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Transit Forecasting Accuracy: 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.

Background

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. Here we focus on the accuracy of transit use and finance forecasting in the US more generally, and whether it has improved with time.

To put the importance of this is context, federal funding of the capital costs of transit in the US was first authorized in the Urban Mass Transportation Act of 1964 that provided subsidies of up to 66% of project costs. This 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). The macroeconomic stimulus package of 2009 added some $8.4 billion to this.

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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.

Concern over the impact of these federal grants has a long 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 on maintaining and operating the more heavily used bus systems.

John Kain (1990) first expressed concern about this, but Donald Pickrell (1992) produced more general evidence. 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 that 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?

Literature Review

Prior to Pickrell, Kain conducted an analysis of ridership forecasting for a planned 91-mile rail transit for the Dallas metropolitan area and found unrealistic land use forecasts and overly optimistic ridership forecasts used by the Dallas Area Rapid Transit (DART). He argued the agency did this 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 update 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

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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.

which to better determine statistically whether a "Pickrell Effect" can be observed. In other words, did his study have any practical impact.

Issues

As a simple value judgment, good forecasts of ridership and capital costs should influence policy decisions. 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 forecasts[4] for 47 US transit systems[5]. 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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[4] The outturn ridership figures relate to the earliest ridership data available. It is appreciated that there may be issues regarding short term impacts, etc. but the objective is not to seek complete accuracy but to pick up broader trends.
[5] A full list of the transit systems examined can be obtained from the authors.
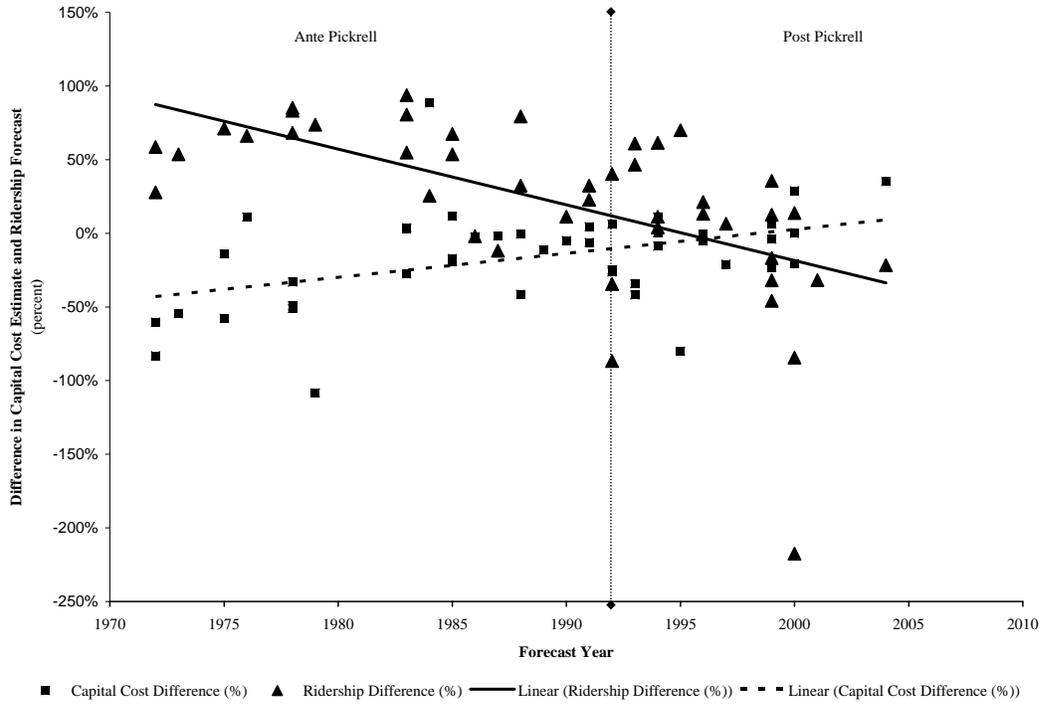
Figure 1 Ridership Forecast and Capital Cost Estimate Trends
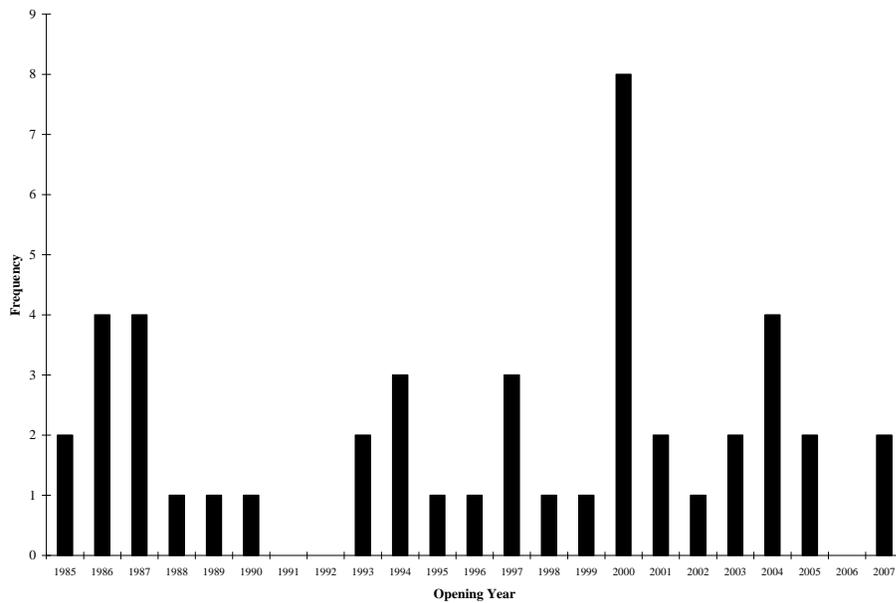
Figure 2 The Systems Opening Each Year

During the ante-Pickrell period, visual inspection of the simple trend lines, 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 forecasting, 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 to draw out whether Pickrell actual had an effect.

Analysis

Essentially want is done here is to deploy a simple meta-regression analysis approach by making use of previous statistical forecasts to see if there has been any sea change in their accuracy after the publication of Pickrell's paper. Stanley and Jarrell (2005) introduce a generalized meta-regression model as:

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

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 (moderator) 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.

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.

- **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.

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[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.

- **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[7]. 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

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[7] Standard Chow tests were conducted to ensure that the periods prior and after Pickrell's publication should treated together and not as separate time periods. The results indicate that the data should not be separated into two time periods.

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[8]; US Federal Transit Administration (2007) contractor performance assessments; individual transit agencies; and other sources[9]. 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:

$LN | \Delta R | =$

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

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

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 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. Several variables were eliminated or modified after some initial regression analysis. 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 the 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.

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

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 3 Regression Results

Variables	Model 1 Ridership_gap_abs[1]	Model 2 LnRidership_gap_abs[1]	Model 3 Capital_gap_abs[1]	Model 4 LnCapital_gap_abs[1]
Tech_HRT	0.397*	-0.027	0.457	0.092
Tech_LRT	-0.226	-0.531**	-0.002	-0.357
Tech_BRT	-0.313	-0.637***	-0.094	-0.399
Characteristic_line	0.356**	0.414***	0.169	0.250*
Time_Trend_and_Pickrell	-0.155	-0.234*	0.008	-0.106
Station_per_mile	-0.140	-0.272*	-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 these latter effects is unclear and can probably only be fully understood at the detailed case study level where qualitative factors may need to be combined with harder variables. Following Kain, the ways in which federal monies and the resultant incentive structure are allocated may be one answer, but equally there may be instinctive selection of forecasts that favor non-efficiency goals such as equity[10]. Following a Chicago School line of reasoning, the adoption of favorable forecasts for transit schemes may be more narrowly focused on the utility functions of the administrators that are primarily driven by self-interest. It is also still not clear whether the problem is due to these types of political and institutional biases in the adoption of forecasts, or to more intrinsic problems with the current methods of financial estimation and cost assessmenting.

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[10] Frey (2001) and others, for example, have highlighted the prime importance politicians and administrators put on the immediate distributional effects of actions rather than on their efficiency.

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, suggest that Pickrell's 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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