percent of the forecasts prepared before entering final design. Ridership forecasts analyzed in the 2007 PvA study are slightly more accurate than the forecasts in FTA's 2003 study and are significantly more accurate than the forecasts analyzed in the 1990 PvA study.

1.2. Before and After (B&A) Studies

Since 2001, project sponsors receiving a Full Funding Grant Agreement (FFGA) for construction have been required to prepare a Before-and-After Study (B&A Study) as a condition of each FFGA, and as required since 2005 by Federal transit law at 49 U.S.C. § 5309(k)(2)(E). The B&A Studies are intended to: assess the impact of CIG projects on public transportation, compare the actual and forecast costs, service levels, scope of the projects and ridership two years after opening, and identify the sources of any differences between predicted and actual outcomes. Federal transit law requires B&A Studies for New Starts and Core Capacity projects at 49 U.S.C. § 5309(k)(2)(E)(i)(I). In addition, FTA encourages, but does not require, project sponsors to perform B&A Studies for Small Starts projects.

Because of this statutory requirement, FTA has an extensive library of B&A Studies that were used to develop the 2020 PvA Study. The B&A Study summaries are located on the FTA public website at https://www.transit.dot.gov/funding/grant-programs/capital-investments/and-after-studies-new-starts-projects. FTA is required to submit a B&A Study Report to Congress annually, and those summaries provided a useful resource for this version of the PvA analysis of capital cost and ridership. The B&A Study summary for each project identifies the specific reasons why a specific project had a higher (or lower) capital cost estimate or ridership forecast compared to their actual capital cost or ridership.

Projects Considered in the Current Predicted versus Actual Study

Within the 2020 PvA study, FTA assessed the predicted versus actual outcomes for 29 CIG projects. Two of these projects were not required to submit travel forecasts because they were exempt from the CIG evaluation and rating process. Thus, 27 projects submitted travel forecasts for CIG project evaluation. These projects were constructed and opened to revenue service

between 2007 and 2015 and represent a variety of transit modes including light rail, heavy rail, commuter rail, and bus rapid transit systems. A significant proportion of the projects were the "first" fixed-guideway projects constructed in that city/region, while others were extensions to existing systems. Finally, several projects introduce a new transit mode to a region that already had fixed-guideway transit.

The information used to assess the projects' capital costs and ridership in the 2020 PvA Study has a greater level of consistency than the prior PvA studies. For example, each of the projects within the 2020 PvA study applied a similar method to calculate capital costs and entered their cost estimates into a Standard Cost Category excel workbook developed and maintained by FTA. Additionally, almost all the projects developed an opening year ridership forecast that could be used for the predicted versus actual ridership estimates and results. In prior PvA studies, the CIG projects did not develop opening year ridership forecasts. Thus, the earlier PvA studies had to use ridership forecasts based on a "20-year forecast." This has made the compilation of the data in the 2020 PvA study to be based upon the information provided directly by project sponsors, with less interpretation and correction by FTA, compared to the prior PvA studies.

Table 1.3-1 shows the 29 projects reviewed in the 2020 PvA study. The table shows the state and metropolitan area of the project, as well as the project name and mode (light rail, commuter rail, bus rapid transit, streetcar, and heavy rail). It also notes if it is the first fixed-guideway project, an additional mode for an existing transit system, or an expansion an existing fixed-guideway transit system. Finally, the table notes if the project is a New Start, Small Start, or Very Small Start project and the year it opened for revenue service. Additional information about any of these projects may be found within the B&A Study report summary located on FTA's public website linked above.

Table 1.3-1 – Projects in the 2020 Predicted versus Actual Study

State	Metro Area	Project	Mode	Nature	Type	Open
NC	Charlotte	South Corridor LRT	LR	1ST	NS	2007
UT	Salt Lake City	Weber County to Salt Lake City Commuter Rail	CR	ADD	NS	2008
AZ	Phoenix	Central Phoenix / East Valley Light Rail	LR	1ST	NS	2008
OH	Cleveland	Euclid Corridor Transportation Project	BRT	ADD	NS	2008
CA	San Diego	Oceanside-Escondido Rail Corridor	CR	EXP	NS	2008
OR	Portland	South Corridor I-205/Portland Mall LRT	LR	EXP	NS	2009
OR	Portland	Wilsonville to Beaverton Commuter Rail	CR	ADD	NS	2009
CA	Los Angeles	Metro Gold Line East Side Extension	LR	EXP	NS	2009
MN	Minneapolis	Northstar Corridor Rail	CR	ADD	NS	2009
WA	Seattle	Central Link Initial Segment	LR	1ST	NS	2009
TX	Dallas	Northwest/Southeast LRT MOS	LR	EXP	NS	2010
AZ	Flagstaff	Mountain Links BRT	BRT	1ST	VSS	2011
UT	Salt Lake City	Mid Jordan LRT	LR	EXP	NS	2011
VA	Norfolk	Norfolk LRT	LR	1ST	NS	2011
PA	Pittsburgh	North Shore LRT Connector	LR	EXP	NS	2012
OR	Portland	Streetcar Loop	SC	EXP	SS	2012
CO	Denver	West Corridor LRT	LR	EXP	NS	2013

TX	Houston	North Corridor LRT	LR	EXP	NS	2013
UT	Salt Lake City	Draper Transit Corridor	LR	EXT	NS	2013
FL	Orlando	Central Florida Commuter Rail -- Initial Segment	CR	1ST	NS	2014
CO	Fort Collins	Mason Corridor BRT	BRT	1ST	SS	2014
MN	Minneapolis-St. Paul	Central Corridor LRT	LR	EXP	NS	2014
VA	Dulles	Dulles Corridor Metrorail Extension to Wiehle Ave.	HR	EXP	NS	2014
CA	Sacramento	South Sacramento Corridor Phase 2	LR	EXT	NS	2014
TX	Austin	MetroRapid BRT	BRT	1ST	VSS	2014
CN	Hartford	New Britain - Hartford Busway	BRT	1ST	NS	2015
TX	Houston	Southeast Corridor LRT	LR	EXP	NS	2015
AZ	Phoenix	Central Mesa LRT Extension	LR	EXT	SS	2015
OR	Portland	Portland-Milwaukie Light Rail	LR	EXP	NS	2015

Abbreviations:

LR	light rail	1ST	first fixed-guideway mode	NS	New Starts
CR	commuter rail	ADD	added fixed-guideway mode	SS	Small Starts
SC	streetcar	EXP	expansion into a new corridor	VSS	Very Small Starts
BRT	bus rapid transit	EXT	extension of an existing line		

1.3. Summary of Findings from 1990, 2003, 2007 studies

The FTA and the transit industry have applied numerous "lessons learned" from the 1990, 2003, and 2007 PvA Studies. The following are examples of how these PvA studies have been applied to improve the accuracy of capital cost and ridership forecasts prepared for the CIG program:

- FTA improved methods to estimate capital costs and ridership forecasts;
- FTA applied a "risk assessment" methodology to project scope estimates, schedule, and capital cost estimates; and
- FTA maintained proactive oversight of projects undertaking engineering and construction.

These methods have been adopted by CIG project sponsors since the early 2000's, resulting in better data and information to assess PvA capital cost and ridership forecasts prepared for CIG projects.

The B&A Studies provide a useful resource for identifying the reasons for the differences in predicted and actual capital cost and ridership of CIG projects. The availability of the 29 B&A Studies provided a solid foundation for the analysis in the 2020 PvA Study of Capital Costs and Ridership. Therefore, this study considers a larger number of projects than each of the prior PvA Studies and is based upon higher quality and more consistent data than the prior PvA studies.

2. Predicted versus Actual Capital Costs

This chapter compares the capital cost estimates prepared during project development to the actual capital costs of CIG projects that opened for revenue service. The planning level capital cost estimates were used to support the decision to select the locally preferred alternative, and were, generally, the capital cost forecasts that were presented to FTA when the project entered the preliminary engineering phase of the CIG program. The capital cost estimate used to support FTA's decision to allow the project to advance to the CIG phases of final design and construction was almost always prepared after the conclusion of the environmental review process and based upon a locally preferred alternative with a defined project scope.

The definition of the project scope, including the project's location, alignment, and station area design, was often limited in detail in the early stages of project development, including at approval to enter the preliminary engineering phase of the CIG program. As the environmental review and public involvement processes were undertaken, the project scope became more detailed with greater level of certainty. At this stage of project development, project scope items including station locations, design characteristics, location and capacity of park-and-ride lots, maintenance facilities, and environmental mitigation measures were more refined and descriptive. Third party agreements, right-of-way acquisition, and items like utility relocations can also have a significant impact on project scope and may not be finalized until around the time an FFGA is executed.

As additional engineering and design work is completed, particularly during the CIG final design phase, there is greater certainty in the capital cost estimate, as the project scope becomes more fully defined and cost estimates for items such as right-of-way, construction materials, and labor can be calculated based upon higher level specificity of the project definition. At the time of the FFGA, or Project Construction Grant Agreement (PCGA) for small starts projects, project contingencies have been fully established, the scope and schedule is defined, and there are few remaining uncertainties in the project cost estimate.

A variety of factors may require a revision of the capital cost, including inflation of construction materials and labor costs, local bid climate, construction delays, right-of-way acquisition, lawsuits, unanticipated changes in project scope, delays in vehicle delivery/testing, and a variety of other causes. Any of these issues, and many others, may result in an increase to the actual capital cost after an FFGA is issued.

2.1. Methodology

This study compares the capital cost estimates for 29 CIG projects from the key decision points in the CIG program (Preliminary Engineering, Final Design, Full Funding Grant Agreement) to the actual capital cost after each project opened for revenue service.

There are significant differences between the three prior PvA studies and the 2020 PvA study as they relate to the capital cost estimates. Below is a summary:

- 1990 Predicted versus Actual Study: In the 1990 Study PvA study, the capital cost estimates for the "predicted" costs were based on the inflated current year capital cost

estimate at the CIG preliminary engineering phase, and the "actual" costs were based on the final construction cost.

- 2003 and 2007 Predicted versus Actual Study: The 2003 and 2007 studies based the "predicted" capital cost on the "current year" capital cost estimate at the time the FFGA was awarded, and the "actual" capital cost in the "current year" capital cost at the completion of construction.

- The 2020 Predicted versus Actual Study benefited from the availability of the FTA Standard Category Cost excel workbooks, and the "predicted" capital costs are based upon the PD or FFGA Year of Expenditure (YOE) escalated capital cost estimates compared to the "actual" capital cost estimate at the completion of construction.

Table 2.1-1 shows the 29 projects in the 2020 PvA study and the estimates of capital costs at entry into Preliminary Engineering (PE), entry into Final Design (FD), at FFGA (or Project Construction Grant Agreement) and the actual capital cost of the project. The remainder of the analysis in this chapter is based upon the information in this table.

Table 2.1-1: All projects; actual capital cost and all predictions

Project Characteristics				Milestone Years				Capital Cost in YOE Dollars			
Project	**Mode**	**Nature**	**Type**	**Open**	**PE Entry**	**FD Entry**	**FFGA/ PCGA**	**Actual**	**PE Entry**	**FD Entry**	**FFGA/ PCGA**
CLT-S	LR	1ST	NS	2007	2000	2003	2007	$463	$331	$371	$463
SLC-CR	CR	ADD	NS	2008	2003	2005	2006	$614	$408	$581	$612
PHX-EV	LR	1ST	NS	2008	1998	2003	2005	$1,315	$1,076	$1,174	$1,253
CLE-EUC	BRT	ADD	NS	2008	1997	2002	2004	$197	$177	$229	$197
SD-CR	CR	EXP	NS	2008	1995	2000	2006	$478	$214	$332	$484
PLD-GRN	LR	EXP	NS	2009	2004	2005	2007	$576	$495	$557	$576
PLD-CR	CR	ADD	NS	2009	2001	2004	2008	$162	$85	$104	$117
LA-GLD	LR	EXP	NS	2009	2000	2002	2004	$899	$760	$818	$899
MSP-CR	CR	ADD	NS	2009	2005	2006	2007	$309	$265	$307	$317
SEA-APT	LR	1ST	NS	2009	1997	2000	2008	$2,558	$1,858	$2,651	$2,680
DAL-N/S	LR	EXP	NS	2010	2001	2005	2006	$1,406	$1,151	$1,490	$1,406
FLG	BRT	1ST	VSS	2011	2009	---	2011	$8	$10	---	$8
SLC-MJ	LR	EXP	NS	2011	2007	2008	2009	$510	$522	$510	$535
NFK	LR	1ST	NS	2011	2002	2006	2007	$315	$195	$235	$232
PBG-NS	LR	EXP	NS	2012	2001	2003	2006	$514	$110	$390	$539
PLD-SC	SC	EXP	SS	2012	2007	---	2009	$149	$152	---	$149
DEN-W	LR	EXP	NS	2013	2001	2005	2009	$710	$555	$74	$692
HOU-RED	LR	EXP	NS	2013	2008	2009	2011	$601	$641	$612	$654
SLC-DRA	LR	EXT	NS	2013	2009	2010	2011	$146	$212	$194	$194
ORL-SUN1	CR	1ST	NS	2014	2007	2008	2011	$357	$362	$357	$357
FTC-MAS	BRT	1ST	SS	2014	2007	---	2012	$83	$74	---	$87
MSP-CC	LR	EXP	NS	2014	2006	2010	2011	$926	$932	$957	$957
DULLES	HR	EXP	NS	2014	2004	2008	2009	$3,047	$1,521	$2,988	$3,142
SAC-SX	LR	EXT	NS	2014	2005	2012	2012	$270	$153	$270	$270
AUS-BRT	BRT	1ST	VSS	2014	2009	---	2012	$39	$47	---	$48
HFD-NB	BRT	1ST	NS	2015	2000	2006	2011	$546	$88	$459	$567
HOU-PRP	LR	EXP	NS	2015	2008	2009	2011	$728	$591	$730	$762
PHX-MSA	LR	EXT	SS	2015	2010	---	2012	$197	$198	---	$199
PLD-MIL	LR	EXP	NS	2015	2009	2011	2012	$1,463	$1,418	$1,490	$1,490

Abbreviations:

LR	light rail	1ST	first fixed-guideway mode	NS	New Starts
CR	commuter rail	ADD	added fixed-guideway mode	SS	Small Starts
SC	streetcar	EXP	expansion into a new corridor	VSS	Very Small Starts
BRT	bus rapid transit	EXT	extension of an existing line		

2.2. Findings from the Current Set of Projects

Predicted versus Actual Capital Cost at the PE/PD Milestone

Project capital cost estimates at the time the FFGA or PCGA was awarded compared to the actual capital cost estimate have greater accuracy than the capital cost estimates prepared at the PE or PD (for Small Starts projects) CIG phases. This is because at the PE or PD phase there is greater uncertainty in the project scope and schedule, and many elements of a project are not fully defined. Thus, there will be greater variation in a project's capital cost estimate prepared at the PE/PD phase compared to the actual construction capital cost of the project. Figure 2.2-1: Actual versus Predicted Capital Cost at entry into PE/PD, shows that that majority of projects under-estimate the projects capital cost at PE/PD approval. Of the 29 projects, 17 of them had actual capital costs estimates that exceeded the PD/PE capital cost estimate by more than 10 percent.

For projects with capital costs below $800 million, as shown in Figure 2.2-2: Actual versus Predicted Capital Cost at entry into PE/PD, lower cost CIG projects had a significant level of variation between the actual capital cost and the estimated capital cost at entry into PE/PD. While a few projects had actual capital costs lower than the PE/PD approval cost estimate, many of the projects (17) under-estimated the project capital cost at PE/PD approval stage. As noted previously, there are a variety of reasons why there will be a greater difference in the actual capital cost at PE/PD. Table 2.2-1 shows the causes of significant differences of actual project capital costs compared to the estimate at PE/PD.

Table 2.2-1: Causes of Significant Differences at the PE/PD Phase

Cited Causes of Predicted-vs-Actual Capital Costs Differences Greater Than ±10 Percent at Entry into PE		Actual Greater Than Predicted	Actual Less Than Predicted	Subtotal	Total
Differences in Baseline Cost Estimate	Physical scope	9	1	10	19
	Railroad right-of-way	6	0	6	
	Unit costs	2	1	3	
Differences in Soft Costs	Professional services	3	0	3	7
	Unallocated contingency	[17]	1	1	
	Financing costs	3	0	3	
Differences in Inflation Costs	Schedule	10	0	10	19
	Annual rates of inflation	9	0	9	
Summaries	Total cites	42	3	45	45
	Total projects	17	2	19	19

As noted in Table 2.2-1, there is a wide range of causes for differences in actual capital costs compared to those predicted at the PE/PD phase. The predominant reason for the under-estimate of capital costs is that the assumptions made for capital cost estimates at PE/PD are based upon a limited definition of project scope, with significant uncertainty. Nine of the projects had significant changes in project scope that resulted in a change in actual capital cost and 17 projects added contingency costs to account for uncertainties. Ten of the projects had substantial

changes in their project schedules. A delay in a project schedule typically results in inflation of materials or labor that can substantially increase construction costs.

Figure 2.2-1: Actual versus Predicted Capital Cost at Entry into PE/PD

All 2020 PvA Projects

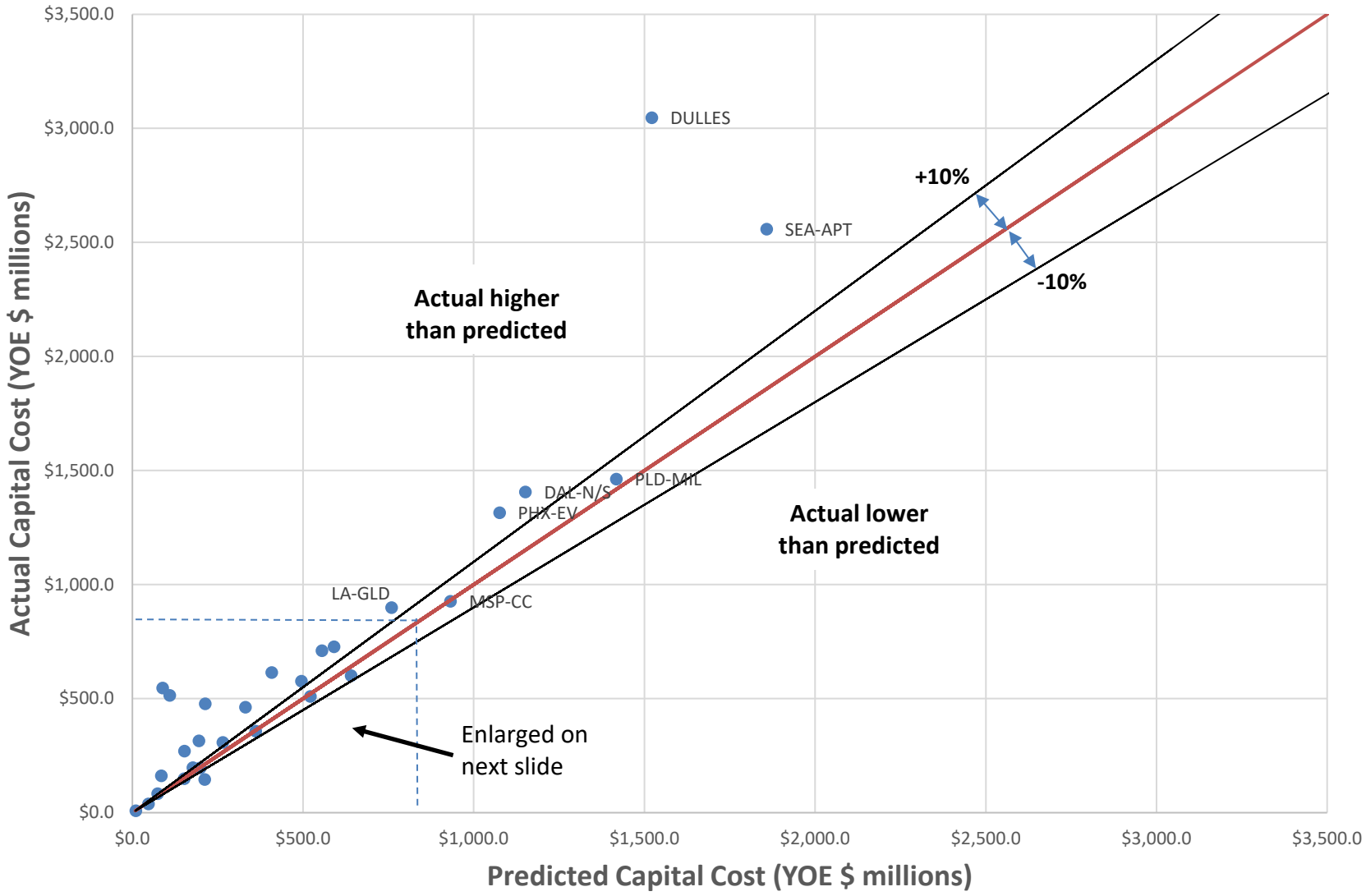
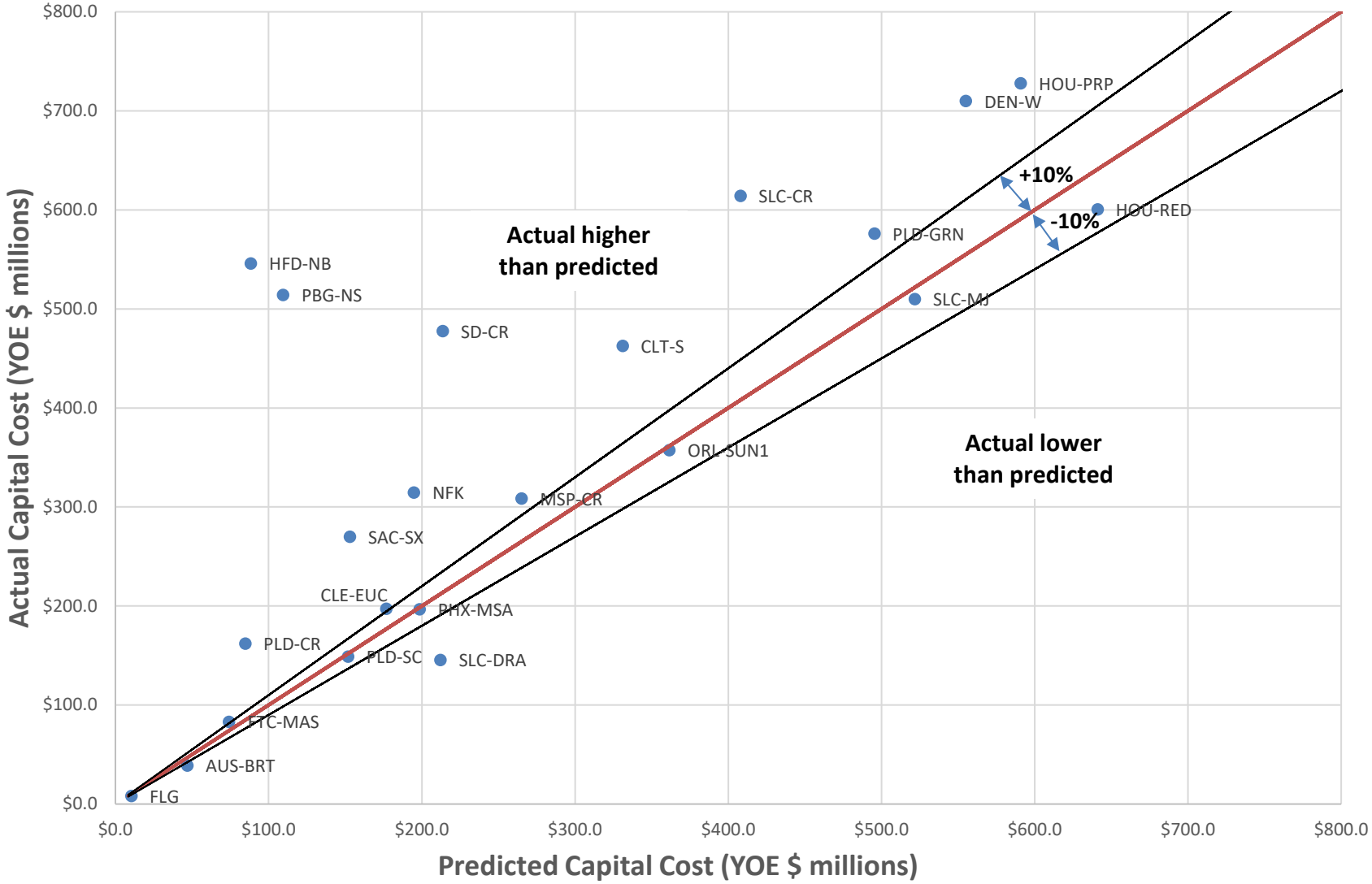


Figure 2.2-2: Actual versus Predicted Capital Cost at Entry into PE/PD

2020 PvA Projects with Less Than $800M Actual Cost



Predicted versus Actual Capital Cost at the FFGA/PCGA

Most of the CIG projects with capital costs above $800 million have actual capital costs that are within 10 percent of the construction cost estimate at FFGA or PCGA, as shown in Figure 2.2-3*,* Actual versus Predicted Capital Cost at the FFGA/PCGA (projects over $800M).

Two CIG projects with capital costs below $800 million exceed their capital cost estimate by greater than 10 percent, per Figure 2.2-4 Actual versus Predicted Capital Cost at the FFGA/PCGA (projects under $800 M). However, most projects below $800 million in cost have been near, or slightly under, their capital cost estimate at the time the FFGA/PCGA was signed.

Table 2.2-2: Causes of Significant Differences at the FFGA/PCGA

Cited Causes of Predicted-vs-Actual Capital Costs Differences Greater Than ±10 Percent at the FFGA/PCGA		Actual Greater Than Predicted	Actual Less Than Predicted	Subtotal	Total
Differences in Baseline Cost Estimate	Physical scope	1	1	2	5
	Railroad right-of-way	1	0	1	
	Unit costs	1	1	2	
Differences in Soft Costs	Professional services	1	0	1	2
	Unallocated contingency	[2]	1	1	
	Financing costs	0	0	0	
Differences in Inflation Costs	Schedule	2	0	2	4
	Annual rates of inflation	2	0	2	
Summaries	Total cites	8	3	11	11
	Total projects	2	1	3	3

Table 2.2-2 shows the causes of the significant differences in the actual capital cost versus the predicted capital cost at the FFGA/PCGA. Two projects exceeded their capital cost estimate by greater than 10 percent primarily due to changes in project scope, project schedule delays, increases in inflation for materials and labor, and right-of-way costs.

In many cases, a post-FFGA change in project scope has a ripple effect on the project schedule, with the resulting delay increasing capital cost through inflation, additional professional services, and increased unit costs beyond what the construction cost would have been without a change in project scope.

Overall, 27 of the 29 project's actual capital costs are within 10 percent of their FFGA construction cost estimate. This is because of several reasons: 1) increased levels of contingency applied prior to the issuance of an FFGA; 2) FTA's requirement that any increase in a project's capital cost after the FFGA be paid for with non-Federal funds (this is an added incentive to maintain the projects capital cost and scope after receipt of an FFGA); 3) many project sponsors had prior experience constructing CIG projects; and 4) proactive oversight by FTA and the project sponsor.

Figure 2.2-3: Actual versus Predicted Capital Cost at the FFGA/PCGA

All 2020 PvA Projects

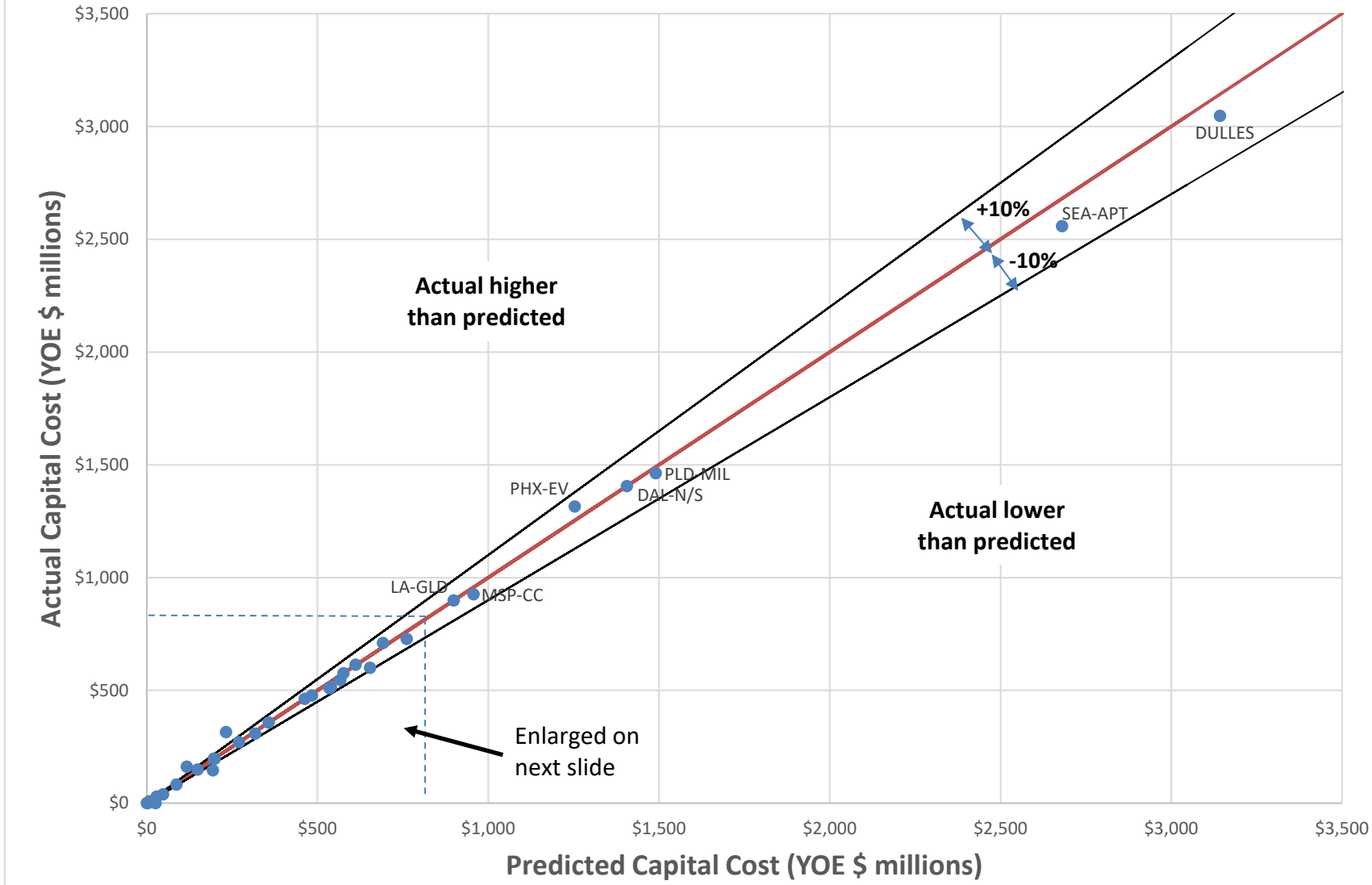
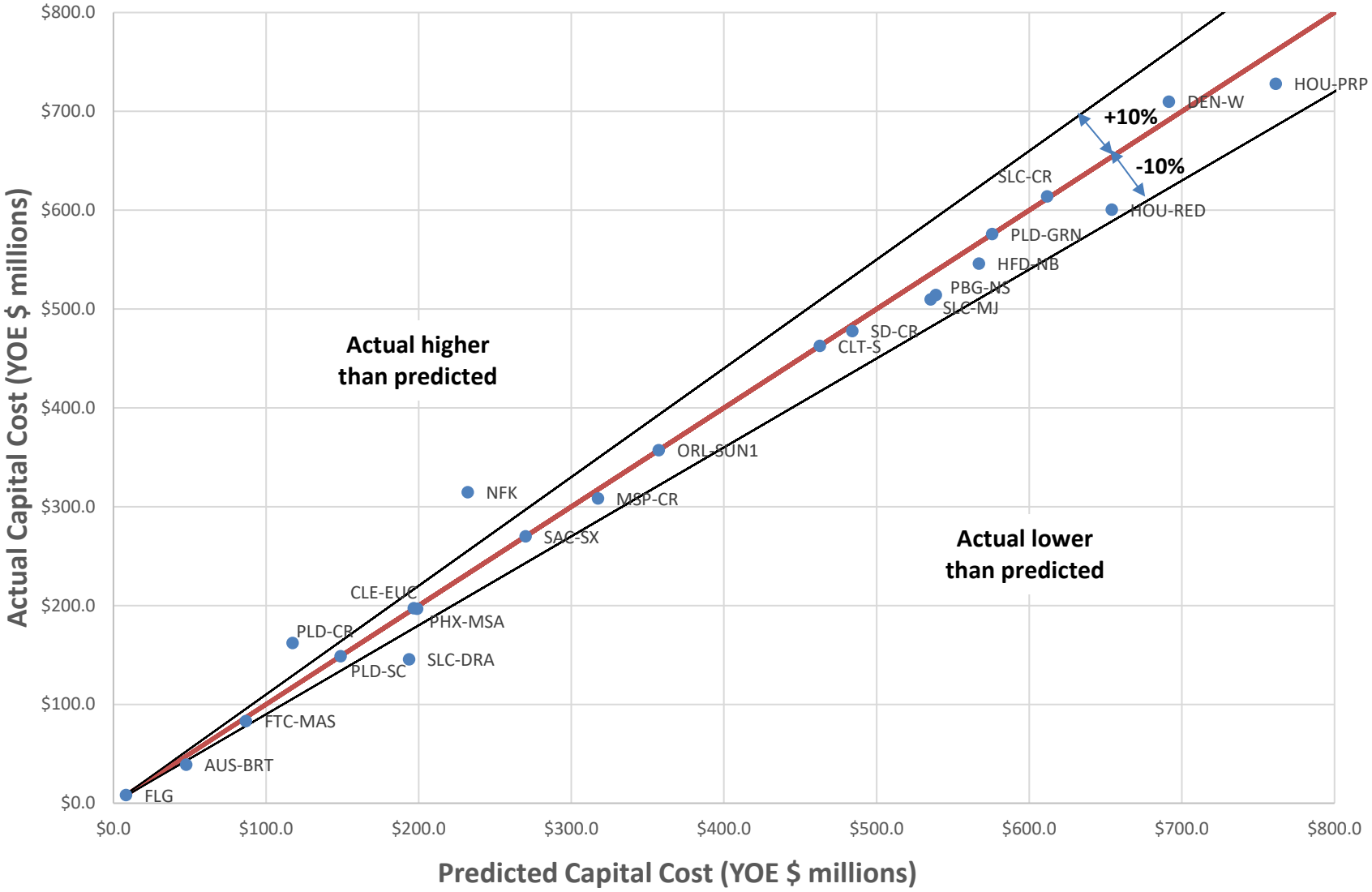
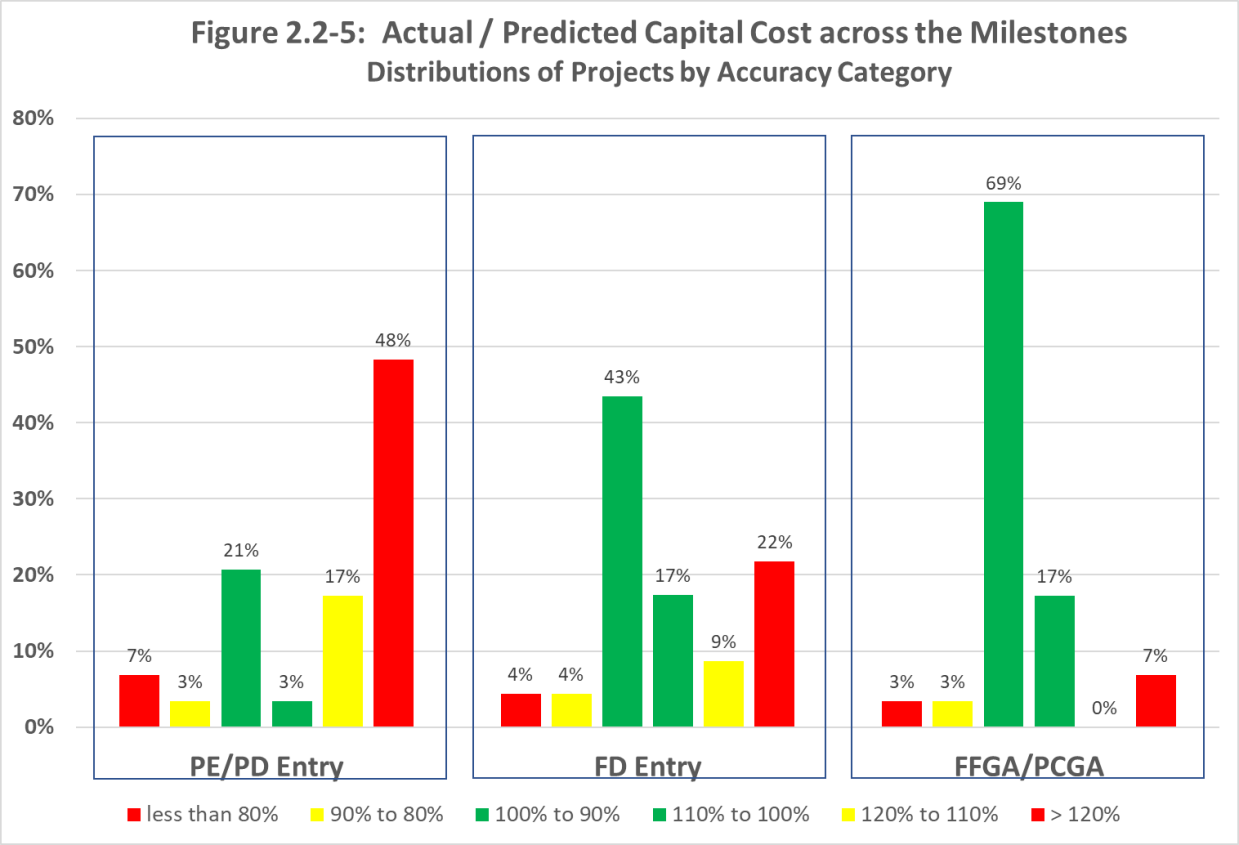


Figure 2.2-4: Actual versus Predicted Capital Cost at the FFGA/PCGA

2020 PvA Projects with Less Than $800M Actual Cost





The accuracy of a project's capital cost estimate improves as the project's scope becomes more fully defined. This takes place as project sponsors undertake the environmental review process, PE, and FD. As shown in Figure 2.2-5, the level of accuracy of a projects capital cost estimate, compared to the actual capital cost, improved substantially from entry to PE/PD to FD entry, and FFGA/PCGA, for the 29 projects in the 2020 PvA Study.

As shown in the chart on the left of Figure 2.2-5, at entry into PE/PD, a small proportion (24 percent) of the project cost estimates were within 10 percent of the "actual project cost" after construction. Per the middle set of bar charts in the table above, at the entry to FD phase, the scope of the project is more fully defined, leading to significantly improved capital cost estimates, with 60 percent FD capital cost estimates within 10 percent of the actual construction costs.

By the time a project is ready to receive an FFGA, there is greater certainty about the project scope, schedule, and budget and contingency funding is allocated to account for remaining uncertainties. Per the bar graphs on the right side of Figure 2.2-5, 86 percent of the projects' actual capital costs came within 10 percent of the FFGA/PCGA capital cost estimate.

2.3. Comparisons across the Four PvA Studies

In the thirty years between the 1990 and 2020 PvA study, there have been substantial improvements in the methods used to estimate capital costs of CIG projects. CIG project sponsors and FTA have employed techniques to proactively mitigate project risks, implement controls for cost and schedule, and apply prior experience gained during the construction of new transit projects through Project Construction Roundtables and Project Management Oversight (PMO) contractor reviews.

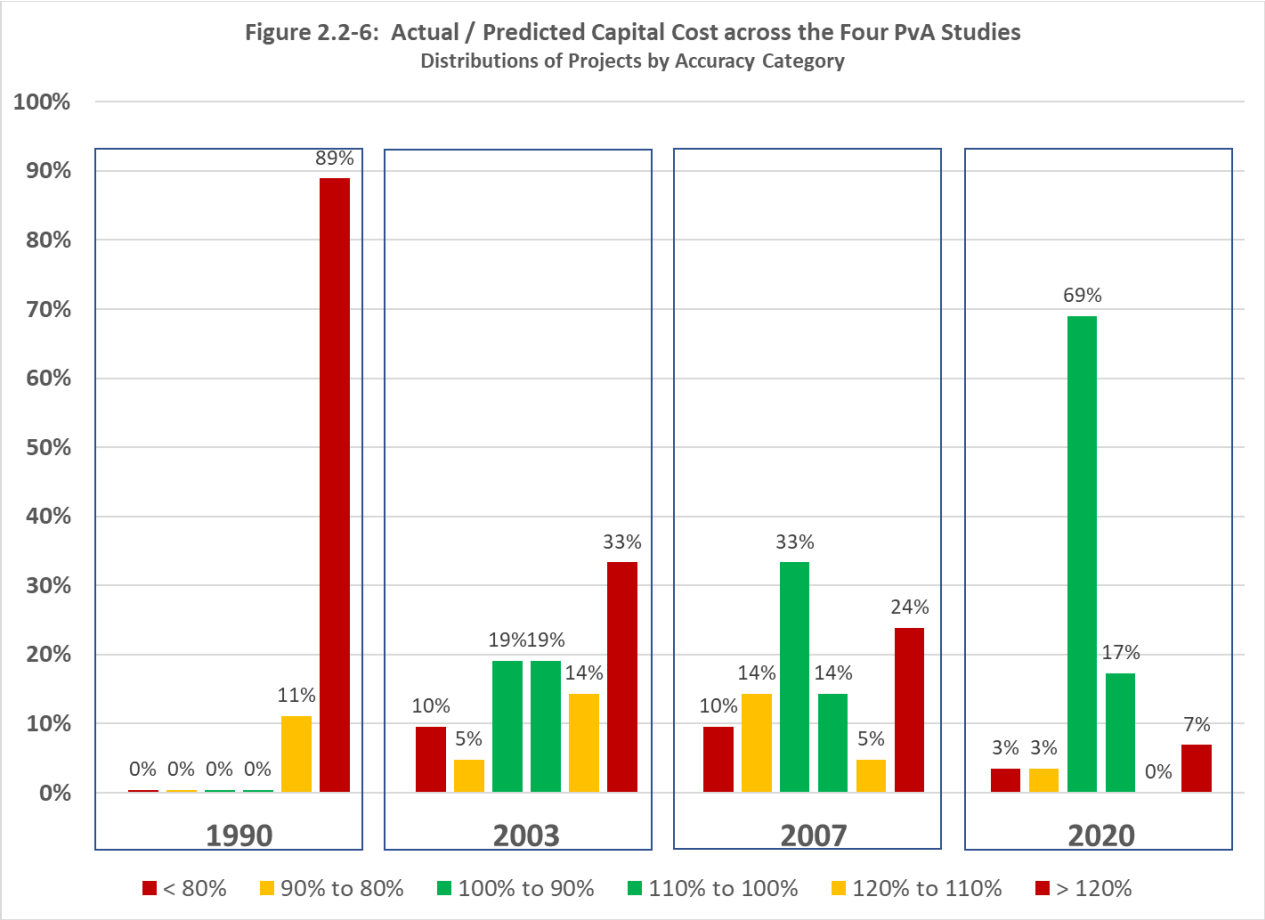
Table 2.2-3, Accuracy of Predicted Capital Costs across the Four PvA Studies, shows the improvements in the accuracy of the actual capital costs, compared to the FFGA/PCGA capital cost, of the PvA studies completed to date.

Table 2.2-3: Accuracy of Predicted Capital Costs across the Four PvA Studies
(All costs in millions of year-of-expenditure dollars)

Actual Divided by Predicted	Characteristics of Each Stratum	1990	2003	2007	2020
		Entry into PE	FFGA or PCGA	FFGA or PCGA	FFGA or PCGA
more than 120%	projects	8	7	5	2
	% of all projects	89%	33%	24%	7%
	total costs predicted	$4,416	$5,373	$3,863	$349
	total costs actual	$9,171	$6,742	$5,583	$477
120% to 110%	projects	1	3	1	0
	% of all projects	11%	14%	5%	0%
	total costs predicted	147	$1,318	$363	$0
	total costs actual	172	$1,419	$385	$0
110% to 100%	projects	0	4	3	5
	% of all projects	0%	19%	14%	17%
	total costs predicted	0	$905	$1,065	$2,753
	total costs actual	0	$924	$1,096	$2,836
100% to 90%	projects	0	4	7	20
	% of all projects	0%	19%	33%	69%
	total costs predicted	0	$1,214	$3,715	$15,608
	total costs actual	0	$1,176	$3,587	$15,153
90% to 80%	projects	0	1	3	1
	% of all projects	0%	5%	14%	3%
	total costs predicted	0	$346	$1,139	$48
	total costs actual	0	$325	$1,070	$39
less than 80%	projects	0	2	2	1
	% of all projects	0%	10%	10%	3%
	total costs predicted	0	$473	$201	$194
	total costs actual	0	$420	$164	$145
All Projects	projects	9	21	21	29
	% of all projects	100%	100%	100%	100%
	total costs predicted	$4,563	$9,629	$10,347	$18,952
	total costs actual	$9,343	$11,007	$11,885	$18,650

Table 2.2-3 and Figure 2.2-6 (a graphical representation of Table 2.2-3) shows a comparison of the accuracy of PvA capital cost estimates in the four studies. In the 1990 PvA Study, 89 percent of projects' actual capital costs were greater than 120 percent of their predicted capital cost estimates. None of the nine projects in the 1990 PvA Study were at or below their capital cost estimate. Overall, the actual capital costs (for all projects) exceeded the predicted capital costs by 205 percent. Conversely, in the 2020 PvA Study, of the 29 projects reviewed, only two projects (seven percent) had an actual capital cost greater than 120 percent of its FFGA cost estimate, and 75 percent of the CIG projects were at or under the FFGA capital cost estimate. Five projects (17 percent) were over the FFGA capital cost estimate but within 10 percent. Overall, the total actual capital cost for all 29 projects was slightly under the predicted capital

cost estimate at FFGA by two percent. This is a large improvement when compared to the 1990 PvA study and continued improvement over the 2003 and 2007 PvA studies. Based upon this analysis, FTA considers the 1990 PvA Study no longer representative of FTA's recent experience with accuracy of capital cost estimates of CIG projects.



3. Predicted versus Actual Ridership

This chapter compares the ridership forecasts prepared to support key decisions in the planning and project development process for CIG projects to the actual ridership after project opening. The ridership forecasts were used to support the selection of the locally preferred alternative and used by FTA for the project justification criteria to rate and evaluate CIG projects.

This chapter compares the ridership forecasts for 27 CIG projects at key decision points (Preliminary Engineering, Final Design and Full Funding Grant Agreement) to the actual observed ridership two years after the projects opened for revenue service.

3.1. Methodology

Actual ridership for projects presented in this study are measured via on-board rider surveys, which are a required element of B&A Studies. The rider survey is typically conducted two years after project opening, allowing for the project's ridership market to mature. The survey is typically conducted in the spring or fall, which are generally thought to be most representative of typical ridership patterns. These surveys are conducted on either a system-wide or project corridor basis, depending on the complexity of the regional transit system. More complex transit systems typically use the corridor-based approach.

The FTA, partnering with survey vendors serving the transit industry, has made significant improvements in conducting on-board rider surveys. Prior to 2012, the standard survey methodology used paper-based surveys on-board transit vehicles and expanded the returned surveys to aggregate route-level boarding counts. The process resulted in a very crude understanding of ridership by route and travel markets. This understanding tended to: 1) over-represent long-distance transit trips, as short-distance transit riders struggled to complete the paper form during their trip; 2) be limited by a relatively large segment of the survey responses (upwards of 10 percent) with illogical data, due to confusion of the transit rider or questions that were unanswered; and 3) use estimates for aggregate boarding riders for data expansion that didn't guarantee accurate on-to-off movements on an individual route.

The current state of the practice in transit rider surveys provides a much stronger understanding of transit markets and the characteristics of transit riders. Several methodological improvements have occurred since 2012. Survey vendors have migrated from paper-based surveys to in-person tablet interviews on-board the vehicle to obtain survey responses. The tablet interview process has several advantages including: use of interactive maps to identify key locations during the trip; customization of the interview to capture short-distance trips; surveys programmed in multiple languages to capture responses from non-English speaking riders; an interviewer guides the rider through the questions to reduce confusion; and the data collected is quality controlled in real-time to identify illogical responses, allowing the interviewer to clarify details of the trip. Thus, the survey records obtained from the current method of on-board rider surveys have superior quality than those obtained through earlier, paper-based methods.

The approach for the data expansion of these surveys has also improved with the current generation of rider surveys. Survey firms use a combination of transit system passenger counts, typically obtained from automated passenger count (APCs) machines, to identify where riders

board and alight a transit line. In addition, standard survey methodology now includes samples of on-to-off passenger movements on a route; this ensures that the collected sample of survey records can be accurately weighted to represent the actual on-to-off movements by line, time-period, direction and route segment boarding to alighting counts. These changes amount to far more accurate actual ridership information in B&A Studies than the data FTA collected 10 years ago.

In collaboration with project sponsors, FTA staff develop standard tabulations of rider surveys before and after a CIG project investment to describe transit ridership outcomes for each CIG project. These tabulations include detailed district-to-district movements by trip purpose, time-of-day, access mode and socio-economic class of the rider. These tabulations are performed for the overall regional transit system, as well as trips that use the CIG project. The surveyed tabulations of trips on the project, two years after the CIG project opened for revenue service, was used as the basis for the actual ridership in the predicted versus actual comparisons.

The predicted ridership forecasts were obtained from opening year forecasts prepared by project sponsors during the CIG project development milestones. B&A Study requirements call for project sponsors to archive their travel forecasts made for CIG projects. This allows FTA and the project sponsor to retrospectively analyze the travel forecasts made during project development milestones and compare them directly to the actual outcomes as measured by the rider survey. The comparison allows for the identification of travel markets with significant predicted versus actual difference and for FTA to identify the causes of differences. For individual project's specific details of these ridership comparisons, please visit FTA's Before and After Study webpage at: https://www.transit.dot.gov/funding/grant-programs/capital-investments/and-after-studies-new-starts-projects.

This PvA study uses the opening year ridership predictions for CIG projects, which marks a substantial improvement over prior PvA studies that used horizon year forecasts. The use of horizon year forecasts required FTA staff to extrapolate regional ridership trends to estimate actual horizon year ridership. This means the PvA comparisons in the 2003 and 2007 studies were, themselves, projections of actual outcomes to the horizon year. This version of the PvA Study yields a direct comparison between planned and actual ridership outcomes.

It is important to note that while FTA required the submission of opening year forecasts, the FTA project rating and evaluation process at the time these projects were in the CIG program used horizon year forecasts only. Thus, the quality of the opening year forecasts prepared by sponsors vary, sometimes significantly. The FTA's B&A Study experience shows that some projects carefully constructed opening-year forecasts, while others treated them as after-thoughts, since they were not used in FTA's evaluation and rating process. As such, the opening year forecasts were not subjected to the same level of scrutiny as the horizon year forecasts.

Project sponsors tabulate their opening year ridership forecasts to prepare tabulations of their ridership forecast. The tabulations are identical to those identified above in the description of rider survey. The tabulations of the ridership forecasts include the same detailed district-to-district movements by trip purpose, time-of-day, access mode and socio-economic class of the

rider. These tabulations are performed for the overall regional transit system, as well as trips that use the CIG project.

In B&A Studies, the project sponsors compare the tabulations from the opening-year project ridership forecasts to the data collected from the on-board rider survey to identify markets where material differences occur between predicted and actual outcomes. This focuses the retrospective analysis on identifying the causes of differences and allows FTA technical staff to identify where the technical methods worked well, and where they struggled to predict actual outcomes.

For this iteration of the PvA Study, FTA has focused the PvA comparison on the travel forecasts at the time of the Full Funding Grant Agreement (FFGA) or Project Construction Grant Agreement (PCGA). This decision was made because the forecasts at the grant agreement were the basis for FTA's commitment to the project. These well-documented and preserved forecasts incorporate the final project scope and operating plan.

Table 3.1-1 shows the 27 projects with travel forecasts in the 2020 PvA study, and the ridership forecasts at entry into Preliminary Engineering (PE), entry into Final Design (FD), at FFGA/PCGA and the actual measured ridership on the project. The remainder of the analysis in this chapter is based upon the information shown in this table.

Table 3.1-1: Data on Actual and Predicted Ridership by Project

Project Characteristics				Actual Ridership	Predictions			
					Opening-year			Horizon
Label	Mode	Nature	Open		PE-entry	FD-entry	FF/PCGA	FF/PCGA
CLT-S	LR	1ST	2007	14,400	---	---	12,100	17,650
SLC-CR	CR	ADD	2008	5,300	8,400	5,650	5,900	11,800
PHX-EV	LR	1ST	2008	40,700	---	---	26,000	49,900
CLE-EUC	BRT	ADD	2008	14,300	21,100	21,100	13,500	39,000
SD-CR	CR	EXP	2008	7,600	---	---	12,000	19,000
PLD-GRN	LR	EXP	2009	24,000	30,400	25,300	25,300	46,500
PLD-CR	CR	ADD	2009	1,700	2,400	2,000	1,600	3,000
LA-GLD	LR	EXP	2009	13,000	---	---	---	16,300
MSP-CR	CR	ADD	2009	2,200	4,000	3,600	3,400	5,900
SEA-APT	LR	1ST	2009	23,400	34,900	37,800	37,800	42,500
DAL-N/S	LR	EXP	2010	33,000	---	40,300	40,300	45,900
FLG	BRT	1ST	2011	4,200	4,150	4,150	4,150	---
SLC-MJ	LR	EXP	2011	7,400	---	6,300	6,300	9,500
NFK	LR	1ST	2011	4,600	---	2,900	2,900	7,100
PBG-NS	LR	EXP	2012	11,100	---	10,000	10,000	14,300
PLD-SC	SC	EXP	2012	2,500	8,100	8,100	3,900	---
DEN-W	LR	EXP	2013	11,950	---	24,900	19,300	29,700
HOU-RED	LR	EXP	2013	14,400	17,400	17,400	17,400	29,900
SLC-DRA	LR	EXT	2013	3,200	2,275	3,600	3,600	6,800
ORL-SUN1	CR	1ST	2014	3,200	---	4,300	4,300	7,400
FTC-MAS	BRT	1ST	2014	5,300	4,100	4,100	4,100	---
MSP-CC	LR	EXP	2014	40,400	34,300	32,400	32,400	40,900
DULLES	HR	EXP	2014	32,100	62,800	69,600	69,600	85,700
SAC-SX	LR	EXT	2014	4,300	3,600	3,600	3,600	10,000
AUS-BRT	BRT	1ST	2014	9,300	---	---	---	---
HFD-NB	BRT	1ST	2015	8,200	---	13,700	13,400	16,300
HOU-PRP	LR	EXP	2015	5,600	17,200	17,200	17,200	28,700
PHX-MSA	LR	EXT	2015	8,100	8,700	8,700	8,700	---
PLD-MIL	LR	EXP	2015	11,160	17,000	17,000	17,000	22,800

Abbreviations:

LR	light rail	1ST	first fixed-guideway mode	NS	New Starts
CR	commuter rail	ADD	added fixed-guideway mode	SS	Small Starts
SC	streetcar	EXP	expansion into a new corridor	VSS	Very Small Starts
BRT	bus rapid transit	EXT	extension of an existing line		

3.2. Findings from the Current Set of Projects

This section presents the findings for the PvA ridership outcomes. The key findings from this analysis are:

- Actual ridership on 13 of 27 projects (48 percent) were within 20 percent of their forecast
- Actual ridership on 22 of 27 projects (81 percent) were within 40 percent of their forecast
- Actual ridership on 25 of 27 projects (93 percent) achieved at least 60 percent of their forecast

The comparisons of predicted versus actual ridership are summarized in two scatter plots in Figure 3.2-1 and 3.2-2 below. These scatter plots contain the predicted ridership on the horizontal axis and actual ridership on the vertical axis. The 45-degree line that is drawn on these plots represent where actual ridership is equivalent to predicted ridership. The closer a point is to this 45-degree line, the more accurate the forecast was to the actual ridership. The FTA has also placed a 20 percent upper and lower bound of accuracy on these plots. Each of the 27 projects has been labeled and plotted. Figure 3.2-1 includes all data points for the 27 projects, while Figure 3.2-2 focuses the plot on those projects with PvA ridership of under 20,000 trips per day.

Figure 3.2-1: Actual versus Predicted Ridership
Predictions at the FFGA/PCGA for All 2020 PvA Projects

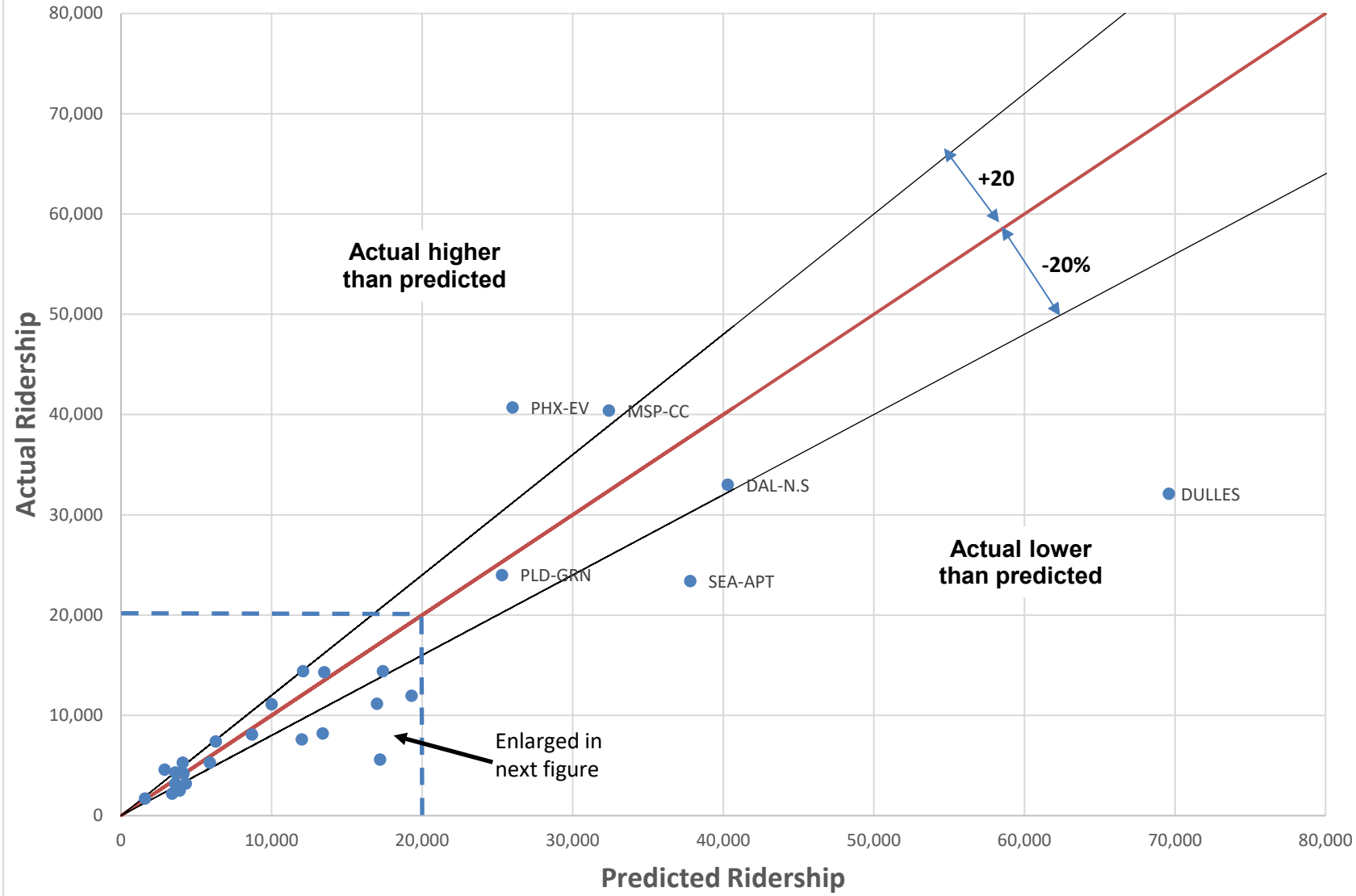
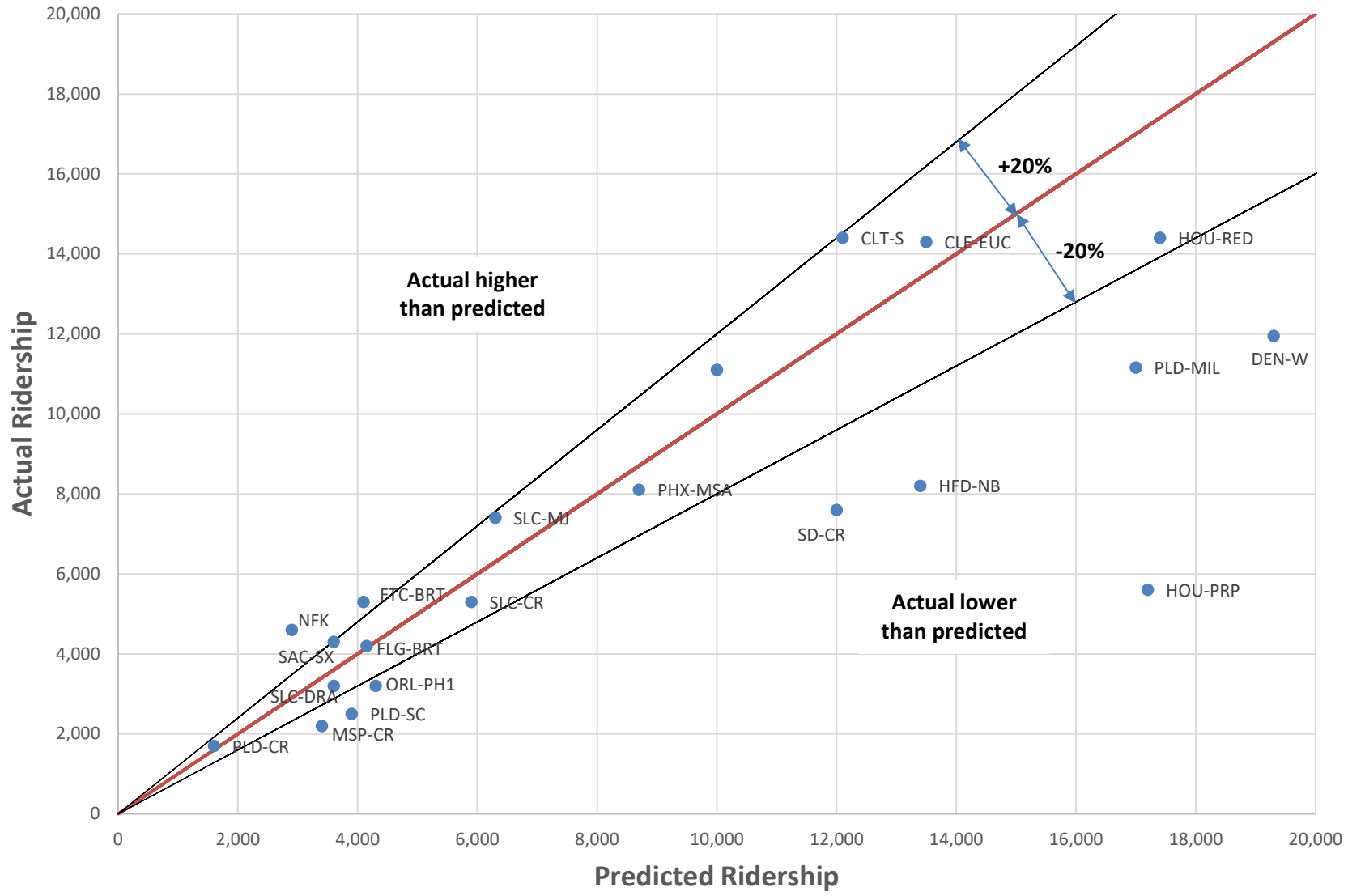


Figure 3.2-2: Actual versus Predicted Ridership
Predictions at the FFGA/PCGA for 2020 PvA Projects with Fewer Than 20,000 Actual Riders



Through the B&A Study process, FTA has identified the causes of PvA ridership differences. Table 3.2-1 identifies the cited causes for those projects which have more than a 20 percent difference between their predicted FFGA/PCGA and actual ridership.

Table 3.2-1: Causes of Ridership Differences Greater than ±20 Percent at the FFGA/PCGA

Cited Causes of Predicted-vs-Actual Ridership Differences Greater Than ±20 Percent at the FFGA/PCGA		Actual Less Than Predicted	Actual Greater Than Predicted	Subtotal	Total
Measurement	Ramp-up	1	0	1	1
Inaccurate Representation of the Setting	Demographics	5	2	7	14
	Project performance	3	0	3	
	Bus changes not made	3	0	3	
	Other lines not built	1	0	1	
Uncertain Context	Problematic markets	1	1	2	10
	Atypical setting	1	0	1	
	1st project	2	3	5	
	New mode	2	0	2	
Methodology	Model properties	4	1	5	7
	Inattention to quality control	1	1	2	
Summaries	Total cites	24	8	32	32
	Total projects	11	3	14	14

The FTA has taken steps to address the recurring issues cited in Table 3.2-1. The most frequently cited issue is inaccuracy in the underlying demographic assumptions used to make ridership forecasts. As discussed earlier, the projects in this study submitted opening year forecasts, typically five to ten years in the future. According to Table 3.2-1, with a relatively short prediction horizon, half of the projects with significant PvA differences had problematic demographic forecasts. Current FTA CIG evaluation addressed this issue by requiring project sponsors to submit a current-year travel forecast. Using a current-year forecast removes horizon-year demographic forecasts from project ridership forecasts.

The second most frequent causes involve model properties and the CIG investment being the first project in a region. The FTA has developed the Simplified Trips-on-Project Software (STOPS) as a simplified forecasting method, which automates and provides a FTA best-practice transit forecasting methodology to project sponsors. STOPS has been calibrated and validated to the measured national experience with actual CIG projects built around the country using the B&A Studies. STOPS eliminates large-scale methodological errors from travel forecasts by standardizing effective travel forecasting procedures. First time project sponsors, who often face challenges forecasting how a new fixed-guideway transit system will affect local transit markets, benefit from STOPS being validated to actual CIG project ridership outcomes from across the United States.

3.3. Comparisons across the Four PvA Studies

This section compares the PvA ridership forecasts from the current study to the prior three efforts. Table 3.3-1 provides a distribution of the PvA ridership outcomes for each of the four PvA Studies. Figure 3.3-1 summarizes these distributions graphically. The key outcomes from the table and figure are as follows:

- In the current PvA Study, accurate travel forecasts, defined as within 20 percent of their actual outcome, make up 13 of the 27 projects (48 percent), which is a measurable improvement from the prior studies:
    - 2007 Study – 6 out of 18 (33 percent)
    - 2003 Study – 6 out of 19 (32 percent)
    - 1990 Study – 0 out of 10 projects (0 percent)

- In the current PvA Study, projects that achieved significantly less than their predicted ridership (less than 60 percent of their forecast) account for just two of the 27 projects (seven percent). This is a vast improvement over the prior efforts:
    - 2007 Study - 7 out of 18 (39 percent)
    - 2003 Study – 9 out of 19 (47 percent)
    - 1990 Study – 7 out of 10 (70 percent)

Table 3.3-2 summarizes the key accuracy statistics across the four studies. It provides the statistics in two different ways. The top of half of the table sums the PvA ridership across all projects, which it is weighted more heavily to larger projects. The bottom of the table treats each individual project equally and each project prediction is treated as an individual data point. The current PvA Study shows the average project achieves, on average, 92 percent of its ridership forecast, which is a substantial improvement in the average ridership forecast as compared to the prior studies:

- 2007 Study – average project achieved 72 percent of its forecast
- 2003 Study – average project achieved 67 percent of its forecast
- 1990 Study – average project achieved 42 percent of its forecast

Table 3.3-1: Distribution of Accuracy of Ridership Predictions across the PvA Studies

Actual Divided by Predicted	TRIPS ON THE PROJECT	1990	2003	2007	2020
		FFGA or PCGA	FFGA or PCGA	FFGA or PCGA	FFGA or PCGA
more than 140%	projects	0	0	1	2
	% of all projects	0%	0%	6%	7%
	total trips predicted	0	0	10,050	28,900
	total trips actual	0	0	21,811	45,300
140% to 120%	projects	0	0	1	2
	% of all projects	0%	0%	6%	7%
	total trips predicted	0	0	24,800	36,500
	total trips actual	0	0	33,477	45,700
120% to 100%	projects	0	4	0	7
	% of all projects	0%	21%	0%	26%
	total trips predicted	0	120,348	0	51,250
	total trips actual	0	125,222	0	57,400
100% to 80%	projects	0	2	6	6
	% of all projects	0%	11%	33%	22%
	total trips predicted	0	49,370	130,338	101,200
	total trips actual	0	43,456	111,855	88,000
80% to 60%	projects	3	4	3	8
	% of all projects	30%	21%	17%	30%
	total trips predicted	1,051,500	69,719	124,430	111,100
	total trips actual	788,395	50,060	78,689	70,210
less than 60%	projects	7	9	7	2
	% of all projects	70%	47%	39%	7%
	total trips predicted	1,106,060	640,568	315,192	86,800
	total trips actual	390,841	279,068	111,982	37,700
All Projects	projects	10	19	18	27
	% of all projects	100%	100%	100%	100%
	total trips predicted	2,157,560	880,005	604,810	415,750
	total trips actual	1,179,236	497,806	357,814	344,310

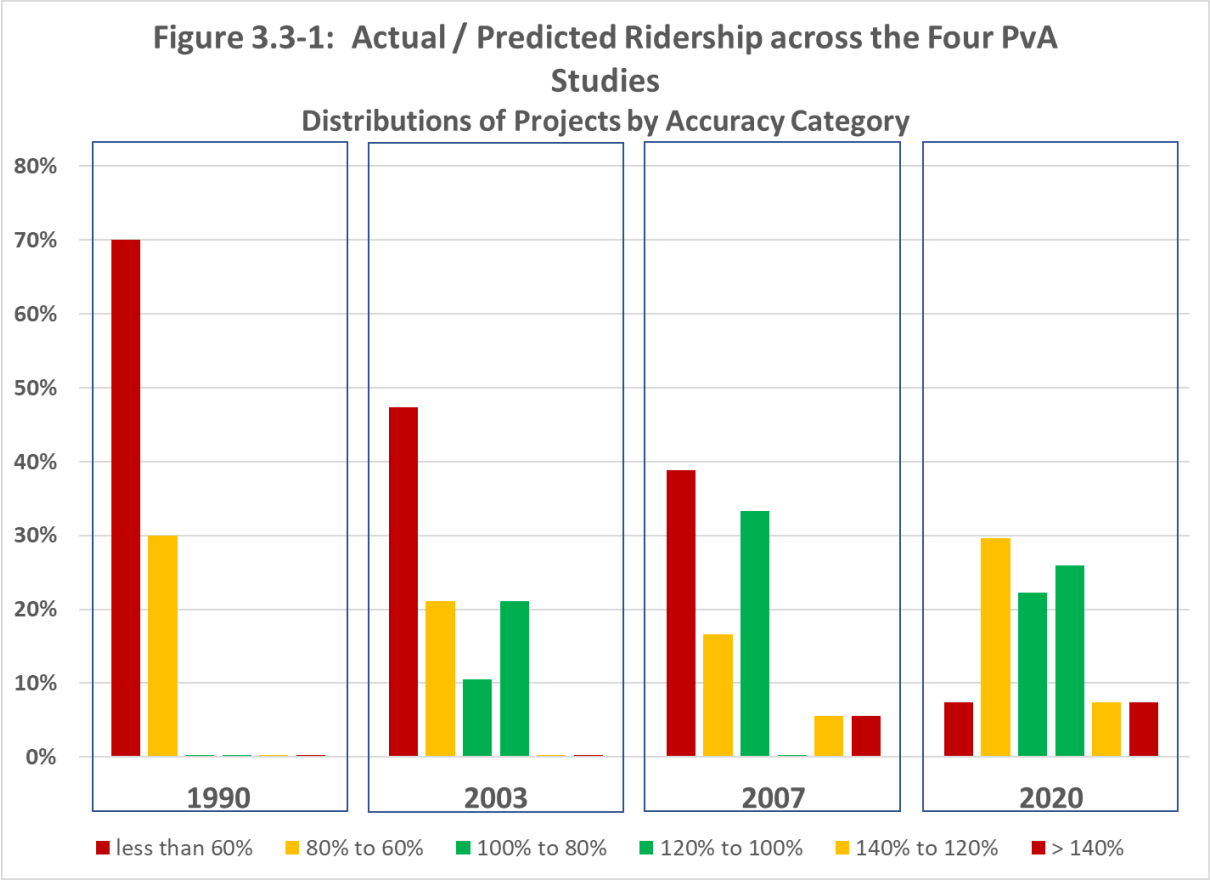


Table 3.3-2: Accuracy of Ridership Predictions across the Four PvA Studies

Measure	1990	2003	2007	2020
Number of Projects	10	19	18	27
Actual and Predicted Ridership for All Projects, Summed across Projects				
Average Actual	117,924	26,200	19,879	12,752
Average Forecast	215,756	46,316	33,601	15,398
Sum of Actual Trips	1,179,236	497,806	357,814	344,310
Sum of Forecast Trips	2,157,560	880,005	604,810	415,750
Sum Actual/Sum Forecast	55%	57%	59%	83%
Actual Divided by Predicted Costs for Each Project, Averaged across Projects				
Average	42%	67%	72%	92%
Median	41%	64%	64%	90%
Minimum	9%	5%	17%	33%
Maximum	76%	108%	217%	159%

3.4. Sources of Improvement

The current PvA Study shows a demonstrated improvement in the accuracy of travel forecasts for CIG projects. The FTA believes there are several reasons for this improvement:

1. **Experience.** The 1990 study evaluated the PvA outcomes for the first batch of capital transit projects that were built since the early 1900s. As such, the technical methods used in making travel forecasts for public transportation projects were built with then-new and unproven technical methods, limited data, and no actual experience with project performance. Since the 1990 study, FTA has compared the PvA outcome for 64 additional projects, which represents 64 additional opportunities to learn and evaluate the performance of travel forecasting methods and encourage the industry to utilize methodologies that work well (and remove those that performed poorly). The FTA has employed a continuous learning culture, which uses past-experiences (good and bad) to improve current and future travel forecasting performance. The prior PvA studies and the B&A Studies show FTA's commitment to improving the practice of travel forecasting accuracy.

2. **FTA Reviews of Transit Forecasts.** The FTA has brought a national perspective and depth of knowledge to the review of ridership forecasts for CIG projects for decades. FTA draws on extensive agency travel-forecasting expertise to conduct these reviews in coordination with project sponsors, and has leveraged the past-experience to improve state-of-the-practice ridership forecasting methods, advancing improved data to identify transit markets, and identified approaches to mitigate risks to transit forecasts. In addition, FTA has developed tools to facilitate better understanding of the travel models employed to make CIG forecasts.

   In the early 2000s, FTA developed the Summit program to identify Transportation System User Benefits (time savings) for CIG projects. It also became an essential quality control tool for transit forecasts and the travel models that produced them. Until this tool was released, most travel models were deemed to be "black boxes" which produced forecasts, with little insight or understanding of what was happening during the execution of the model. This program allowed the project sponsor and FTA review team to identify illogical model attributes during a CIG review. When it was released in the early 2000s, the program revealed many problematic elements from that generation of transit forecasting models and CIG project forecasts. The FTA's reviews, using the Summit program, helped improve travel forecasting models, leading to documented improvement in forecasting accuracy.

3. **Focus on Opening Year.** The FTA's use of the opening year forecasts has dramatically reduced the risk of a forecast being inaccurate. Prior to this PvA study, the earlier PvA studies relied on comparing the actual ridership to a forecast for a point in time that was 20 years in the future. This approach meant that the project ridership forecast was reliant on multiple predictions about 20 years in the future including: socio-economic growth (where it occurs and its magnitude) and the attributes of the future transit system and

future year highway system performance. By focusing on a compressed forecasting period, the range of plausible outcomes for each of these attributes is more tightly banded, allowing for improved accuracy. The FTA has further mitigated the forecasting risk by requiring projects to submit a current year forecast, which demonstrates how a project will perform with the existing transportation context.

4. **Extensive use of Transit Rider Data to Enumerate Transit Travel Markets.** Beginning about 15 years ago, FTA required project sponsors to conduct on-board transit surveys. The data from those surveys is used to identify how transit riders use transit service, the transit travel market origins and destinations, and other attributes. The travel forecasting methods are tested to make sure the forecasts reflect key transit markets and attributes of riders in those markets. The extensive use of rider survey data allowed sponsors' travel forecasters and FTA reviewers to understand the key transit markets for a region and a project corridor, which led directly to models having a stronger representation of existing transit markets. A greater understanding of the transit markets produced better forecasts of what happens with a CIG project investment.

   As discussed earlier, the data collection methods have significantly improved in the past decade to provide a more accurate understanding of regional transit travel patterns. The shift in survey methodology to in-person, interview style has substantially improved the quality and accuracy of the data collected on riders. In addition, new and emerging data sources, such as counts from Automated Passenger Count (APCs) machines and fare-system data are also being used to further increase our understanding of transit rider patterns.

5. Conclusion

This PvA study is the most comprehensive study completed to date, with an assessment of 29 projects. The capital cost and ridership data used for this study are from the Before-and-After Studies produced by recipients of Full Funding Grant Agreements and Project Construction Grant Agreements. As a result, there is a higher level of consistency and quality of information in this PvA study compared to the prior three PvA studies undertaken in 1990, 2003, and 2007. To date, FTA has assessed the predicted versus actual capital cost and ridership of 81 projects constructed with Federal transit Capital Investment Grants program (49 U.S.C. § 5309) funding.

In the thirty-year interval between the 1990 PvA study and the 2020 PvA study, there have been substantial improvements in the methods used to estimate capital costs of CIG projects. CIG project sponsors and FTA have employed techniques to proactively mitigate project risks, implement controls for cost and schedule, and apply prior experience gained during the construction of new transit projects. This is evident in the results of the 2020 PvA study review of capital costs, in which 75 percent of the projects had capital costs at or below the estimate at the FFGA or PCGA. Of the 25 percent of projects in which the actual capital cost exceeded the FFGA capital cost estimate, five projects were within 10 percent of the FFGA estimate, and only two projects exceeded their FFGA capital cost estimate by more than 20 percent. In the 1990 PvA study, almost 90 percent of projects exceeded their capital cost estimates (at PD) by greater than 120 percent.

Similarly, in the thirty-year interval between the 1990 PvA and the 2020 PvA Study, there have been substantial improvements in the methods used to estimate ridership of CIG projects. The 2020 PvA study assessment of ridership is based upon FFGA/PCGA versus opening year ridership forecasts, which are inherently more accurate than ridership forecasts based on a point in time 20 years in the future. Since the earlier PvA studies, FTA and project sponsors have improved the technical methods used for making forecasts, and applied lessons learned about changes in travel behavior in response to the introduction of a new or extended transit system. This includes a close examination of the existing transit markets and use of passenger survey data to carefully calibrate local travel forecasting tools. The FTA has also applied detailed reviews of ridership forecasts and applied tools, such as Summit, to verify that the ridership forecasts reflect the benefits of the transit project, and not mistakes in networks or poor model calibration. This is evident in the results of the 2020 PvA study review of ridership, where 48 percent of the projects had actual ridership within 20 percent of their FFGA/PCGA ridership forecasts. Only two of the projects in the 2020 PvA study had actual ridership outcomes significantly lower (less than 60 percent of the forecast) at the FFGA/PCGA. In the 1990 PvA study, 70 percent of the projects had actual ridership that was less than 60 percent of the forecast.

Based on this analysis, the 1990 PvA Study is no longer representative of FTA's experience with the accuracy of capital cost and ridership estimates for CIG projects.

Key to Project Labels in Charts

Label	State	Metro Area	Project
AUS-BRT	TX	Austin	MetroRapid BRT
CLE-EUC	OH	Cleveland	Euclid Corridor Transportation Project
CLT-S	NC	Charlotte	South Corridor LRT
DAL-N/S	TX	Dallas	Northwest/Southeast LRT MOS
DEN-W	CO	Denver	West Corridor LRT
DULLES	VA	Dulles	Dulles Corridor Metrorail Extension to Wiehle Ave.
FLG	AZ	Flagstaff	Mountain Links BRT
FTC-MAS	CO	Fort Collins	Mason Corridor BRT
HFD-NB	CN	Hartford	New Britain - Hartford Busway
HOU-PRP	TX	Houston	Southeast Corridor LRT
HOU-RED	TX	Houston	North Corridor LRT
LA-GLD	CA	Los Angeles	Metro Gold Line East Side Extension
MSP-CC	MN	Minneapolis-St. Paul	Central Corridor LRT
MSP-CR	MN	Minneapolis	Northstar Corridor Rail
NFK	VA	Norfolk	Norfolk LRT
ORL-SUN1	FL	Orlando	Central Florida Commuter Rail -- Initial Segment
PBG-NS	PA	Pittsburgh	North Shore LRT Connector
PHX-EV	AZ	Phoenix	Central Phoenix / East Valley Light Rail
PHX-MSA	AZ	Phoenix	Central Mesa LRT Extension
PLD-CR	OR	Portland	Wilsonville to Beaverton Commuter Rail
PLD-GRN	OR	Portland	South Corridor I-205/Portland Mall LRT
PLD-MIL	OR	Portland	Portland-Milwaukie Light Rail
PLD-SC	OR	Portland	Streetcar Loop
SAC-SX	CA	Sacramento	South Sacramento Corridor Phase 2
SD-CR	CA	San Diego	Oceanside-Escondido Rail Corridor
SEA-APT	WA	Seattle	Central Link Initial Segment
SLC-CR	UT	Salt Lake City	Weber County to Salt Lake City Commuter Rail
SLC-DRA	UT	Salt Lake City	Draper Transit Corridor
SLC-MJ	UT	Salt Lake City	Mid Jordan LRT

List of Acronyms

ADD - Addition
B&A Study – Before-and-After Study
BRT – Bus Rapid Transit
CIG – Capital Investment Grants Program
CR – Commuter rail
EXP – Expansion
EXT - Extension
FFGA – Full Funding Grant Agreement
FTA – Federal Transit Administration
HR – Heavy Rail
LR – Light rail
NS – New Start
M - Million
PCGA – Project Construction Grant Agreement
PD – Project Development
PE – Preliminary Engineering
PMO – Project Management Oversight
PvA – Predicted versus Actual Study
SC – Streetcar
SS- Small Start
VSS – Very Small Start