The subgrade conduit runs for this work were built during Phase B. The external conduit runs will be built under Phase C. It should be noted that although the contractor pulls in the control cables, the termination of these cables into the working system is to be performed by BART maintenance personnel. The electrical part of this contract was completed in February 1984.

Train Control Construction

The train control tasks under Phase C include the following: the installation and cut over to service of all train control wayside equipment electrical power services; all the additional wayside and train control room equipments needed to provide local and remote supervised and controlled ATO and manual train operations on all new track and through all new turnouts; all new wayside maintenance communications equipments; and the additionally required train destination sign equipment at the 12th and 19th Street Stations. The operational characteristics of the KE Expansion project were previously detailed in Figure 4, completion is expected in November 1985.

SUMMARY

On completion of the KE Expansion project, San Francisco Bay Area commuters will experience an increased level of service even though it is only a part of the Close Headways program. We at BART are confident that the investment of $22,000,000 for this expansion will result in a level of service improvement that will aid BART in continuing to gain ridership through the process of decreasing the perceived advantages of alternate Bay Area transportation methods.

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Estimates of Rail Transit Construction Costs

DON H. PICKRELL

ABSTRACT

Reliable estimates of the costs of constructing new rail transit facilities are necessary to evaluate the growing number of proposals to build new rail lines and extend existing ones. Yet the construction cost estimates used in past studies have often been erroneous, even when they have been based on detailed engineering analyses of proposed projects. Further, rail construction costs appear to have increased rapidly in recent years, even after being adjusted to reflect general price inflation throughout the economy. New estimates of the costs of constructing rapid transit and light rail facilities are reported. These estimates are developed by statistically allocating (via regression analysis) total expenditures for 18 rapid transit and 14 light rail construction projects among their individual components. The results include estimates of unit costs for building rapid transit and light rail lines and stations underground, at grade level, and on elevated structures, including construction outlays and expenses for acquiring the necessary land at typical prices. Some uncertainty exists about the cost estimates for individual rail system components (lines and stations) developed here, but the procedure for estimating them allows this uncertainty to be explicitly quantified. Yet the best estimates of line and station costs suggest that local transportation planners and consultants have seriously underestimated the likely expense for building almost every new rail line or system extension now under serious consideration in the United States.

The recent resurgence of interest in major new rail transit investments among both professional transportation planners and political decision makers, after several decades of widespread disinvestment in rail transit facilities, has focused considerable attention on the costs of constructing new rapid transit and light rail lines. Reliable estimates of these costs play a critical role in evaluating the growing number of proposals to build new rail systems or extend existing ones, as their suitability depends at least in part on how those costs compare with the potential resource savings and other benefits such investments offer. Despite the obvious importance of using reliable cost estimates in such evaluations, past studies of rail transit's suitability have often relied on simple per-mile cost figures derived from limited construction experience. Even when sophisticated engineering cost studies have been undertaken, actual construction costs have typically been much higher than the original estimates produced using their detailed methods.

Another impetus for studying rail construction costs is what appears to be their extremely rapid escalation in recent years, even after taking account of the persistent general price inflation that prevailed throughout the 1970s and early 1980s. For example, Boston's 5.4-mile, 7-station northern extension of its Massachusetts Bay Transportation Authority (MBTA) Orange Line was completed in 1975 for slightly less than $300 million (for comparative purposes this and all subsequent construction costs are reported in equivalent 1983 dollars). [Note that where they were available, annual construction outlays were converted to 1983 dollars using changes from the year in which they were incurred to 1983 in construction cost indices for individual U.S urban areas reported in Engineering News Record (1). Where annual outlays were not available, total project expenditures were adjusted by the change in the appropriate construction cost index between the middle year of the project and its 1983 average value.] Yet an almost identical extension of the Chicago Transit Authority (CTA) Milwaukee line had been constructed only 5 years earlier for about $180 million, whereas the only modestly more extensive 7.7-mile, 9-station Baltimore Mass Transit Administration (MTA) Phase I line, which opened in late 1983, cost more than $900 million to build.

A third reason to investigate further is the puzzling variation in the costs of building what appear to be similar rail transit systems: the 13-mile (90 percent in tunnel), 17-station second segment of the Washington, D.C. Metrorail system was constructed for approximately $980 million, whereas the 13.7-mile (only 40 percent of which is underground), 15-station Metropolitan Atlanta Rapid Transit Authority (MARTA) Phase A project in Atlanta required nearly $1.7 billion to complete.

One question that naturally arises is to what extent these differences can be explained by the extensiveness and capacities of the individual facilities constructed, rather than by harder to identify factors such as variation in local construction prices, geologic and topographic considerations, or effectiveness in project management. Reported here are the results of a preliminary statistical analysis of the costs of constructing 32 recent rail transit systems and line extensions in U.S. and Canadian urban areas. The basic approach used parallels those of previous engineering and accounting-based studies of rail project costs, insofar as an attempt is made to develop estimates of the unit costs for constructing various functional components of transit systems (such as guideway, tunnels, or stations).

This study differs because an attempt is made to estimate the specific costs typically associated with such individual functional units by relating the actual total expenditures for transit construction projects to their respective combinations of those components (using regression analysis), rather than by allocating accounting expenditures or contract prices to specific system components. Despite this difference, the results obtained appear to be consistent with those of previous studies, although somewhat higher unit cost estimates are obtained here than in previous studies. One advantage of this approach is that the results it produces may be more broadly applicable to the problem of forecasting the costs of completing the various rail transit projects now planned or underway, because such results incorporate information on virtually every recent rail transit construction project in North America.

FACTORS LIKELY TO AFFECT RAIL CONSTRUCTION COSTS

Rail transit systems consist of several basic functional components or units: the track or guideway; the right-of-way on which it is located (which can be in underground tunnels, at or slightly below the land surface, or on elevated structures); passenger stations, transit vehicles; and fixed facilities such as yards, depots, and maintenance garages. Much of the wide variation in the costs of constructing rail transit lines is undoubtedly introduced by expenses for acquiring or constructing the right-of-way on which the guideway is located. (Even if building a rail line entails no direct expenditure for land acquisition--such as where land already under public ownership or an inactive railroad right-of-way is available--it will impose real and substantial opportunity costs for right-of-way, because any land it uses certainly has some value in alternative uses that is obviated by locating a transit facility on it.) These land acquisition costs are certainly an important source of potential variation in the costs of providing surface or elevated rail rights-of-way, although it is difficult to specify in advance exactly how extensive land requirements are in specific corridors, and how they are likely to differ between at-grade and elevated alignments. Expenses for right-of-way land can be largely (but certainly not completely) avoided by locating rail lines underground, but only by substituting the high attendant expense of constructing tunnels.

Station locations, passenger handling capacities, and architectural characteristics also appear likely to be among the critical determinants of construction costs. Surface stations are able to use the simplest passenger access facilities and platform designs, and are likely to offer the fewest complications in construction procedures. Thus they would be expected to exhibit considerably lower installation costs than stations of equivalent capacity situated on elevated structures or in underground excavations. On the other hand, as with the guideway itself, land requirements for surface stations may be considerably larger and thus more costly than those for elevated stations. Although underground placement of stations can again substantially reduce land acquisition requirements, excavation and construction costs can be substantial, especially where they must be designed to accommodate large passenger volumes.

Certain physical features of stations, some of which are determined by the anticipated volume of passenger traffic, also appear likely to have a pronounced effect on construction costs. These include total station size or volume, the specific platform layout used, and the number and capacities of passenger access and egress facilities. Some design considerations such as depth underground or architectural elaborateness may also affect station construction costs, even though they may not affect actual passenger-handling capacity or other dimensions of in-use performance. Unfortunately, most of these design parameters are site-specific as well as difficult to measure explicitly, so their individual effects on typical station construction expenses are difficult to isolate.

Although this range of potentially important determinants of rail project costs is quite wide, a logical first step is to investigate the association between actual expenditures for individual rail transit construction projects and readily available measures of their makeup. The two most directly observable characteristics of individual projects are their line lengths and numbers of stations, each of which can be classified according to their location underground, at grade level, or on elevated structures. The makeup of 18 recent rail rapid transit and 13 modern light rail transit construction projects is given in Tables 1 and 2. Because the spacing of stations appears to be relatively consistent among the various projects, it also appears logical to test the simple association of project costs with only the length of right-of-way of each of these three types, leaving implicit the exact number of stations provided.

TABLE 1 Rail Rapid Transit Construction Project Characteristics

		Two-Track Miles/Number of Stations[a]		
City	Project	Tunnel	Surface	Elevated
Cleveland	Initial Line	-	14.9/15	-
	Airport Extension	0.3/0	3.8/3	-
Philadelphia	Lindenwold Line	-	14.5/13	-
	Snyder-Pattison Extension	1.2/1		-
San Francisco	BART System	20.0/14[b]	27.0/7	24.0/13
Washington, D.C.	Metrorail			
	Phases I-IVA	22.4/28	13.3/11	1.5/2
	Phases V-VI	12.5/9	10.7/8	1.0/2
Atlanta	Rail Phase A	5.5/8	5.8/7	2.4/2
Baltimore	Metro Phase I	4.5/6	-	3.2/3
Boston	Red Line South	-	9.5/5	-
	Red Line Northwest	3.2/4	-	-
	Orange Line North	1.0/2	4.4/5	-
Miami	Metrorail N-S Line	-	1.7/0	19.3/20
New York	63d Street tunnel	12.0/0	-	-
	2d Avenue tunnel	7.2/0	-	-
Chicago	Dan Ryan Line	-	9.4/9	1.1/0
	Milwaukee Extension	1.2/2	3.9/4	-
	O'Hare Airport Extension	0.6/1	6.6/3	-

[a]Equivalent miles of two-track line.
[b]Includes approximately 4-mile transbay "tube" (no stations).

A SIMPLE EMPIRICAL MODEL OF PROJECT COSTS

The foregoing discussion suggests two basic models that can be used to relate each project's total costs to its readily measurable characteristics:

$$TC = a_0 + a_1{*}UGMI + a_2{*}AGMI + a_3{*}ELMI \quad (1)$$

and

$$TC = b_0 + b_1{*}UGMI + b_2{*}AGMI + b_3{*}ELMI + b_4{*}UGSTNS + b_5{*}AGSTNS + b_6{*}ELSTNS \quad (2)$$

where

TC = total project expenditures (in 1983 dollars),
UGMI = miles of two-track line in tunnel,
AGMI = miles of two-track line at-grade,
ELMI = miles of two-track line on elevated structures,

TABLE 2 Light Rail Transit Construction Project Characteristics

		Two-Track Miles/Number of Stations		
City	Project	Tunnel	Surface	Elevated
Buffalo	Initial Line	5.2/8	1.2/6	-
Calgary	Southeast Line	0.7/0	6.9/11	-
	Northeast Line	-	6.1/7	-
Edmonton	Initial Line	-	3.5/4	-
	Downtown Subway	0.9/3	-	-
	North Extension	-	1.4/2	-
San Diego	San Ysidro Line	-	15.8/18[a]	-
San Francisco	MUNI/BART Tunnel and Line Extension	5.7/4[b]	13.3/7	-
Boston	Green Line Riverside Branch reconstruction	-	12.0/0[c]	-
Newark	Subway rehabilitation	4.3/4[d]	-	-
Pittsburgh	Tunnel reconstruction and South Hills Line	1.0/3	12.3/7	-
Portland	Banfield Line	-	15.1/16	-
Toronto	Scarborough Line	-	2.7/2	4.3/6
Vancouver	New Westminister Line	0.9/2[e]	3.7/5	8.7/8

[a]Total length is 15.8 miles, of which 1.7 two-track miles and 12 stations were newly constructed.
[b]Part of tunnel and four stations jointly used by BART system.
[c]Minor rehabilitation of 13 stations accompanied line reconstruction.
[d]Tunnel and stations not rebuilt, but line substantially rehabilitated.
[e]Including 0.7 miles in existing single-track tunnel expanded to double-truck capacity.

UGSTNS = number of stations underground,
AGSTNS = number of stations at grade, and
ELSTNS = number of stations on elevated structures.

In model 1, a_1, a_2, and a_3 correspond respectively to the unit--in this case, per mile--construction costs of underground, surface, and elevated rapid transit line segments, inclusive of station construction costs. Analogously, the coefficients b_1, b_2, and b_3 in model 2 represent the unit construction costs of these three types of line segments exclusive of the costs of constructing stations, which are represented by b_4, b_5, and b_6 for underground, surface, and elevated stations.

The interpretation of the terms a_0 and b_0 is more ambiguous, but ideally they represent expenditures for planning and constructing the minimal complement of ancillary facilities necessary to supplement the system described by the line-mile and station variables. Including these terms acknowledges that some project construction costs may not be uniquely associated with a specific structural component of the project. One complication in their interpretation arises, as previously discussed, because new systems will generally require installation of such facilities, whereas projects that represent line additions or extensions of existing systems may not require significant expansion of their capacities. [Note that average station spacings for underground, surface, and elevated alignments are 0.86, 1.34, and 1.42 miles for the 18 heavy rail projects included in this analysis, and 0.84, 1.08, and 0.78 miles for the 14 light rail projects studied.]

Further, if the scale of vehicle storage and maintenance facilities is closely correlated with line mileages or number of stations, their costs will be subsumed within the line and station unit cost estimates instead of being incorporated into the intercept terms. In this case the intercept terms will capture the effects of any remaining expenses not associated with the included measures of the scale of the project (such as planning expenditures) and may be mistakenly interpreted if they are regarded simply as the costs of constructing fixed facilities. Recognizing these potential complications in their interpretation, variants of both models that exclude their respective intercept terms were also estimated and are compared to the specifications that include them in the discussion that follows.

EMPIRICAL ESTIMATES OF UNIT COSTS

A variety of methods can be used to estimate the parameters of these models ($a_0,..,a_3$ and $b_0,..,b_6$). Among them are allocation of expenditure accounts or individual contract awards to individual functional units, engineering-based estimation of resource requirements (labor, materials, etc.) for constructing individual components, and assignment of individual contract awards to particular system components. Another approach is to statistically estimate the parameter values using a sample of observations on project costs and their individual component make-ups. When this method is employed, a residual term is implicitly specified for each model; it corresponds to the variation in individual project costs that is not accounted for by the variables included in the model.

Tables 3 and 4 contain ordinary least squares estimates of unit costs for heavy and light rail transit project components, derived by computing the coefficient values that minimize the sum of the squares of these unexplained residual terms. (Because each project's total expenditures are expressed in equivalent 1983 dollars, the resulting estimates of unit costs for project components can also be interpreted in 1983 dollars.) Of course, the small sample sizes lead to considerable uncertainty surrounding the specific unit cost estimates, but on the whole they exhibit surprising consistency and precision, particularly considering the variety of projects represented and the diversity of their designs and locations. Further, even these simple models account for 60 to 80 percent of the variation in expenses among individual projects.

TABLE 3 Least-Squares Regressions of Rail Rapid Transit Project Construction Costs on Project Characteristics (n = 18)

	Coefficient (Standard Error) in Specification			
Variable	1	1a	2	2a
Constant	34.1 (67.9)		74.9 (62.4)	
Two-track miles in tunnel	137.1 (8.0)	136.5 (8.3)	100.4 (11.2)	102.8 (10.0)
Two-track miles at grade	27.8 (8.1)	30.8 (6.8)	17.8 (7.5)	22.3 (12.2)
Two-track miles on elevated	49.3 (8.4)	55.3 (9.3)	36.5 (17.1)	39.3 (14.6)
Stations underground			36.0 (11.4)	39.5 (11.2)
Stations at grade			6.7 (4.6)	9.7 (5.0)
Stations on elevated			23.0 (16.1)	22.9 (16.3)
Adjusted R^2 of regression	0.75	0.80	0.59	0.64
Standard error of estimate[a]	199.6	211.6	135.7	154.4

[a]Millions of 1983 dollars, around a mean of $987.7 million.

TABLE 4 Least-Squares Regressions of Light Rail Transit Project Construction Costs on Project Characteristics (n = 14)

	Coefficient (Standard Error) in Specification			
Variable	1	1a	2	2a
Constant	56.0 (43.7)		7.4 (52.5)	
Two-track miles in tunnel	98.9 (15.7)	104.1 (16.5)	60.2 (45.1)	67.5 (39.0)
Two-track miles at grade	16.2 (5.6)	16.5 (3.8)	10.4 (6.8)	11.0 (5.2)
Two-track miles on elevated	67.7 (11.5)	72.0 (11.3)	65.9 (11.1)	66.2 (10.4)
Stations underground			31.8 (22.7)	34.2 (26.5)
Stations at grade			8.7 (5.7)	8.9 (5.1)
Adjusted R^2 of regression	0.64	0.68	0.54	0.60
Standard error of estimate[a]	95.3	97.9	91.4	86.8

[a]Millions of 1983 dollars, around a mean of $249.0 million.

A few specific implications of the estimates reported in Tables 3 and 4 are particularly noteworthy. First, the intercept terms are consistently only about as large as their standard errors, suggesting that there is a low probability that the true values of a_0 and b_0 differ significantly from zero. Second, it is interesting to note that the model including only the line length variables (model 1, reported with and without the intercept term as models 1 and 1a in Tables 3 and 4) accounts for more than one-half of the wide variation in the costs of both heavy and light rail projects, despite its simple specification.

This may occur partly because the range of station spacings within each type of project is not extremely wide (it averages about 1.35 miles for rapid rail systems and 0.96 miles for light rail lines, although for both modes the average figure varies considerably among underground, surface, and elevated alignments). Nevertheless, some improvement in the explanatory power of the models is achieved by separately specifying line lengths and numbers of stations, as evidenced by the smaller standard errors in estimating total project costs with this slightly more complex version of the model (reported as models 2 and 2a in Tables 3 and 4). [Note that adjusted R^2, the conventional goodness-of-fit measure, declines despite this improvement in precision, in response to the reduction in the already limited number of degrees of freedom imposed by the more complex specification.]

The data in Table 5 summarize the best point estimates of line and station construction costs obtained from the two samples of rail transit projects. As indicated in Table 5, rapid transit and light rail lines in underground tunnels including conventionally spaced stations (1.16 and 1.30 per mile, respectively) typically cost about $137 and $114 million per mile to construct (again, these and all subsequent estimates are reported in 1983 dollars). Thus some limited cost savings on a line-mile basis appear to be possible using light rail tech-

TABLE 5 Estimates of Unit Construction Costs for Rail Transit Projects

Component	Typical Rapid Transit Unit Construction Cost[a] (millions of 1983 dollars)	Typical Light Rail Unit Construction Cost[b] (millions of 1983 dollars)
Two-track mile, in tunnel:		
Including stations	137	114
Excluding stations	103	68
Two-track mile, at grade:		
Including stations	31	17
Excluding stations	22	11
Two-track mile, on elevated structure:		
Including stations	55	72
Excluding stations	39	-
Underground stations	40	34
At-grade stations	10	9
Elevated stations	23	-

[a] Source: Parameter estimates for specifications 1a and 2a in Table 3, rounded to nearest million.
[b] Source: Parameter estimates for specifications 1a and 2a in Table 4, rounded to nearest million.

nology, although rapid rail transit probably still offers lower costs per unit of passenger-carrying capacity because its maximum capacity is nearly twice that of most light rail systems.

Comparable figures for surface lines are somewhat closer--typically about $31 and $17 million for rapid and light rail lines--including costs for stations at representative spacings of 1.34 and 1.42 miles (corresponding to station frequencies of 0.77 and 0.93 per mile). For lines on elevated structures, estimated rapid transit and light rail construction costs, including stations at typical spacings of 1.42 and 0.84 miles (0.70 and 1.19 stations per mile), are respectively about $55 and $72 million per mile. Although superficially surprising, the higher cost estimate for light rail than for rapid rail transit is no doubt partly explained by the fact that each line-mile of light rail typically includes nearly twice as many stations as each mile of rapid transit line. In addition, only recent examples of elevated light rail lines actually represent an experimental, intermediate-capacity technology, so its slightly higher expense is less surprising.

Disaggregating into line segments and stations, constructing underground rapid transit lines normally entails an expenditure of about $103 million per mile, somewhat higher than the typical $68 million value that appears to be typical for light rail lines constructed in underground tunnels. Underground stations for these two types of lines appear to have similar costs, typically reaching nearly $40 million for those serving heavy rail systems and about $34 million for those serving light rail lines in tunnels. For surface facilities, light rail lines have apparently been only about one-half as costly to construct as their heavy rail counterparts--about $11 million versus $22 million per mile, excluding stations--whereas surface stations for the two types of lines appear to be closely comparable in expense ($9 to $10 million).

Thus it appears that significant construction cost savings can be achieved by cities that choose to employ light rail rather than full-scale rapid transit. Any potential savings from installing light rail facilities underground or at grade apparently stem primarily from the slightly lower costs for right-of-way and line construction, rather than from significant savings in constructing stations or other facilities. Yet the estimation results summarized in Table 5 show surprisingly similar per-mile costs for the two types of lines when stations are included, regardless of whether they are placed in underground, surface, or elevated alignments. This suggests that much of the potential cost savings from light rail may have been sacrificed by incorporating more frequent stations, perhaps in an effort to improve its passenger collection and distribution capabilities to compensate partly for its slower line-haul speed.

EXAMINING THE OUTLIERS

The various specifications given in Tables 3 and 4 generally perform surprisingly well in reproducing the costs of constructing the samples of projects from which they are estimated. Most of the project costs estimated using the different variants of the models fall within 10 percent of their inflation-adjusted total costs. Yet as the data in Table 6 indicate, there are consistently two groups of outliers, or projects with actual costs that are not predicted accurately by the models estimated here. Among heavy rail construction projects, the predicted costs of Boston's MBTA Red Line Northwest extension are consistently only 60 to 65 percent of actual expenditures, whereas those for Atlanta's MARTA Rail Phase A are only 85 to 90 percent of actual outlays. Calgary's Southeast light rail line also appears to have been considerably more costly than predicted by the various models.

At the same time, according to the data in Table 6, predicted costs for two rapid transit projects in Chicago--the Dan Ryan line and O'Hare Airport extension--are considerably above (150 to 200 percent) their actual values. Similarly, the San Ysidro light rail line in San Diego was considerably less costly to construct than anticipated by any of the models estimated here: its estimated costs are about one-third higher than actual construction outlays.

TABLE 6 Predicted versus Actual Costs for Selected U.S. Rail Transit Construction Projects

Project	Predicted Project Cost (millions of 1983 dollars)	Predicted Cost as a Percent of Actual Cost (%)
Boston Red Line Northwest Extension	490[a]	62.6
Calgary Northeast Line	121[b]	75.9
Atlanta Rail System Phase A	1,449[a]	87.5
San Diego San Ysidro Line	127[b]	114.7
Chicago O'Hare Airport Extension	277[a]	150.8
Chicago Day Ryan Line	321[a]	200.7

[a] Predicted using unit cost estimates reported in Table 3 and project descriptions in Table 1.
[b] Predicted using unit cost estimates reported in Table 3 and project descriptions in Table 2.

There are several possible explanations for such large forecasting errors in a few specific locations. First, local construction costs vary among geographic areas in response to differences in prevailing wage rates and delivered prices of construction materials, and they may vary in ways that contribute to the observed pattern of errors. yet the urban area construction cost indices used to adjust project expenditures suggest exactly the opposite pattern: with some minor differences depending on the date for which they are examined, typical construction costs are less than 80 percent of the national average in Atlanta and only about 95 percent of the nationwide figure in Boston, whereas they are no lower in Chicago or San Diego than for the average of large cities nationwide.

Another possible explanation is differences among projects in the cost of land acquisition for rights-of-way, because none of the specifications tested explicitly controls for differences in unit land prices, but land purchase costs are included in some of the project expense totals. This may help explain the surprisingly low costs of projects in San Diego, which makes extensive use of an unused railroad line, as well as in Chicago, where newly constructed transit lines extensively occupy freeway medians. Differences in the effectiveness of local project management could also partially account for the large errors in predicting the costs of these specific projects, although the market in the type of large-scale public works construction management services utilized for rail transit projects appears to be national in scope, and thus unlikely to give rise by itself to such wide variation.

Other possible explanations for the project outliers remain; for example, two of the unusually high-cost projects were new lines that required construction of depot and maintenance facilities, whereas the unusually low-cost line extensions in Chicago apparently utilized existing yards and maintenance facilities. Station designs also appear to vary in ways that could explain some of the wide deviation from the more typical cost experience: two of the stations serving the MBTA Red Line northwest extension, for example, incorporate extensive facilities to serve passengers arriving by automobile or bus, whereas several stations in the MARTA system are architecturally elaborate and designed to accommodate very high passenger volumes. Finally, particularly difficult geologic conditions or tunnel construction characteristics may partially explain the atypically high cost experience, because three of the four projects for which costs are substantially underpredicted incorporate extensive underground facilities.

FORECASTS OF FUTURE SYSTEM COSTS

To illustrate the applicability of the cost estimates developed here, the data in Table 7 compare their predictions of the costs for constructing several planned rail transit systems and line extensions with those prepared by consultants or local planning organizations. These projects range in scale from an 11-mile light rail line planned to utilize almost entirely existing rights-of-way in Rochester, New York, to the nearly 40-mile, 26-station final segment of the Washington, D.C. Metrorail system. (Again, considerable care has been taken to express all figures in 1983 dollars to ensure their comparability, but in a few cases it has not been possible to produce a completely reliable current-dollar estimate from published figures.) Because details about planned station spacings and locations are not available in every case, some of the cost estimates were constructed using the simple forms of the unit cost models presented in Tables 3 and 4, which represent per-mile cost estimates including stations at typical spacings. In most cases, enough detail about their planned configurations was available to allow use of the separate unit cost estimates for line and stations given in Table 5 to produce total cost estimates.

As the data in Table 7 indicate, there is a pronounced tendency for consultants and local planning organizations to substantially underestimate the costs of constructing currently planned light rail systems, compared to those implied by recent U.S. and Canadian experience in building similar systems. That experience--as embodied in the unit cost estimates developed here--implies construction costs ranging from 23 percent (for St. Louis' planned Clayton Airport light rail line) to 188 percent (for an 18-mile light rail line now under construction in Sacramento, California) higher than their consultants' or local planning organizations' most recent published projections. If there is any notable tendency among these discrepancies, it is the somewhat surprising one that those systems that have been studied more recently and in greater detail by consultants and local planners--particularly the light rail lines now under construction in Sacramento and San Jose, California--have projected costs that are more unrepresentative of recent experience than are lines in the early planning phases in cities such as St. Louis, Rochester, and Columbus.

This result may be attributed partly to the difficulty in accurately converting distant future cost estimates for this latter group of cities to current dollars, but it is difficult to tell how much this might contribute to their apparently more realistic estimates. In any event, it appears clear that the currently projected costs of the several U.S. light rail systems now in varying stages of planning and construction are generally much too low to be consistent with typical recent experience. In fact, most of the light rail line construction cost estimates given in Table 7 are apparently also much too low to be consistent with even the comparatively favorable cost record established in the construction of San Diego's celebrated "budget" light rail line.

TABLE 7 Comparison of Published and Author's Cost Estimates for Planned Rail Transit Projects in U.S. Cities

Urban Area	Project Description	Line Miles (Stations)	Construction Cost Estimates[a] (millions of 1983 dollars) Published ($)	Using Table 5 ($)
Sacramento	Light rail at grade	18.3(20)	132 FD	380
San Jose	Light rail at grade	19.7(25)	278 FD	442
Columbus	Light rail at grade	10.6(11)	102 AA	216
Detroit	Light rail in tunnel	15	1,500 PE	1,710
Rochester	Light rail (20% in existing tunnel, 80% at or near grade)	11.4(14)	95 AA	251[b]
St. Louis	Light rail at grade	18.0(26)	350 AA	432
Los Angeles	Heavy rail in subway	17.4(18)	3,325 FD	2,512
Honolulu	Heavy rail in subway	7.8(11)	825 AA	1,243
Houston	Heavy rail (10% in subway, 70% elevated, 20% at grade)	18.5(22)	1,880 FD	1,292
Washington, D.C. (Phases VIA-VIII)	Heavy rail (40% in tunnel, 5% elevated, 55% at grade)	39.6(26)	2,185 FD	2,884
Atlanta (Phases B2 and C)	Heavy rail (20% in tunnel, 30% elevated, 50% at grade)	19.0(11)	857 FD	1,045

[a] "Published" figures are from Alternatives Analyses (AA), Preliminary Engineering Studies (PE), and Final Design (FD) estimates.
[b] Assumes no tunnel construction or rehabilitation expenditures.

The comparisons given in Table 7 between officially projected costs for constructing new heavy rail systems or line extensions and those estimated using the models developed here are more equivocal. On one hand, some of the same tendency to underestimate costs in comparison to recent historical experience is evident. Again surprisingly, it arises mainly in the two cities--Washington, D.C. and Atlanta--that provide much of the recent U.S. experience with constructing heavy rail systems. Certainly the outlying portions of these systems are likely to be less costly to build than their earlier downtown segments, because the at-grade and elevated rights-of-way that can be more readily utilized in suburban locations tend to be less costly than subway lines. Nevertheless, planners in these two cities appear likely to have underestimated the costs of completing their systems even by comparison to the recent experience with building these typically less costly surface and elevated lines in their own and other large U.S. cities such as Baltimore, Miami, and San Francisco.

In contrast, planners currently project that the costs of constructing the entirely new heavy rail systems currently under study in Los Angeles and Houston will substantially exceed those that would be predicted from typical recent experience. The implied unit cost for constructing Los Angeles' underground line would approach that (nearly $250 million per mile) for the most expensive recently constructed subway line, Boston's MBTA Red Line Northwest extension, whereas that for Houston's mixed-alignment system (about 10 percent in tunnel, 20 percent at grade, and 70 percent elevated) would approach the figures for building the most expensive comparable system in recent history, Atlanta's Phase A project. Some of this result may be caused by an inadequate adjustment for the inflation rates anticipated over their construction horizons, although it is difficult to specify how much. It may also partly reflect local planners' recognition of unusually high construction costs in these particular urban areas; local building cost indices show that typical construction costs in Houston and Los Angeles are currently 134 percent and 120 percent of their national average figure (2). In any event, it appears that planners and consultants in these cities have been considerably more cautious in preparing cost estimates for their planned rail systems than have their counterparts in cities planning to build light rail lines or complete planned rapid transit systems.

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