Study of Alternative Transit Corridors and Systems
Prepared for Southern California Rapid Transit District

Technical Report, Part VII

System Cost

August 1973

Prepared by

Kaiser Engineers/DMJM

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CAPITAL COST ESTIMATES

One of the primary objectives of this study was to develop comparative estimates of construction costs to be used in planning Los Angeles transit requirements from alternative corridor/mode concepts. These costs therefore were used principally to compare alternative alignments within each corridor as the study program did not provide for nor warrant the preparation of comprehensive cost estimates with preliminary engineering significance. These estimates are therefore considered to be "Order-of-Magnitude" estimates only.

The cost data generated for the Total First Level System is to a large extent based on the data from prior work in the area upgraded to account for escalation. Costs of similar work in other areas of the country were also considered and where used, they were adjusted to the Los Angeles area.

The following list sets forth the assumptions used in developing the comparative costs:

Estimates are based on conceptual items for alignment, facility designs, and systems definition.

Evaluations of construction methods consider but do not include productivity changes, design innovations, and the effects of the Occupational Safety and Health Act (OSHA) or affirmative action programs for minority advancement on construction costs.

Estimates include only the MRT routes and conversion of the San Bernardino Busway to MRT.

No topographical surveys were made, and no soil borings were taken in the course of this study. Data from previous studies were used where appropriate.

Estimates have been based on steel wheel-steel rail technology.

The construction cost estimates as shown on the summary tables consist of the following:

STRUCTURES AND ROADBEDS - Includes cost of tunnels, aerial structures, special structures, earthwork, tunnel ventilation structures and equipment, retaining walls, slope protection, landscaping, necessary street work, drainage facilities, fencing, trackage, utility relocation, underpinning, and all related construction items. Yard and shop costs are also included in this category.

STATIONS - This line item is comprised of all structures and facilities required to handle passengers at points of access to the transit system including site preparation, structures, parking areas, escalators, ticketing equipment, ventilation and

air conditioning, plumbing, electrical power and lighting, landscaping and all related construction.

SUBSYSTEMS - Includes all facilities and equipment required for providing and distributing the electrical power for vehicle propulsion and all costs of electrical and electronic facilities and equipment required to operate the entire system automatically.

PROJECT MANAGEMENT, ENGINEERING DESIGN, CONSTRUCTION MANAGEMENT AND DISTRICT PRE-OPERATING EXPENSE - These costs cover project administration, detail planning, final design, preparation of construction plans and specifications, control surveying, soils investigation, construction management and inspection, general procurement and other related professional services. Also included is a factor for the District's project administration costs.

CONTINGENCY - A 20% contingency item was added to the sum of the construction costs to make allowances in cost estimates for the incomplete nature of system concepts, and route alignment, lack of data for conditions along new routes, and the unknown and unanticipated conditions of the work which are certain to develop as final detail designs are completed.

VEHICLES

The cost of the required vehicles includes base costs, taxes, delivery and installation in the system, and those costs of the control and communication equipment installed as an inherent part of each car plus an allowance for escalation.

ESCALATION

The total cost of any project is greatly affected by escalation and the compounding of escalation throughout the construction period. It therefore follows that any change in the construction schedule will affect the total project cost and will change the estimates due to cost escalation. Based upon current and historic trends, wages and prices will continue to increase. These are, however, particularly difficult to asses for projects spanning a relatively long period of time.

By definition, cost escalation generally includes the following:

- Labor escalation which is an estimate of the increases in the base wages and fringe benefits, payroll burden and also increases in costs due to changes in work assignments and working hours which are anticipated to be incurred during the engineering and construction period.

- Materials escalation is an estimate of material price increases anticipated to be incurred during the same period and is dependent upon the policies of each individual supplier as to whether or not prices for that supplier are firm or are also subject to escalation.

- Construction Equipment escalation is an estimate of the increase in ownership costs which includes not only increases in the purchase cost but cost increases for spare parts, fuel, interest rates, sales tax and maintenance.

After a careful review and analysis of these factors, the following escalation rates were selected:

Construction	9%
Right-of-way	6%
Vehicles	5%

ESTIMATED PROJECT COST

The accompanying table presents cost data for the Total First Level Mass Rapid Transit System. The cost data has been prepared on an order-of-magnitude basis for evaluation of alternative corridors and modes. The estimates therefore require additional engineering and substantiation.

ALTERNATIVE CORRIDOR & SYSTEM STUDY

TOTAL FIRST LEVEL SERVICE PROGRAM

TWELVE YEAR SCHEDULE

ESTIMATE OF COSTS ($,000)		TOTALS
1.	WAY STRUCTURES	$ 1,414,176
2.	STATIONS	624,000
3.	SUBSYSTEMS	323,208
4.	RIGHT OF WAY	289,154
5.	VEHICLES	405,132
6.	ENGINEERING, CONSTRUCTION MANAGEMENT, & OWNERS ADMINISTRATION	306,980
	TOTAL 1973 ESTIMATE	$ 3,362,650
	ESCALATION	3,279,390
	TOTAL PROJECT ESTIMATE	$ 6,642,040

OPERATIONS COST FOR MRT

The operating cost factor recommended in 1973 dollars is $1.26 per vehicle-mile. Annually, this amounts to some $80.0 x 10^6 for the "total first-level" system. For the "Phase I" system defined, the comparable annual operating cost expenditure required is $31.8 x 10^6.

To provide data base consistency, the results reported in 1968 SCRTD Final Report were used as the point-of-departure for estimating operating cost as was done in estimating capital costs where alignments and support facilities were similar. In 1968, annual operating cost, for a system needing 756 vehicles in use approximately 50,000 miles yearly, was estimated as $29,800,000, or $0.79 per vehicle-mile. It has been established by using ATA Labor Practices records for 1971 that an annual escalation of 8% compounded (a factor of 1.59 from 1 Jan. '68 to 31 Dec. '73) is reasonable but somewhat conservative. Thus, equivalent end-of-year-1973 operating cost factor, as re-evaluated, is $1.26 per vehicle-mile for the Los Angeles Metropolitan Area regional rapid transit system.

The estimate of annual miles per vehicle assumes an overall average speed of 40 mph, 4-hour peak periods per day, 33-1/3% vehicle utilization during off-peak, 25% vehicle utilization during weekends, and no account for holidays. As re-evaluated, annual miles per vehicle is estimated as 60,000 on this basis. Source information for likely vehicle usage as a function of time and type of day was provided by AMV during the latter part of this study.

In estimating system capital cost, which preceded Task II E-Plan Refinement, it was calculated that 1056 vehicles for the "total first-level" system and 420 vehicles for the "Phase I" system would be needed, based on a specifically assumed operating plan and generalized estimate of average-vehicle speed aggregated over annual usage. These same vehicle fleet requirements were used for estimating annual operating cost in end-1973 dollars. It should be recognized that, depending on the operating plan finally selected, these fleet requirements are subject to readjustment.

The operating cost componene s included in the dollars-per-vehicle-mile factor are as follows:

Maintenance of Way - This category includes the expenses of maintaining fixed facilities such as subways, aerial structures, tracks, stations, electrical and control equipment, power systems, fare collection equipment, escalators, landscaping, fencing and parking lots.

Maintenance of Equipment - This category includes expenses of maintaining, inspecting, repairing and cleaning of rolling stock.

Power - This category includes the expense of providing traction power for the propulsion of the cars and auxiliary power for station illumination and operation of machinery. such as escalators, fans, pumps and other power equipment.

Labor & Material - This category includes the wages of the train attendants, station attendants, porters, platform men and other personnel and material directly associated with train operation.

General and Administrative Expense - This category includes the administrative personnel required in such functions as accounting, purchasing, scheduling, personnel, etc. that will be added to the District's present staff as a result of the rapid transit system; insurance expenses including liability and property damage insurance; employee benefits for rapid transit employees; and other administrative expenses.

Damages - This component has not been estimated separately since there exists no local history for a comparable operating system.

Allocation of operating cost by component has been estimated and is shown on the accompanying figure. This allocation varies significantly as can be seen by comparison with the experience of other operating properties. Factors which probably account for such variations are extent of on-going rennovations and rehabilitation, age of facilities and equipment, local cost of power, geographic differences in labor rates and material costs, type of system (e.g. SWVS or RTVS), nature of organizational structure, and manner of cost accounting.

Considerable effort has been expended, without success, to obtain similar information for the BARTD system because it was judged most representative of an up-to-date system. It was learned only that operating cost is expected to be "....in excess of $1.00 per vehicle-mile but less than the experience of NYCTA and CTA". Additionally, based on FY '73-'74 budget estimates, total staff requirements are expected to range between 3:1 and 4:1 people per vehicle in the system fleet. Energy consumption is expected to be in the range of 6.0 to 8.0 kilowatt-hours per vehicle mile.

On the basis of system definition and available data, it is concluded that the 1973 annual operating cost values estimated by system stage for the Los Angeles Metropolitan Area regional rapid transit system are realistic.

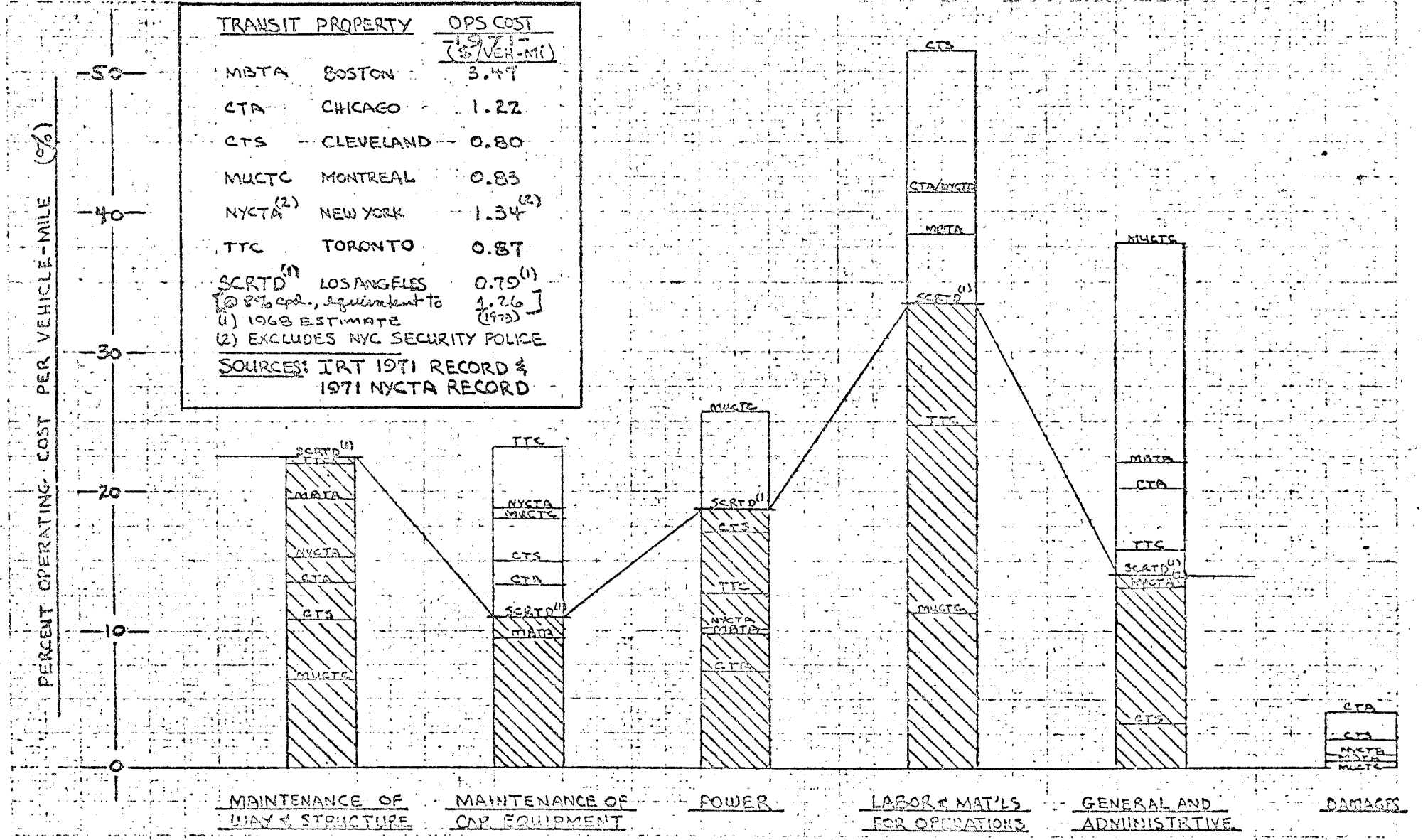
RANGES OF O&M COST COMPONENTS

(excludes debt service, depreciation, and taxes)

TRANSIT PROPERTY		OPS COST 1971 ($/VEH-MI)
MBTA	BOSTON	3.47
CTA	CHICAGO	1.22
CTS	CLEVELAND	0.80
MUCTC	MONTREAL	0.83
NYCTA(2)	NEW YORK	1.34(2)
TTC	TORONTO	0.87
SCRTD(1)	LOS ANGELES	0.79(1)
[@ 8% cpd., equivalent to		1.26 (1973)]

(1) 1968 ESTIMATE
(2) EXCLUDES NYC SECURITY POLICE

SOURCES: IRT 1971 RECORD & 1971 NYCTA RECORD



OPERATING AND MAINTENANCE (O&M) COST COMPONENTS

KE/DWJM
6/73

BUSWAY SYSTEMS

Capital Costs

There were estimated in a similar fashion to those of the Mass Rapid Transit System. There were, however, a few exceptions. The right-of-way was assumed to be publically owned with the exception of stations and storage and maintenance facilities, which are included. Also, no allowance for escalation was included as this is dependent upon the freeway construction schedule which is administered and controlled by the California Division of Highways. The following table summarizes these costs.

BUSWAY COSTS

Construction	$ 108,000,000
Engineering and Construction Management	16,190,000
Right-of-Way (Stations and Yards Only)	11,000,000
Vehicles	5,850,000
Total	$ 141,040,000

Construction concurrent with freeway construction.

CONSTRUCTION SCHEDULE AND STAGING

Construction Schedule

Actual commencement of the detailed design and construction will follow the completion of several prerequisite steps which include adoption of a long range transportation program, preliminary engineering design and cost estimates of the adopted transit system, and voter approval of the project financing. Meaningful construction could commence within two years after funding approval with the total system taking approximately twelve years to complete. Revenue service can, however, start on certain lines prior to the completion of the total system.

The following list sets forth the assumptions used in preparing the schedule:

An adequate labor force would be available

No provisions were made for construction delays due to strikes, material shortages, etc.

Other major transit projects would have no effect on the Los Angeles project

Program start assumes completion of preliminary engineering and firm funding

No delay due to court actions and citizen suits

ROW acquisition precedes with sufficient lead time over construction

Environmental impact statements completed and accepted.

Construction Staging

The sequence of construction to permit an orderly completion of the project is as follows:

CBD corridor from Union Station to Exposition Park Station and from the interchange at 8th and Olive to Alvarado Station

South Central corridor from Exposition Park Station to Compton Station and Dominguez Yard

Wilshire corridor from Alvarado Station to interchange at Wilshire Boulevard and La Brea Avenue

San Fernando Valley Corridor from Wilshire/La Brea interchange to North Hollywood Station

Southwest Corridor from Wilshire/La Brea interchange to LAX Station (Aviation Boulevard/Imperial Highway)

South Central corridor from Compton/Dominguez Yard to Long Beach

Wilshire corridor from Wilshire/La Brea interchange to Century City

San Fernando Valley corridor from North Hollywood to Canoga Park

Southwest Corridor from LAX Station to Del Amo Station (Hawthorne Blvd./Carson St.)

Santa Ana Corridor from Civic Center to the County Line

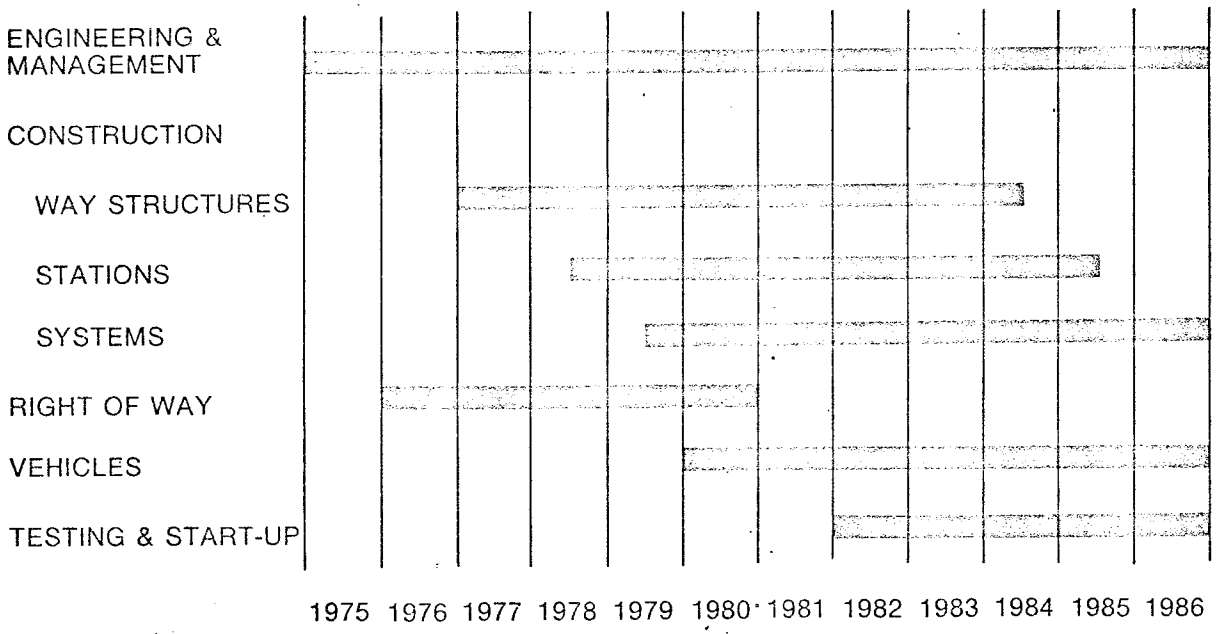
Wilshire Corridor from Century City to Santa Monica

San Gabriel Valley Corridor from Union Station to El Monte

El Segundo-Norwalk Freeway Corridor from LAX Station to Santa Ana corridor junction

The order of construction will permit completion of the system phases which will be in operationally useful segments. The South Central corridor segment to Compton/Dominguez Yard will allow testing and checkout of equipment and systems, training of operating personnel, and storage of operating equipment. The remaining sequence will permit operation of service to areas with greatest potential of patrons.

The size, complexity and interrelated features of a project of this magnitude demand a sophisticated method for developing and controlling the work from start to finish. This scheduling will require development in the form of a network (PERT, CPM, Precedence Diagraming, etc.) set up for use on a computer. Basic divisions should include field surveys/investigation, right-of-way acquisition, detailed design, preparation of contract documents, construction, and testing of equipment and operational systems. This type of program provides distribution and control of scheduling, and manpower and cash flow requirements of both design and construction phases of the program.



Construction Schedules

The aerial way structures, the subways system, and the stations are primary concerns since the construction of these facilities will have a major impact on the community and the general public during the construction period. The design of these facilities requires careful attention to achieve the established design objectives with minimum disruption to the community during construction. This can be accomplished by closely correlating the design with construction elements. This takes into consideration subsurface conditions, interference with existing utilities, and interference with and disruption of existing surface improvements and their use.

For construction of aerial way structures, it can be established that the use of pre-cast concrete girders will offer favorable aesthetic and structural design features, and in addition, it would be the least disruptive to the community during construction. Girders would be fabricated in a central casting yard which would normally be located in an aera zoned for heavy manufacturing. The pre-cast girders would then be transported to the construction site and quickly erected on the support columns. This method is efficient in terms of both cost and time and would drastically reduce the costly and unsightly construction of concrete forms and shoring, the disruption of smooth traffic flows in nearby streets, the inherent noise of construction operations, and the continuous flow of heavy trucks hauling concrete and reinforcing steel.

Subway tunnels would be designed as a twin tube system which is the most suitable for the subsurface conditions encountered. For the soil conditions generally encountered in the Los Angeles area, the use of tunneling shields or mining machines is a feasible, safe, and economical construction method. During detailed design, each section would be carefully analyzed to determine the proper type of construction to be used in order to utilize the least expensive methods. In some cases, it may be advantageous to call for alternate bids for cut and cover versus tunnel; cast in place concrete lining versus steel liner plate; horseshoe versus circular tunnel section; or other similar variable construction methods.

In the construction of subway stations, the cut and cover method is the most feasible in the type of subsurface soil conditions to be encountered. The construction procedure most commonly consists of first excavating one-half of the longitudinal section of the station to a depth required to continue operating the equipment when the excavation is decked over. This will permit one-half of the street to be decked over at all times for maintaining traffic flow. When the second half has been excavated and decked over, the street will be opened to its full width except for an area required to operate surface construction equipment. By the use of this method, subway stations can be constructed with minimum disruption of traffic flow and business activities.

ALTERNATIVE CORRIDOR AND SYSTEM STUDY

FOR THE

SOUTHERN CALIFORNIA RAPID TRANSIT DISTRICT

COST ESCALATION REPORT

April 1973

Kaiser Engineers/DMJM

DISCUSSION

Previously, escalation studies titled "Report on Cost Escalation, September 1967" and "Supplementary Report on Cost Escalation, February 1968" were prepared for the Southern California Rapid Transit District. The purpose of this study is to up-date these reports reflecting recent cost experience in order to allow forecasting of future construction cost trends.

The Los Angeles Rapid Transit Cost Index developed in the February 1968 report has been evaluated for December 1970 and March 1973. Exhibit 3 tabulates the various cost components of these evaluations as well as the four previous evaluations.

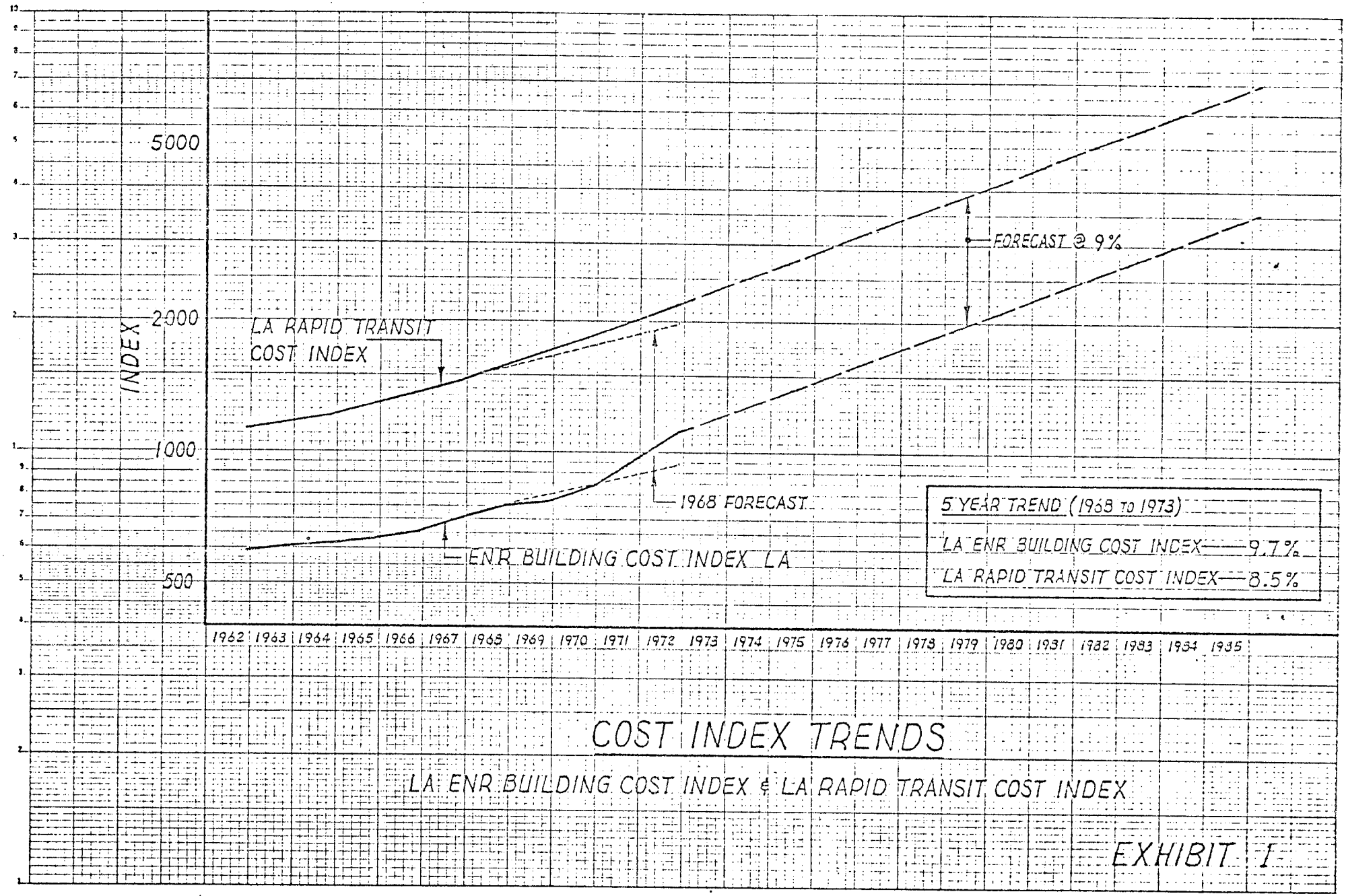
Exhibit 2 compares the Los Angeles Rapid Transit Cost Index with the Engineering News Record Building and Construction Cost Indices, both national and local. A review of the compounded annual increases reveals a dramatic increase in escalation rate has occurred in the last five years.

Exhibit 1 is a graphical plot of the Los Angeles Rapid Transit Cost Index, and the Los Angeles ENR Building Cost Index (the ENR Index considered most applicable to Los Angeles transit construction). As noted, the 5 year trends 1968 to 1973 are as follows:

L.A. Rapid Transit Cost Index	8.5% per year
L.A. ENR Building Cost Index	9.7% per year

After careful review of this study, particularly the L.A. Rapid Transit Cost Index, and considering the probable construction period, we recommend an escalation factor of 9% per year for determining the cost of future construction. This assumes the trend of the last 5 years will continue through the duration of the project. Some may say we are about to turn the corner and reduce the inflation rate but there seems to be little evidence to substantiate it. On the other hand, it could be pointed out that the 2 year trend for the Los Angeles Rapid Transit Cost Index is almost 10% per year and that high and possibly increasing escalation may be here to stay.

This escalation study does not take into consideration changes in craft labor productivity, design innovations, improved construction techniques or changes in statutory requirements.



COST INDEX TRENDS

LA ENR BUILDING COST INDEX & LA RAPID TRANSIT COST INDEX

EXHIBIT 1

EXHIBIT 2

ENGINEERING NEWS RECORD INDICES AND LOS ANGELES RAPID TRANSIT COST INDEX COMPARISON

DATE	LA RAPID TRANSIT COST INDEX		LA AREA ENR CONSTRUCTION COST INDEX		ENR CONSTRUCTION COST INDEX		LA AREA ENR BUILDING COST INDEX		ENR BUILDING COST INDEX	
	INDEX(1)	% PER YEAR(2)	INDEX	% PER YEAR	INDEX	% PER YEAR	INDEX	% PER YEAR	INDEX	% PER YEAR
December 1957	1000		778		738		513		516	
December 1958		2.4	824	5.9	774	4.9	530	3.3	535	3.7
December 1959		2.4	868	5.3	807	4.3	554	4.5	553	3.4
December 1960		2.4	901	3.8	831	3.0	561	1.3	562	1.6
December 1961		2.4	940	4.3	855	2.8	579	3.2	570	1.4
December 1962	1125	2.4	966	2.8	880	2.9	595	2.8	584	2.5
December 1963		3.9	991	2.6	915	4.0	614	3.2	603	3.3
December 1964	1215	3.9	1017	2.6	948	3.6	625	1.8	617	2.3
December 1965		6.8	1068	5.0	988	4.2	635	1.6	634	2.8
December 1966		6.8	1135	6.3	1038	5.1	662	4.3	658	3.8
December 1967	1481	6.8	1203	6.0	1103	6.3	708	6.9	690	4.9
December 1968		7.5	1274	5.9	1201	8.9	755	6.6	754	9.3
December 1969		7.5	1309	2.8	1306	8.7	775	2.6	802	6.4
December 1970	1842	7.5	1482	13.2	1445	10.6	841	8.5	866	8.0
December 1971		9.9	1704	15.0	1655	14.5	965	14.7	993	14.7
December 1972		9.9	1966	15.4	1807	9.2	1138	17.9	1086	9.4
March 1973	2279	9.9	1979	2.6	1859	11.5	1151	4.6	1123	13.6

Note 1: 1957 cost arbitrarily set at 1000.
Only points actually computed are shown.
2: % per year is averaged between computed points.

EXHIBIT 3

LOS ANGELES RAPID TRANSIT COST INDEX

Item	December 1957 Cost	December 1962 Cost	December 1964 Cost	December 1967 Cost(1)	December 1970 Cost	March 1973 Cost
LABOR						
Tunnel Labor	13,296	17,041	19,645	23,100	29,130	40,790
Common Labor	31,871	40,854	43,637	49,282	63,440	82,230
Operating Engineer	29,262	36,870	41,508	47,437	63,250	77,960
Teamster	15,784	19,705	22,590	26,969	33,660	41,770
Electrician	31,253	39,066	42,557	44,369	56,600	75,040
Carpenter & Miscellaneous	30,396	37,109	40,809	45,367	60,420	70,990
Subtotal:						
Payroll Taxes & Insurance	Incl w/crafts	Incl w/crafts	Incl w/crafts	34,245	42,730	56,550
Total: Labor	$151,862	$190,645	$210,746	$270,769	$349,230	$445,330
CONSTRUCTION PLANT AND EQUIPMENT	50,000	52,899	59,446	73,000	85,140	89,550
CONSTRUCTION MATERIALS						
Electrical	38,713	38,713	42,650	50,327	69,900	87,690
Tunnel Liner	35,100	35,100	35,694	42,120	52,320	65,400
Structural Steel	27,941	26,073	25,286	28,472	34,030	37,920
Reinforcing Steel	14,494	14,494	14,944	19,712	18,630	19,020
Cement	7,222	5,896	6,047	6,120	6,990	8,750
Lumber	3,132	2,812	2,844	3,163	3,180	6,630
Equipment Parts	3,333	3,333	3,540	4,000	4,670	4,920
Fuel	719	719	800	1,000	1,220	1,670
Concrete Pipe	1,311	1,527	1,527	2,000	2,260	2,870
Small Tools & Consumables	9,228	10,980	11,601	13,538	15,840	16,650
Miscellaneous Construction Invoice	60,127	71,550	75,983	85,861	104,750	143,390
Total: Material	$201,320	$211,197	$220,916	$256,313	$313,790	$394,960
PERMANENT EQUIPMENT	17,424	18,548	20,105	23,000	26,400	28,660
TOTAL DIRECT COST	$420,606	$473,289	$511,213	$623,082	$774,560	$958,540
LA RAPID TRANSIT COST INDEX	1000	1125	1215	1481	1842	2279

Note 1 December 1967 cost is the base and is from SCRTD Estimate of 9-1-67
2 All costs in thousands of dollars