The Accuracy of Transit System Ridership Forecasts and Capital Cost Estimates

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ABSTRACT

In 1992, Pickrell published a seminal piece examining the accuracy of ridership forecasts and capital cost estimates for fixed-guideway transit systems in the US. His research created heated discussions in the transit industry regarding the ability of transit planners to properly plan large-scale transit systems. Since then, evidence has arisen to suggest that ridership forecasting and capital cost estimation of both new transit systems and extensions to existing transit system has improved. However, no statistical analysis has been conducted of US transit systems to determine this. This research fills this gap in the literature by examining 47 fixed-guideway transit projects planned in the US between 1972 and 2005 to see whether or not a Pickrell Effect can be observed whereby ridership forecasting and capital cost estimations improved due to Pickrell's work.

KEY WORDS: Pickrell effect, Transit, Ridership, Capital costs, Forecast errors

Introduction

In his classic paper on "The methodology of positive economics", Milton Friedman (1953) emphasized the need for a good model to predict relatively well. In practice, however, very little retrospective work is done assessing the predictive abilities of models in transport economics. A noted exception was the assessment of Dan MacFadden's forecasts, deploying a random utility model, of the mode split to examine the construction of the Bay Rapid Transit System (BART) in the San Franscico area[1]. The quality of his results may help explain why he was awarded the Nobel Prize in Economic Science, although it has not stopped the continued use of engineering consultants' four stage modeling sequence for transportation forecasting. Capture is as endemic in transportation work as elsewhere. Here we focus particularly on the sensitivity of transit use and finance forecasting in the US to the critiquing of earlier methodologies.

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[1] As McFadden (2001) points out, while the conventional aggregate gravity model forecast a 15% mode share for BART, his disaggregate forecast was 6.3% and the actuality was 6.2%. Despite this, BART has never adopted disaggregate modeling as a policy tool.

Federal funding of capital costs for transit projects in the US was first authorized in the Urban Mass Transportation Act of 1964 that provided subsidies up to 66% for project costs. The act was intended as a one-time "shot in the arm" for transit systems to upgrade buses to better compete with the automobile. Today, transit agencies are competing for federal grants under the auspices of the US Federal Transit Administration (FTA) New Starts Program for the funding of a variety of technology-based system including heavy rail transit, light rail transit and bus-based rapid transit systems. The value of these grants has increased considerably from $2.23 billion in the 1964 act to $52.6 billion with SAFETEA-LU in 2005 (2003 prices) (Hess and Lombardi, 2005)

Concern over the impact of these federal grants on localities seeking funds has a rich history. While the intent of the original grants was to reduce the need for operating subsidies, the reality was that the construction of capital intensive projects (such as fixed-guideway heavy and light rail systems) were completed at the expense of operating bus systems and maintaining existing facilities not eligible for the capital subsidies. Thus, throughout the 1970s and 1980s transit utilization continued to decrease as transit agencies placed more emphasis on capital intensive projects, and less emphasis on maintaining and operating the more heavily used bus systems.

The first to quantify this effect was Donald Pickrell (1992). Based upon data four heavy and four light rail systems, Pickrell concludes that the tendency of localities to prefer more capital intensive projects over other projects (e.g. light rail transit over an equivalent bus-based system) was due, in part, to the effect of the federal subsidy program which did not hold localities accountable for their forecasts. Pickrell's work had an impact on the transit industry as more critical analysis was placed upon ridership forecasts and capital cost estimates made by new transit systems being planned at the time. Since Pickrell conducted his initial assessment many things have changed. Given the reception that Pickrell's work received, it begs the question: have things improved?

Background

Prior to Pickrell, Kain (1990) conducted an analysis of ridership forecasting for a planned 91 mile rail transit for the Dallas metropolitan area. Kain points to unrealistic land use forecasts and

overly optimistic ridership forecasts used by the Dallas Area Rapid Transit (DART) agency to persuade voters and board members to approve a dedicated source of tax revenue to fund the transit system. Kain concludes that the most egregious error made by the planners was their unwillingness to consider any type of alternative other than rail technology and the subsequent federal funding with which to construct the system.

Kain also suggested that similar abuses were commonplace in other metropolitan areas throughout the US. Pickrell (1992), after conducting a before and after analysis of ridership, capital costs and operating expenses for eight rail-based transit systems in the US reached a similar conclusion. His analysis shows that planners overestimated ridership forecasts and underestimated capital costs, but does acknowledge a great deal of uncertainty when estimating values with a long time horizon, often 20 to 30 year years. However, he does suggest changes ought to be made to better inform the public that pays for these systems, as well as the local policy-makers who must vote to construct and finance them. In the end, Pickrell attributes the tendency for localities to prefer capital-intensive projects on the federal grant-making process that sets preference for funding capital rather than operating expenses.

Others have also considered similar issues. Mackett and Edwards (1997) look at the underlying decision-making processes for the construction of capital-intensive public transportation systems. They use Pickrell's basic data on ridership and but updated them, and add additional systems including the St. Louis light rail transit and three light rail transit systems from the UK. Their analysis suggests that generally actual ridership is overestimated, but in two of the four new systems there was underestimation.. In these cases the planning was completed and the systems became operational after Pickrell published his work.

Flyvbjerg *et al*. (2002) look solely at cost estimations for public works projects to evaluate the merits of Pickrell's findings, that cost estimates are generally underestimated, and those of Nijkamp and Ubbels (1999) who claim they are more accurate than not. Looking at 258 transportation infrastructure projects (including rail, fixed-link and roads), Flyvbjerg *et al.* conclude that cost estimates used in the decision-making process are systematically misleading. In fact, rail projects had the largest error where actual costs were 45% higher than estimated. While international examples were included in the analysis, it does suggest that Pickrell's conclusion is supported but that his original analysis has not had an impact on planners improving capital cost estimates.

Most studies, in part because they were done soon after Pickrell's work, have focused on individual projects, or a comparison across a small sample, rather than providing a cross-sectional, large size study. Furthermore, few of these studies systematically and statistically examine what factors lead to the forecasting inaccuracy.[2] It is also not clear whether Pickrell's analysis has had an impact on planners improving the accuracy of ridership forecasts and capital costs estimates. Mackett and Edwards provide a brief glimpse to suggest it does when referring to ridership, but Flyvbjerg *et al.* suggest the opposite for capital cost estimates[3]. Enough time has passed that numerous transit systems have been planned and are operating to collect data with which to better determine statistically whether a "Pickrell Effect" can be observed.

The Issues

Good forecasts of ridership and capital costs in influencing policy decisions are important.. Public transport projects concern the social and economic welfare of large groups of people and involve large investments, often financed mainly from taxation. Here we consider data regarding differences between planned and actual capital cost and ridership forecast for 47 US transit systems[4]. Figure 1 provides details of the forecast versus out-turn investment costs. A positive value indicates overestimation, while a negative value is underestimation. Visual inspection of the data show that most transit systems do not perform as forecasted in terms of ridership nor are they constructed consistent with their estimated costs/ For example, in the case of the Los Angeles Orange Line, ridership was underestimated by more than 200%. (Figure 2 provides details of the s in which these systems began operations). The dotted vertical line in Figure 1 for 1992 marks the point at which the Pickrell Effect would most likely have had an impact on forecasting and capital costing (the "ante-Pickrell" and "post-Pickrell" periods). While it is difficult to say whether there was an immediate Pickrell Effect, nonetheless, there is a two-year gap in which no new systems began operations.

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[2] Flyvbjerg *et al*. being the key exception. However, covering cases from 14 countries, his study mainly discussed forecasting inaccuracies in the comparison between rail and road projects and the analysis of causes of inaccuracies largely relies on a survey of project managers.

[3] Anecdotal discussions with transit industry professionals suggest that after Pickrell's work was published, federal bureaucrats more heavily scrutinized many of the assumptions that went into ridership forecasts and required such conservative values that ridership forecasts not only improved, but were underestimated.

[4] A full list of the transit systems examined can be obtained from the authors.

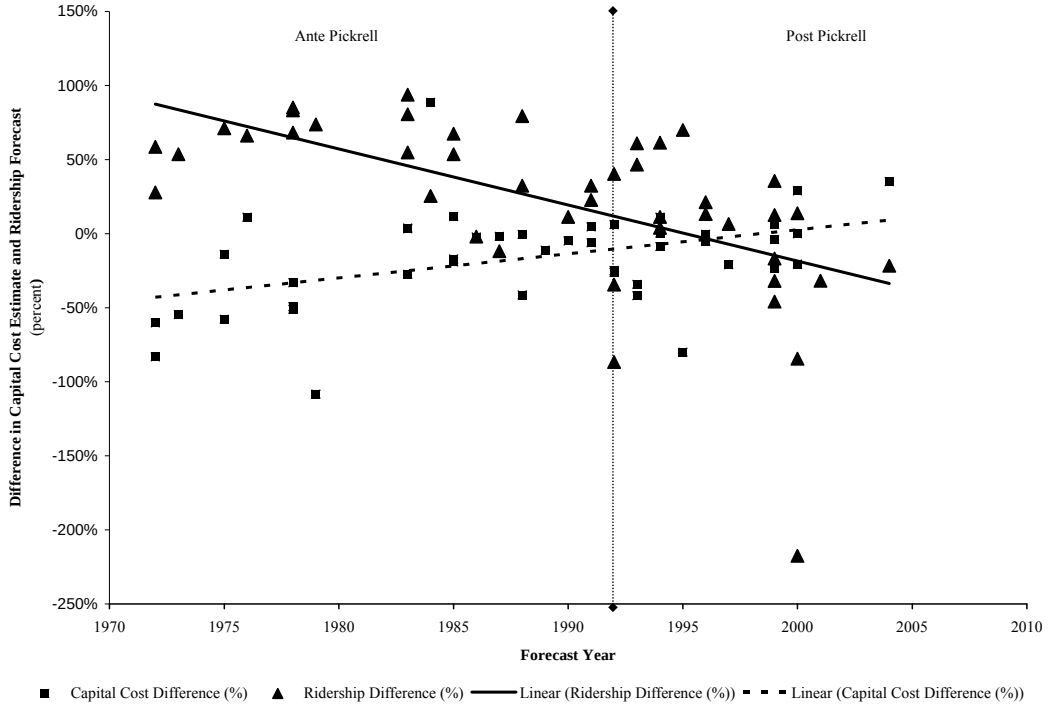

Figure 1 Ridership Forecast and Capital Cost Estimate Trends

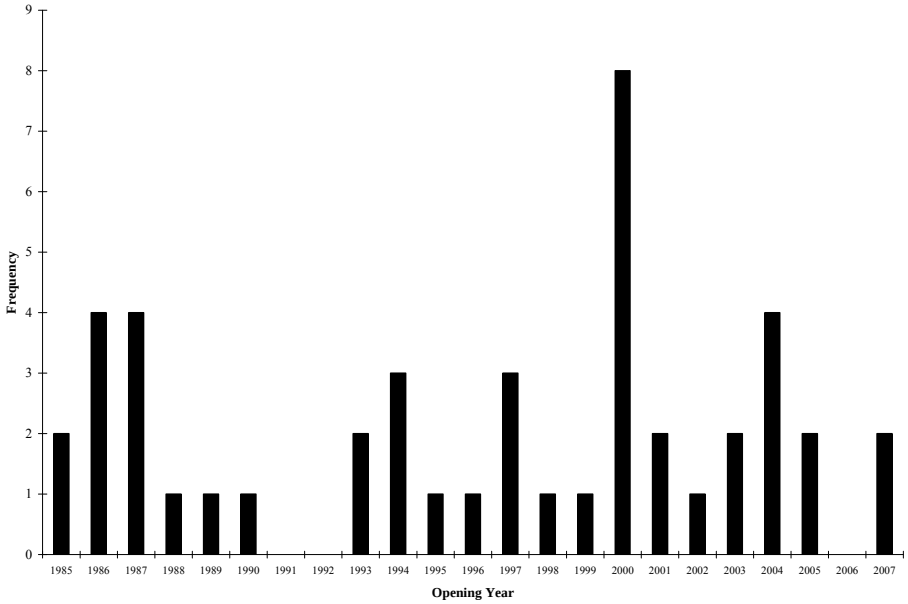

Figure 2 The Systems Opening Each Year

During the ante-Pickrell period, visual inspection suggests that ridership was overestimated while capital costs are underestimated. However, during the post-Pickrell period,

there is a slight reversal of this. Further, post-Pickrell values are smaller than ante-Pickrell values (generally within 50% difference) implying an overall improvement in the forecasting and estimation process. The simple linear trend lines of the differences in ridership forecasts and capital cost estimates reinforces this notion of improved forecast, the differences moved closer to 0% line. Of course, external factors change with time (including land use characteristics, transit system types, and transit technology) and corrections are needed to reflect this.

Quasi-meta analysis of ridership and cost forecasts

Meta-analysis is defined as "the statistical analysis of a large collection of analysis results from individual studies for the purpose of integrating the findings. It connotes a rigorous alternative to the casual, narrative discussions of research studies that typify our attempts to make sense of the rapidly expanding research literature" (Glass, 1976). The basic purpose of meta-analysis is to provide the same methodological rigor to consider a series of prior analyses that focus on one particular topic, as was adopted in each individually. It also aims to avoid general biases which may be a part of previous studies[5].

Stanley and Jarrell (2005) introduced a generalized meta-regression model as:

$$b_j = \beta + \sum_{K=1}^{K} \alpha_k Z_{jk} + e_j, j = 1, 2, \ldots \text{L} \qquad (1)$$

Where: b_j is the reported estimate of β in the jth study in the literature that is made up of L studies; β is the 'true' value of the parameter of interest; Z_{jk} includes various independent variables that measure the relevant characteristics of an empirical study and explain the variations from studies; α_k is the coefficient that reflects the biasing effect of particular study characteristics; and e_j is the error term.

While a strict meta-analysis, the analysis follows the basic underlying methodology of seeking to explain variations in the finding of prior work; essentially its is concerned with identifying moderator variables. It makes use of the generalized function:

[5] Meta-analysis is increasingly used in economics to synthesize a the results of a body of work. For example, in the transportation context, it has been employed in evaluation of environmental impacts in transportation projects (van den Bergh and Button, 1997). For a more general discussion of meta-analysis in applied micro-economics see, Button (2002}

$$Y = f(P, X, R, T, L) + \varepsilon \quad (2)$$

where, Y is the dependent variable under study; P includes several specific causes of the outcome Y; X are characteristics of some objects affected by P to determine the outcome Y; R includes characteristics of different research methods in different studies; T is time period covered by each study; L is the location of each study conducted; and ε is the error term.

Dependent Variables

Ridership and capital costs are taken to reflect the overall performance of a transit system and are important because the decision-makers who determine whether a project receives approval for implementation use them. Thus, two dependent variables are created that measure the difference between forecasted and actual ridership and between estimated and actual capital costs.

Flyvbjerg *et al.* went through a process where they used the percentage difference in road traffic between actual and forecasted values that are considered normally distributed. However, a normal distribution of percentage difference might not be accurate. Though a logarithmic transformation could improve normality, they abandoned this idea because logarithm transformation complicates interpretation of results. The advantages of using a natural logarithm transformation are that it helps stabilize the variance and makes the scale of all the variance comparable such that when one inverses the matrix, fewer numerical problems emerge. Here we are concerned with comparing of two dependent variables for each measure: absolute difference between actual and forecast value and the natural logarithmic value of the absolute difference between actual and forecast value. As a result of using the natural logarithm transformation, the coefficients of the independent variables represent elasticities. Therefore, we emphasize the signs of the coefficients because we want to know the importance of various factors on inaccuracy of the forecast results, rather than make forecasts. Thus, while using natural logarithm of the gap between forecast and actual values is more difficult to interpret, we use them to better refine the overall model. The four dependent variables are summarized in Table 1.

Table 1 Dependent Variables

Name	Description
Ridership_gap_abs	Absolute value of the difference between forecasted ridership and actual ridership.
LnRidership_gap_abs	Natural Log of the absolute value of the difference between forecasted ridership and actual ridership.
Capital_gap_abs	Absolute value of the difference between the estimated capital cost and actual capital cost.
LnCapital_gap_abs	Natural log of the absolute value of the difference between the estimated capital cost and actual capital cost.

Independent Variables

Numerous factors inevitably influence the extent of inaccuracy in ridership forecasts and capital cost estimates. We limit ourselves to the following (see also Table 2).[6]

- **System Characteristics**—System length (miles), number of stations, vehicles, and station density (stations per mile). We hypothesize that these elements, because of scale effects, will cause a larger difference between planned and actual values for both ridership and capital costs forecasts.
- **Type**: New system or extension to an existing (operational) system. A new system will likely be more difficult to forecast ridership and estimate capital costs because of the lack of any information on demand determinants on any prior parts of a network.
- **Technology**: Heavy rail transit (HRT), light rail transit (LRT), bus rapid transit (BRT) and others (automated guideway transit, streetcars, bus lanes, etc.). HRT is the most complex and carries the most passengers. LRT is less complex than HRT with BRT having the least complex technology. We hypothesize that for these variables, HRT systems will suffer a larger difference between planned and actual values for both ridership and capital costs because the systems of the complexity of the technology involved technologies.

[6] Two other variables were also considered but were rejected: population density change and difference in gas price. Population density values were only available for the Metropolitan Statistical Areas and not for specific corridors or areas of interest for the various projects. Gas prices were available but the values used as part of the planning process (i.e. those used in the forecasting models) are not readily available.

- **Time**: The year in which system planning was completed with 1972 as the base. It is hypothesize that before of continual improvements in methodology, the later systems were planned and completed, the more accurate the ridership and capital cost estimates should be.
- **Pickrell Effect**: Indication of whether system planning was completed before or after 1992 (the ante-Pickrell and pre-Pickrell time periods). We include a Pickrell/Time interaction variable to better account for the impact of Pickrell's work. We hypothesize that the Pickrell Effect has improved ridership forecasting and capital cost estimations.

Table 2 Independent Variables

Name	Description
Tech_BRT	Technology dummy: BRT = 1, others = 0
Tech_HRT	Technology dummy: HRT = 1, others = 0
Tech_LRT	Technology dummy: LRT = 1, others = 0
Tech_Other	Technology dummy: Reference Variable. This variable includes systems such as AGT, streetcars, bus lanes, etc. that are not considered one of the other three technologies (HRT, LRT, BRT).
Characteristic_line	System Type dummy: New System = 1, Extension = 0
Characteristic_length	System length (miles)
Characteristic_stations	Number of stations constructed as part of the system
Station_per_mile	Density of stations per mile
Characteristic_vehicle	Number of vehicles purchased as part of the system
Planning_Year	Year that major planning for the system was completed.
Pickrell_Effect	Dummy Variable; where: Planning_Year < 1992; Pickrell = 0 (Ante-Pickrell) Planning_Year > 1991; Pickrell = 1 (Post-Pickrell)
Time_Trend	Time_Trend = Planning_Year - 1971
Time_ trend_and_Pickrell	Interaction variable between Pickrell and Time_Trend

Data and Model Specification

Data were collected from a number of sources including governmental reports, system evaluation reports, transit agency websites and transit agency contacts. Primary data sources included Pickrell (1992); National Bus Rapid Transit Institute collection of BRT evaluation reports[7]; US Federal Transit Administration (2007) contractor performance assessments; individual transit

[7] Evaluation reports are available at http://www.nbrti.org/evaluate.html. Evaluations for Boston, Oakland, Las Vegas, Miami, Pittsburgh and Los Angeles were used. Graham Carey at Lane Transit District provided data regarding the Eugene, Oregon system.

agencies; and other sources[8]. A dataset of 47 observations was created with each observation representing either a new transit system or extension of an existing one. Forty-four observations included necessary data to estimate the ridership dependent variable and 47 included data regarding capital costs. Four models are investigated.

Model 1:

$$|\Delta R| = \beta_0 + \beta_1 T_{BRT} + \beta_2 T_{LRT} + \beta_3 T_{HRT} + \beta_4 Char_{sys} + \beta_5 Char_{stations} + \beta_6 Char_{length} + \beta_7 Char_{veh} + \beta_8 Char_{station\_denisty} + \beta_9 Pickrell\_Effect + \varepsilon$$

Model 2:

$$LN|\Delta R| = \beta_0 + \beta_1 T_{BRT} + \beta_2 T_{LRT} + \beta_3 T_{HRT} + \beta_4 Char_{sys} + \beta_5 Char_{stations} + \beta_6 Char_{length} + \beta_7 Char_{veh} + \beta_8 Char_{station\_denisty} + \beta_9 Pickrell\_Effect + \varepsilon$$

Model 3:

$$|\Delta C| = \beta_0 + \beta_1 T_{BRT} + \beta_2 T_{LRT} + \beta_3 T_{HRT} + \beta_4 Char_{sys} + \beta_5 Char_{stations} + \beta_6 Char_{length} + \beta_7 Char_{veh} + \beta_8 Char_{station\_denisty} + \beta_9 Pickrell\_Effect + \varepsilon$$

Model 4:

$$LN|\Delta C| = \beta_0 + \beta_1 T_{BRT} + \beta_2 T_{LRT} + \beta_3 T_{HRT} + \beta_4 Char_{sys} + \beta_5 Char_{stations} + \beta_6 Char_{length} + \beta_7 Char_{veh} + \beta_8 Char_{station\_denisty} + \beta_9 Pickrell\_Effect + \varepsilon$$

where: ΔR is the difference in forecast and actual ridership; ΔC is the difference in estimated and actual capital cost; T_{BRT} is bus rapid transit; T_{LRT} is light rail rapid transit; T_{HRT} is heavy rail

[8] These include Vincent and Callaghan (2008), Transportation Research Board (2003), and US Federal Transit Administration (2007).

rapid transit; $Char_{sys}$ is the type of line; $Char_{stations}$ is the number of stations; $Char_{length}$ is the length of the line; $Char_{veh}$ is the number of vehicle; $Char_{station\_denisty}$ is stations-per-mile; $Pickrell\_Effect$ is the Pickrell effect; and ε is the error term

Results

Descriptive statistics are presented in Table 3. The ranges of differences between the forecast and actual values of both ridership and capital costs are clearly large

Table 3 Summary Statistics

	Variables	N	Min.	Max.	Mean	Std. Dev.
Dependent variables	*Ridership_gap_abs*	44	0.42	204.50	27.87	45.42
	LnRidership_gap_abs	44	6.04	12.23	9.09	1.61
	Capital_gap_abs ($ millions)	47	0.00	6160.14	308.58	931.81
	LnCapital_gap_abs	47	0.00	22.54	17.05	3.40
Independent variables	*Characteristic_line*	47	0.00	1.00	0.79	0.41
	Characteristic_length	47	0.90	60.50	10.69	9.77
	Characteristic_stations	47	0.00	57.00	14.11	10.08
	Characteristic_vehicles	47	0.00	414.00	37.87	72.41
	Tech_HRT	47	0.00	1.00	0.21	0.41
	Tech_LRT	47	0.00	1.00	0.43	0.50
	Tech_BRT	47	0.00	1.00	0.26	0.44
	Time_trend_and_Pickrell	47	0.00	33.00	11.64	13.29
	Station_per_mile	47	0.00	6.67	1.84	1.53

Initial regression analysis, led us to the elimination of several variables. First, rather than separating length and stations, a density function is preferred (*Station_per_mile*). Second, the *Characteristics_vehicles* produced a series of counterintuitive results that seem largely the result of peculiarities of some projects. For example, the construction of the 1.75 miles Seattle Bus Tunnel also included the purchase of over 380 vehicles. The results using the combined and remaining variables are seen in Table 4.

Model 1 shows that whether a line is a new one or an extension has a statistically significant effect, at the 5% level, and whether it involves heavy transit, at the 10% level, are the only factors impacting on absolute differences between forecast and actual ridership.. However, in Model 2, based on the natural log transformation of ridership, all of the independent variables

except for the heavy rapid transit dummy exhibit statistically significant coefficients, most at the 5% level. The signs, except for that associated with the number of stations per mile, are as anticipated and the overall fit is good. The negative sign of the *Time_Trend_and_Pickrell* variable supports the notion that the Pickrell Effect is positively correlated with the decrease in the difference between forecast and actual ridership irrespective of the nature of the transit system being examined.

Table 4 Regression Results

Variables	Model 1	Model 2	Model 3	Model 4
	Ridership_gap_abs[1]	*LnRidership_gap_abs*[1]	*Capital_gap_abs*[1]	*LnCapital_gap_abs*[1]
Tech_HRT	0.397 *	0.397	0.457	0.092
Tech_LRT	-0.226	-0.226 **	-0.002	-0.357
Tech_BRT	-0.313	-0.313 **	-0.094	-0.399
Characteristic_line	0.356 **	0.356 **	0.169	0.250 *
Time_Trend_and_Pickrell	-0.155	-0.155 **	0.008	-0.106
Station_per_mile	-0.140	-0.140 *	-0.038	-0.214
R-square	0.568	0.588	0.253	0.301
Cases	44	44	47	47

* Significance at 10%, ** significance at 5%
[1] The standardized coefficient of each variable

In the case of capital costs, Model 3, that looks at the absolute value of the difference between estimated and actual capital costs, throws up no significant independent variable at the 10%, level and in Model 4, based on the natural log transformation of the capital cost value, only the characteristic of the line is statistically significant. These results are consistent with Flyvbjerg *et al*. that show a continued systematic misrepresentation of cost estimates in transit project assessments with no discernable Pickrell Effect. What causes this is unclear and whether it is due to political biases in the forecasting process or to more intrinsic problems with the current methods of financial estimation is uncertain.

Conclusions

The paper explored the hypothesis that when planning transit systems, ridership forecasts and capital cost estimates have improved because of the impact of the findings of Don Pickrell's work the early 1990s. Furthermore, this analysis attempted to control for other factors in

determining the performance of ridership forecasting and capital cost estimates for US transit systems. Overall, the results of looking at 47 US transit projects, suggests that Pickrell contribution may in part explain the improvement in ridership forecasts from the mid-1990s, although it seems not to have impacted on the quality of cost estimates.

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