

# Are We Pricing Light Rail Transit Systems Out of Range?

*A Comparison of Cost Experiences*

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## ABSTRACT

Capital costs for light rail transit (LRT) systems are showing a wide range of variability as well as rapid increases. System planners are now using planning estimates for costs that often exceed \$22 to \$28 million/km (\$35 to \$45 million/mi) for new LRT lines. With costs at these levels, many agencies are faced with a significant problem to identify adequate sources of funds early in the planning process. An especially difficult problem is encountered in pre-New Start cities, where study data from other cities is used to estimate costs during planning studies. Conclusions of some of those studies may result in LRT alternatives being set aside because expected costs appear to be too high. Comparisons of cost experiences among cities that have built lines in recent years are helpful to show where costs are higher and how factors such as right-of-way type influence these costs. The 1990s were a busy time for LRT construction. Several cities in the western United States completed initial LRT lines, and in other cities new lines and extensions were added. Cost data for actual construction is now available for comparison across several of these projects. These comparisons are useful in early planning work in cities where similar types of projects are envisioned.

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## OVERVIEW OF PROJECT COSTS OF SELECTED SYSTEMS

Capital costs for light rail transit (LRT) systems are often discussed in very general terms, without regard to conditions specific to location. Conditions such as grade, alignment, and the adjacent built environment, can have a substantial effect on project costs.

Planners use costs from cities where LRT lines have recently been constructed to guide system-level and corridor feasibility analyses. If these LRT lines meet evaluation criteria, they are usually advanced to the next stage of the project development process in which significant time and effort are spent to develop detailed cost estimates.

In these early planning phases, planners use available cost information and apply this data with limited knowledge of the actual conditions under which these costs were expended. However, data are now available on a variety of different LRT lines and segments. This data can be used to provide more specific estimates during the early planning phases and can also be used to compare actual costs of LRT lines in order to understand at what point different choices have been made during planning and design.

This research examines cost data from two perspectives:

- Major Cost Component—data for systems, stations, structures, and typical section, are presented and compared.
- Project Costs by Right-of-Way Type—total LRT line costs (including pro rata share of vehicles, maintenance facility, and other costs) for projects are presented for five different right-of-way types.

Cost information was obtained from projects in six cities: Dallas, St. Louis, Denver, Salt Lake City, Portland, and San Diego. The data was obtained for projects that have been constructed and opened to revenue service as well as projects that are now under construction and will open over the next 2 years. To the extent possible, data from actual bid tabs or other similar summaries were used in the following comparisons.

### TOTAL PROJECT COSTS

Total project costs are usually expressed by agencies as the fully allocated cost for planning, design, and construction of a project. These costs usually include the expense for vehicles and maintenance facilities. Fully allocated costs also typically include expenses for engineering and administration and other add-on costs.

Comparing costs for LRT projects must also take into account the difference associated with the year in which the costs were committed by bidders. Because total project costs are not known until the end of the project, the year the line was opened was used in the comparisons in this research.

Table 1 presents the total cost of LRT lines as reported by each of the agencies studied. Total cost includes all the categories typically used in estimates:

**TABLE 1 Total Cost of LRT Lines (1998 Dollars in Millions)**

Project Location	Total Line KM (MI)	Project Year Dollars	1997/1998 Dollars	Cost Per Kilometer	Cost Per Mile
<b>1. Dallas (Dart)</b>					
Starter System	33.3 (20.7)	\$806.12	\$907.2	\$27.2	\$43.8
Northeast/North Central	38.2 (23.7)	\$762.5	\$762.5	\$20.0	\$32.2
<b>2. St. Louis (BSDA)</b>					
Starter System	29.1 (18.1)	\$300.7	\$469.5	\$16.1	\$25.9
Illinois/BAC Extension	28.0 (17.4)	\$248.8	\$236.3	\$8.4	\$13.6
<b>3. Denver (RTD)</b>					
Starter System	8.5 (5.3)	\$116.5	\$133.1	\$15.7	\$25.1
Southwest Line	14.0 (8.7)	\$177.0	\$168.1	\$12.0	\$19.3
<b>4. Salt Lake City (UTA)</b>					
North/South Line	25.4 (15.8)	\$297.5	\$297.5	\$11.7	\$18.8
<b>5. Portland (Tri-Met)</b>					
Eastside	24.3 (15.1)	\$244.9	\$353.9	\$14.6	\$23.4
Westside	19.0 (11.8)	\$940.0	\$940.0	\$49.5	\$79.7
Hillsboro	10.0 (6.2)	\$143.9	\$143.9	\$14.4	\$23.2
<b>6. San Diego (MTDB)</b>					
South	25.8 (16.0)	\$116.6	\$181.6	\$7.0	\$11.4
East	33.6 (20.9)	\$250.6	\$356.6	\$10.6	\$17.1
Old Town	5.2 (3.2)	\$114.0	\$120.3	\$23.1	\$37.6
Mission Valley West	9.8 (6.1)	\$220.0	\$225.9	\$23.1	\$37.6
Mission Valley East	9.5 (5.9)	\$401.0	\$345.4	\$36.4	\$58.5

Sources: Agency Data; BRW, Inc.

- Guideway
- Stations
- Structures
- Systems
- Utilities/Drainage
- Vehicles
- Maintenance facility
- Right-of-way
- Design, PM/CM
- Other/Miscellaneous

Depending on the specific conditions of each line, cost components may be attributed to projects that are not actually a cost of the LRT line. These other components are included because they are needed to make room for the LRT line. An example is Portland's Tri-Met, which included \$31 million (1985 dollars), or 12 percent of the project, for the Oregon Department of Transportation portion of the Banfield Highway work on the Eastside LRT project. Specific conditions will affect total project cost, sometimes dramatically.

The Federal Transit Administration (FTA) prepared a report in 1995 that developed a capital cost price index from as-built costs for LRT and heavy rail projects (1). The total price index for the period 1985 to 1993, coupled with an estimate of the index change averaging 2.8 percent for the years 1994 to 1998, was used to normalize costs to 1998.

Table 1 seems to indicate that LRT costs are widely variable, ranging from a low of \$7 million/km (\$11.4 million/mi) for the South line in San Diego and \$8.4 million/km (\$13.4 million/mi) for the Illinois Extension to Belleville Area College for the system in St. Louis, to \$41.4 million/km (\$66.6 million/mi) for the Westside Extension in Portland. The data from two recent projects show that the Illinois line is five to six times less expensive than the Portland line.

Based on this type of simple cost comparison, questions arise on why so much variability exists. In order to understand the reasons for this variability, different components of LRT lines were examined.

## PROJECT COST COMPONENTS

Costs were divided into different categories to examine what type of variability is present and how these categories of individual costs relate to the total project cost. The following categories were examined:

- Systems Costs, organized into three components—traction power electrification, signals, and communications
  - Station Type, organized by grade separated, at-grade, transit center, transit mall, and tunnel/subway
  - Major Structures, organized into profile change for LRT or no profile change.
  - Typical Section, composed of standard units and prices from each of three projects

## Systems Costs

Systems costs from actual costs were analyzed for the traction power system, signals, and communications. Table 2 presents the data for five of the systems studied.

The data show significant variability, but the variance is by small amounts compared to the total project costs. Average costs and a sample standard deviation are shown for each of the components. Totaling all costs and converting that total to a cost per track-kilometer shows a cost of \$1.75 million/km (\$2.80 million/mi) for recent installations. This compares favorably to an overall average cost for systems contained in the FTA Index Report (1) of \$1.92 million/km (\$3.08 million/mi).

## Station Type

Data from four of the cities in the review were available for five different station types: grade separated, at-grade, transit center, transit mall, and tunnel/subway. Table 3 shows the data for these stations. The costs are for the station platforms, finishes, and the adjoining facility.

The data show some variability, primarily within the grade separated station type. The sample size for transit mall and subway are too small for comparison.

The FTA Index Report (1) shows an average for at-grade stations, either side or center platform, of \$745,000 in 1998 dollars. The report also shows an average cost for subway stations of \$19.5 million. This amount is similar to the costs currently being encountered by Dallas Area Rapid Transit (DART) in Dallas for the Cityplace Station finish project on the North Central line.

Data were also available for parking space construction from Dallas and Portland, with an average cost of \$4,200 per space for surface parking. Portland constructed a parking

**TABLE 2 Systems Costs of LRT Lines (1998 Dollars in Millions)**

Project Location	Systems Cost Per Kilometer (Mile)		
	Traction Power	Signals	Communications
<b>Dallas (DART)</b>			
Starter System	\$0.91 (\$1.45)	\$1.23 (\$1.97)	\$0.32 (\$0.51)
Northeast/North Central	\$0.96 (\$1.54)	\$1.31 (\$2.10)	\$0.49 (\$0.78)
<b>St. Louis (BSDA)</b>			
Starter System	\$0.54 (\$0.86)	\$0.59 (\$0.94)	\$0.17 (\$0.27)
Illinois Extension	\$0.56 (\$0.89)	\$0.49 (\$0.78)	\$0.25 (\$0.40)
<b>Denver (RTD)</b>			
Southwest Line	\$0.89 (\$1.80)	\$0.38 (\$0.60)	\$0.21 (\$0.33)
<b>Salt Lake City (UTA)</b>			
North-South	\$0.43 (\$0.68)	\$0.24 (\$0.39)	N/A
<b>Portland (Tri-Met)</b>			
Eastside	\$0.65 (\$1.04)	\$0.24 (\$0.39)	\$0.24 (\$0.39)
Westside/Hillsboro	\$0.94 (\$1.50)	\$0.99 (\$1.58)	\$0.62 (\$0.99)
<b>Average Cost</b>	\$0.74 (\$1.18)	\$0.68 (\$1.09)	\$0.33 (\$0.53)
Sample Standard Deviation	\$0.21(\$0.34)	\$0.43 (\$0.69)	\$0.17 (\$0.20)

Sources: Agency Data; BRW, Inc.

**TABLE 3 Construction Costs by Station Type for LRT Projects  
(1998 Dollars in Millions)**

Project Location	Grade Separated	At-Grade	Transit Center	Transit Mall	Tunnel/Subway
<b>Dallas (DART)</b>					
Starter System	\$4.90	\$2.60	\$4.30	--	\$19.90
Northeast/North Central	\$5.60	\$2.60	--	--	--
<b>St. Louis (BSDA)</b>					
Starter System	\$2.10	\$1.00	\$5.60	--	--
Illinois Extension	--	\$1.10	--	--	--
<b>Denver (RTD)</b>					
Southwest Line	--	\$2.10	--	--	--
<b>Portland (Tri-Met)</b>					
Banfield	\$2.20	--	--	--	--
Westside/Hillsboro	--	\$0.90	\$5.10	\$2.50	--
<b>Average Cost</b>	<b>\$3.70</b>	<b>\$1.70</b>	<b>\$5.00</b>	<b>\$2.50</b>	<b>\$19.90</b>
Sample Standard Deviation	\$1.80	\$0.80	\$0.70	--	--

Sources : Agency Data; BRW, Inc.

structure for \$6,800 per space. The FTA Index Report shows an average of \$5,700 per space for surface parking in 1998 dollars.

### Major Structures

Limited data were available for major structures to carry the LRT line over roadways, waterways, or other obstacles. Cost experience from Denver and Dallas is presented in Table 4, along with the results of the FTA Index Report (1).

These data show a close relationship for structure costs, whether the structure changes profile grade or remains level to pass over an obstacle. The data from recent projects show that structure costs range from \$6,620 to \$7,800/m (\$2,020 to \$2,380/ft). The FTA Index Report shows higher costs for projects in the 1980s, at \$9,440/m (\$2,880/ft).

**TABLE 4 Major Structure Costs for LRT Projects (1998 Dollars)**

Project Location	Elevated Profile Change		No Profile Change	
	Total Per Structure	Cost Per Meter (Foot)	Total Per Structure	Cost Per Meter (Foot)
<b>Dallas (DART)</b>				
Northeast/North Central	\$2.83 M	\$7,230 (\$2,205)	\$0.44 M	\$7,800 (2,380)
<b>Denver (RTD)</b>				
Southwest Line	\$2.42 M	\$6,620 (\$2,020)	\$0.43 M	\$7,410 (\$2,260)
<b>FTA Index Report</b>				
Elevated		\$9,440 (\$2,880)		
Underground		\$29,100 (\$8,875)		

Sources : Agency Data; BRW, Inc.

### At-Grade Typical Section

To examine the differences in costs for a typical section, data from three cities were used for a ballasted, double-track cross section. Presented in Table 5, these data show a similar cost per meter of between \$1,150 to \$1,212 (\$350 to \$370 per foot) for lines in Denver and Salt Lake City. These two lines are in former railroad corridors and had minor amounts of grading and fill that were necessary to prepare the cross section for the trackway. By contrast, the Portland Westside project shows almost double the cost, at \$2,200/m (\$670/ft). This line was placed through a variety of different areas that required extensive work to prepare the corresponding section. This work is reflected in the costs where clear and grub, excavation, backfill, and drain pipe are all significantly higher than the Denver and Salt Lake City projects.

By comparison, costs contained in the FTA report also vary because of right-of-way type, from \$1,125 to \$2,025/m (\$343 to 617/ft). The average of these projects was \$1,450/m (\$440/ft).

### VEHICLES AND MAINTANENCE FACILITY COSTS

Two areas of capital cost that have been included in the total cost values are vehicle and maintenance facility costs. The need for vehicles will vary for each line or segment depending upon such factors as service frequency, spare ratio, and operating plans. In a start-up situation, costs will be higher than for an extension because a base level of vehicles is needed.

Similarly, a maintenance facility is not always needed for each LRT line. Starter systems will begin with a basic yard and shop, with the potential to expand with extensions.

Vehicle and maintenance facility costs were available for Dallas, St. Louis, Denver, Salt Lake City, and Portland systems. Converting these costs to a per kilometer/per mile basis gives the following results:

Vehicle and Maintenance Facility:

- Average Cost: \$3.3 million/km (\$5.3 million/mi)
- Standard Deviation: \$2.4 million/km (\$3.9 million/mi)

**TABLE 5 At-Grade Ballasted Double-Track LRT Guideway Costs (1998 Dollars)**

Quantity	Unit	Salt Lake City		Denver		Portland		
		Price	Total	Price	Total	Price	Total	
Clear & Grub	80	SF	--	--	--	--	\$0.20	\$16.00
Excavation	0.30	CY	\$4.00	\$1.20	\$6.75	\$2.00	\$8.30	\$2.49
Back Fill	4.40	CY	\$3.00	\$13.20	\$6.20	\$27.28	\$22.56	\$99.26
Fence	2	SF	\$16.00	\$32.00	\$18.86	\$37.22	\$28.96	\$57.92
Subballast	16	TON	\$4.00	\$6.40	\$17.13	\$27.41	\$19.79	\$32.66
Ballast	2.40	TON	\$40.00	\$96.00	\$21.30	\$51.12	\$49.46	\$118.70
Rail	2.00	TF	\$40.00	\$80.00	\$32.40	\$64.80	\$34.50	\$69.00
Drain Pipe	2	LF	\$22.00	\$44.00	\$37.60	\$75.20	\$32.40	\$64.80
Conduits	2	LF	\$10.00	\$20.00	\$6.33	\$12.66	\$23.46	\$46.92
Ductbank	2	LF	\$29.00	\$58.00	\$36.06	\$72.12	\$52.78	\$105.56
Cost Per				\$350.80		\$369.81		\$671.23
Linear Foot								
Cost Per				\$1,150		\$1,212		\$2,200
Linear Meter								

Sources: Agency Data; BRW, Inc.

## **COSTS BY RIGHT-OF-WAY TYPE**

A comparison of capital costs for major components provides some detail that may be useful in planning studies. However, cost data is rarely in a similar format among agencies. Some agencies have been able to assemble detailed summaries and breakdown costs. Others have detailed bid tabs. A uniform reporting format is not available.

Because availability of cost data by major component was not available for all LRT lines studied, costs were segregated by right-of-way type. Projects constructed in each of the six cities studied were reviewed for the type of right-of-way where lines were constructed. To the extent possible, lines were characterized according to the following definitions used by Schumann and Tidrick (2) in their paper for the Seventh National Conference on Light Rail Transit:

1. Exclusive with Grade Separations—aerial or surface, such as along a freeway with no grade crossings.
2. Private At-Grade—surface on private right-of-way, such as a railroad line, or adjacent to a city street or highway with at-grade crossings.
3. Street/Highway Median—surface with reserved section in medians of streets and highways with at-grade crossings.
4. Reserved Lanes/Mall—surface with reserved section in pedestrian malls with at-grade crossings.
5. Tunnel/Subway—below grade in tunnel.

Table 6 organizes the projects by type of right-of-way for the five categories listed above. Total line miles and year of opening are also included. Some of these segment lengths were obtained from the agencies, and others were obtained from the Schumann and Tidrick paper (2).

Guideway construction costs were then broken down into each of the five categories. Costs per kilometer (mile) were calculated and are incorporated in Table 7.

These latter tables show a different relationship of costs than Table 1, where total costs were used. Because of the variability in types of right-of-way, LRT line costs are also shown to vary substantially depending on specific conditions along the alignment.

Simple statistics were calculated for these comparisons. Table 8 presents the averages and sample standard deviation for each of the categories by cost per kilometer and cost per mile.

### **Observations**

The averages and the sample standard deviations of several right-of-way categories continue to show wide differences. Further analysis of this variability was conducted to attempt to explain the differences, as summarized in the following sections.

#### *Exclusive Right-of-Way*

This category includes guideway alignments that are on existing railroad rights-of-way and alignments that are on new rights-of-way. The existing railroad right-of-way often allows

**TABLE 6 Right-of-Way Type by LRT Project**

Project Location	Total Line Kilometers (MI)	Exclusive (Grade Sep)	Private At-Grade	Street/Highway Median	Reserved Lanes/Mall	Tunnel/Subway
<b>Dallas (DART)</b>						
Starter System	33.3 (20.7) opened 1997	9.5 (5.9)	10.1 (6.3)	5.9 (3.7)	2.1 (1.3)	5.6 (3.5)
North East	18.0 (11.2) to open 2001	18.0 (11.2)				
North Central	20.1 (12.5) to open 2001	15.0 (9.3)	5.2 (3.2)			
<b>St. Louis (BSDA)</b>						
Starter System	29.1 (18.1) opened 1993	15.9 (9.9)	11.9 (7.4)			1.3 (0.8)
Illinois Extension	28.0 (17.4) to open 2001	—	28.0 (17.4)			
<b>Denver (RTD)</b>						
Starter System	8.5 (5.3) opened 1993		5.6 (3.5)		2.9 (1.8)	
Southwest Line	14.0 (8.7) to open 2000		14.0 (8.7)			
<b>Salt Lake City (UTA)</b>						
North – South	25.4 (15.8) opened 1999		21.1 (13.1)	2.3 (1.3)	2.2 (1.4)	
<b>Portland (Tri-Met)</b>						
Eastside	24.3 (15.1) opened 1986	8.7 (5.4)	3.7 (2.3)	8.4 (5.2)	3.5 (2.2)	6.8 (4.2)
Westside	19.0 (11.8) opened 1998	2.7 (1.7)	7.2 (4.5)		2.3 (1.4)	
Hillsboro	10.0 (6.2) opened 1998		8.5 (5.3)	1.4 (0.9)		
<b>San Diego (MTDB)</b>						
South	25.8 (16.0) opened 1981		23.8 (14.8)		1.9 (1.2)	
East – Euclid	7.2 (4.5) opened 1986		7.2 (4.5)			
East – El Cajon	2.1 (1.3) opened 1989		18.2 (11.3)			
East Bayside	2.4 (1.5) opened 1990		2.4 (1.5)			
East – Santee	5.8 (3.6) opened 1995		1.6 (1.0)	4.2 (2.6)		
Old Town	5.2 (3.2) opened 1996		5.2 (3.2)			
Mission Valley West	9.8 (6.1) opened 1997	9.2 (5.1)	1.6 (1.0)			
Mission Valley East	9.5 (5.9) to open 2004	8.5 (5.3)				1.0 (0.6)

Source: Agency Data; Schumann and Tidrick (2); BRW, Inc.

the LRT alignments to take advantage of existing grade separations or to use embankments to cross over obstructions. The new right-of-way alignments are often along a freeway or perhaps are largely elevated, thereby requiring extensive structure to carry the guideway.

In reviewing the costs for this category, two projects with costs substantially higher than the others were the Mission Valley West and soon-to-be-under-construction Mission Valley East segments in San Diego. Both alignments were predominately carried on structure. Without these two projects, the average cost now shown in Table 7 would drop to \$15.5 million/km (\$24.5 million/mi), with a sample standard deviation of \$4.5 million/km (\$7.4 million/mi).

The grouping of projects without the Mission Valley segments consists primarily of segments in the other cities that were built within railroad rights-of-way. These projects have been able to take advantage of the existing grade of the rail line, with grade separations being achieved without a major profile change. This keeps the LRT bridges shorter and still provides for a grade-separated alignment.

In some cases, significant construction projects that directly benefited the LRT line were performed years in advance. For example, the Southwest line in Denver benefited from a number of improvements afforded by the old Interstate Transfer program when implementation of an area freeway was stopped. Funds were shifted to begin improving the Southwest Corridor that includes US-85 and the Burlington Northern Santa Fe (BNSF) north/south mainline. Over a period of 20 years, projects such as roadway overpasses at Evans Avenue and Dartmouth Avenue were built, and a mile-long depression of the railroad mainline was built through downtown Littleton. These projects reserved room for the future LRT line with minor cost-sharing by the Regional Transportation District

**TABLE 7 LRT Total Cost by Right-of-Way Type (1998 Dollars in Millions)**

Exclusive (Grade Sep) Project Location	Private At-Grade		Street Median		Reserved Lanes/Mall		Tunnel/Subway		Total Cost	Cost Per KM (MD)	Total Cost	Cost Per KM (MD)	Total Cost	Cost Per KM (MD)
	Total Cost (1998 Dollars)	Total Cost	Cost Per KM (MD)	Total Cost	Cost Per KM (MD)	Total Cost	Cost Per KM (MD)	Total Cost						
Dallas (DART)														
Starter System	\$907.2	\$181.5	\$19.3 (\$30.7)	\$118.1	\$11.7 (\$18.8)	\$101.2	\$17.1 (\$27.3)	\$169.8	\$81.6 (\$130.6)	\$336.8	\$60.0 (\$96.2)			
Northeast	\$348.6	\$348.6	\$19.5 (\$31.0)											
North Central	\$413.9	\$321.2	\$21.6 (\$34.6)	\$92.7	\$18.0 (\$28.8)									
St. Louis (BSDA)														
Starter System	\$469.5	\$210.0	\$13.4 (\$21.1)	\$169.5	\$14.3 (\$22.8)					\$90.1	\$70.4 (\$112.6)			
Illinois Extension	\$236.3			\$236.3	\$8.5 (\$13.6)									
Denver (RTD)														
Starter System	\$133.1	\$68.5	\$12.3 (\$19.6)			\$64.6	\$22.3 (\$35.9)							
Southwest Line	\$168.1	\$168.1	\$12.0 (\$19.3)											
Salt Lake City (UTA)														
Starter System	\$297.5			\$210.2	\$10.0 (\$16.1)	\$42.3	\$20.1 (\$32.5)	\$45.0	\$20.5 (\$32.2)					
Portland (Tri-Met)														
Eastside	\$353.9	NA		NA		NA		NA						
Westside	\$940.0	\$82.8	\$10.4 (\$15.4)	\$155.5	\$21.6 (\$34.6)			\$97.2	\$42.3 (\$44.2)	\$604.5	\$88.9 (\$143.9)			
Hillsboro	\$143.9			\$82.5	\$10.0 (\$15.8)	\$61.4	\$42.7 (\$68.2)							
San Diego (MTDB)														
South	\$181.6			\$159.1	\$6.7 (\$10.8)			\$22.5	\$11.8 (\$18.8)					
East - Euclid	\$46.2			\$46.2	\$6.4 (\$10.3)									
East - El Cajon	\$140.0			\$140.0	\$7.7 (\$12.4)									
East Bayside	\$58.2			\$58.2	\$24.3 (\$38.8)									
East - Santee	\$118.1			\$36.6	\$22.9 (\$28.0)									
Old Town	\$120.3			\$120.3	\$23.1 (\$37.6)	\$81.0	\$19.3 (\$31.2)							
Mission Valley, West	\$225.9	\$210.0	\$22.8 (\$41.2)	\$15.9	\$9.9 (\$15.9)									
Mission Valley, East	\$345.4	\$256.0	\$30.1 (\$48.3)							\$89.4	\$89.4 (\$149.0)			

Sources: Agency Data; BRW, Inc.

**TABLE 8 Average Cost and Standard Deviation for LRT Projects by Right-of-Way Type (1998 Dollars in Millions)**

Right-of-Way Category	Cost Per Kilometer		Cost Per Mile	
	Average	Standard Deviation	Average	Standard Deviation
Exclusive (Grade Separated)	\$17.9	\$5.1	\$29.0	\$11.1
Private, At-Grade	\$13.9	\$21.0	\$21.0	\$9.1
Street/Highway Median	\$24.3	\$10.5	\$41.0	\$18.5
Reserved Lanes/Mall	\$39.1	\$31.1	\$56.5	\$50.5
Tunnel/Subway	\$82.9	\$10.8	\$125.4	\$25.3

Source: BRW, Inc.

(RTD). This type of long-range planning, followed by careful attention to the overall plan year after year, is a very effective way to leverage funds over time.

#### *At-Grade, Private Right-of-Way*

This category contains the most projects and the most overall length. The average cost for this category is \$13.9 million/km (\$21.0 million/mi). Of the categories studied, this category had the best sample standard deviation, \$6.7 million/km (\$9.1 million/mi), which is still somewhat high.

The projects in Dallas, St. Louis, Denver, Salt Lake City, the Hillsboro Extension in Portland, and the South, Euclid and El Cajon lines in San Diego are all in former railroad rights-of-way. These projects operate within these reserved alignments with at-grade crossings. When examined as a subgroup, costs average \$10.4 million/km (\$21.0 million/mi), with a sample standard deviation of \$3.8 million/km (\$9.1 million/mi).

The segments used for the Westside project in Portland also use a former rail line for a portion, but much of the alignment is through developed areas, which required extensive coordination and reconstruction of existing facilities.

The Bayside and Old Town lines in San Diego are within railroad corridors as well. These projects are in the dense downtown Centre City of San Diego, with many existing roadways, utilities, and other features. The Bayside line required work with many new projects that were in the process of redevelopment and involved reconstruction of many utilities and other public works components along the waterfront district. The Old Town line was required to construct an underpass and an overpass of several busy arterials feeding the international airport and the harbor area. These facilities required substantial additional costs in order to implement the projects.

#### *Street/Highway Median Right-of-Way*

This category typically provides a paved track section within the right-of-way of a street. The data show a wide range of different projects, from a relatively modest project on Lancaster Avenue in Dallas to a major street reconstruction project in Hillsboro, Oregon. The sample standard deviation was found to be \$10.5 million/km (\$18.5 million/mi).

Three of the projects were close in cost per kilometer and were therefore analyzed as a subgroup: 700 South/200 West in Salt Lake City, downtown Denver, and the Santee Extension in San Diego. As a subgroup, the average cost was \$21.1 million/km (\$33.2 million/mi), with a sample standard deviation of \$1.6 million/km (\$2.4 million/mi).

The Hillsboro project is substantially more costly because of street reconstruction. This work required utility relocation, access modifications, and roadway construction. The guideway section is paved track similar to the other projects.

#### *Reserved Lanes/Transit Mall Right-of-Way*

This category also exhibits a very wide range of differences among the projects. Newer projects, such as a continuation of the street treatment in downtown Portland for the Westside line, Pacific Avenue in downtown Dallas, and Main Street in Salt Lake City, are true transit malls. Each of these projects involved reconstruction of the entire streetscape, from building face to building face. These projects also prohibit automobile traffic except for short blocks to access parking facilities or for similar uses. Substantial utility relocation and upgraded pavements were also required.

By contrast, C Street and 11th Avenue in San Diego was the first downtown LRT line constructed in the United States. This segment shares the right-of-way with automobiles on several blocks. Simple station treatments and concrete paving in the station areas characterize the streetscape.

The San Diego segment on C Street/11th Avenue appears to fit better with the types of treatments within the street right-of-way of the previous category of Street Highway Median. If the C Street/11th Avenue segment were moved to that category, the new average for that category would drop from \$22.2 million/km (\$35.7 million/mi) to \$18.4 million/km (\$29.6 million/mi). The sample variance would improve to \$4.6 million/km (\$7.5 million/mi), an improvement of \$6.1 million/km (\$9.5 million/mi).

#### *Tunnel/Subway Right-of-Way*

A wide cost difference exists for each of the tunnel projects. The North Central segment in Dallas was bored with a tunnel boring machine (TBM). The Portland Westside project also used a TBM in combination with mining techniques, with much of the alignment more than 150 ft (45.7 m) below the ground line. The St. Louis tunnel was an old railroad tunnel that was extensively refurbished and widened for the LRT line. The tunnel on the Mission Valley East line will also be bored under San Diego State University, combined with cut-and-cover in selected areas. Given this range of different projects, the correlation of costs for these projects is not possible.

#### **Comparison to Planning Estimates**

An interesting comparison is made by taking early planning level estimates and relating those estimates to actual results for some of the projects listed in Table 7. The FTA 1996 New Starts Report (3) showed the following:

- Mission Valley East, \$332 million (Systems Planning),
- St. Louis Illinois Extension, \$296 million Preliminary Engineering (PE)/Environmental Impact Statement (EIS),
- Denver Southwest, \$177 million (PE/EIS), and
- Dallas North Central, \$354 million (PE/EIS).

From Table 7, the St. Louis and Denver projects are essentially coming in at or below the estimate (adjusted to 1998 dollars). The Dallas and San Diego projects are both higher because of additional structure and station costs. The St. Louis and Denver projects are within railroad rights-of-way, which is a more stable cross section relative to unknown problems. The Dallas project is also along an abandoned railroad line for a portion of its length, but it is also adjacent to a major freeway with substantial adjacent urban development. The San Diego project is entirely on new alignment and almost 100 percent on structure or tunnel.

These projects show the wide variation of right-of-way types and the corresponding range of capital costs. Each situation is unique, and careful attention to the major differences in right-of-way type is therefore required.

## **CONCLUSIONS**

Descriptions of costs for LRT systems for specific lines or extensions usually include costs for several types of right-of-way treatments. This type of generalization can sometimes make LRT costs appear to be higher than what would actually be incurred. To obtain a more accurate indication of expected costs, planning must take into account the individual components of LRT lines and the different right-of-way types within which those lines operate.

This study has found that costs for components of LRT lines remain generally consistent for systems elements among different projects. Costs for structures and for stations will vary extensively depending on the character and policy direction of each system and agency. Some agencies will choose to spend capital funds to provide more grade separations, thus providing a potentially higher operating speed and level of service.

In other systems, the choice of the right-of-way within which the LRT line will operate can help to manage costs and provide for a high level of service. The analysis of costs for specific segments reveals reasonable comparisons among projects in similar types of rights-of-way. Data from actual projects shows that projects in four categories have some comparability:

- Exclusive (Grade Separated), where the alignment does not change profile grade extensively.
- At-Grade in Private Right-of-Way, where the alignment does not change profile grade extensively.
  - Street or Highway Median.
  - Reserved Lanes/Transit Mall.

Data from a fourth category was found not to offer any correlation among projects.

It is expected that alignments that are Exclusive/Grade Separated on structure would also be comparable among projects. However, data were not available from the projects studied for this analysis to provide these comparisons.

These types of data will be helpful in the initial planning stages of projects, before detailed information is available from actual alignment studies. It may be helpful to establish a database of information on costs by right-of-way type, and for each of the primary components of LRT lines, to provide some comparability among projects and guidance to agencies that may be considering the implementation of LRT lines.

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