Trolley Bus and Motor Coach Operational Cost Comparisons Utilizing Section 15 Data

D. DUNOYE AND W. DIEWALD

An examination of the costs of operating and maintaining trolley buses and motor coaches in Dayton, Ohio, is presented. The cost comparisons used the Section 15 data submittal prepared by the Miami Valley Regional Transit Authority (MVRTA) for 1984. Cost-allocation assumptions for joint expense items are detailed. The analyses indicate that the trolley bus costs more to operate and maintain in Dayton than the motor coach in terms of dollars per vehicle mile. Optional scenarios for the future trolley bus and motor coach systems were developed in view of the current need to replace the existing trolley buses, the power distribution system, and the overhead system. Consideration was also given to the potential changes in future UMTA capital grants and operating assistance programs and the impacts that these changes can have on the ability of the MVRTA to pay for all the currently needed capital improvements and future operating and maintenance costs.

Trolley buses have operated in Dayton, Ohio, since 1933 when the Dayton Street Railway Company introduced Dayton's first trackless trolley coaches (*1*). Currently the Miami Valley Regional Transit Authority (MVRTA) operates 65 trolley buses under 132 mi of one-way overhead on nine routes.

Dayton is one of five U.S. cities and one of eight North American cities with a trolley bus operation. There are many such systems in Europe and Asia, but trolley bus operations in the United States have declined since their zenith in about 1950. At that time there were more than 3,000 "trackless trolleys" (*2*).

It is generally accepted that trolley bus operations are highly advantageous when one or more of the following factors prevail:

1. There is an inexpensive source of electric power,
2. The bus system operates in hilly terrain, or
3. There are stable, high-density travel corridors that can be served by transit.

With one exception, the trolley bus operations in the United States can point to these factors in one combination or another as the bases for their operation. These factors, however, are not in evidence in Dayton.

D. Dunoye, Division of Transport, S. A. Matra, Taipei, Taiwan, W. Diewald, Office of Technology Assessment, Washington, D.C. 20510-8025.

Data comparisons of North American and European trolley bus systems portray Dayton in a similar light. For example, Figure 1 shows the ratio of miles of overhead wire per trolley bus for the North American systems and a group of European systems. Dayton stands out as the only trolley bus system with a value greater than 2. Another factor of comparison is the overhead utilization ratio or the ratio of feet of one-way overhead wire to feet of vehicle as shown in Figure 2. As can be seen, the European systems are very consistent in terms of this ratio, whereas the North American systems are widely dispersed; Dayton has the highest ratio, a value of 272.

There is a vocal pro-trolley faction in Dayton that has succeeded in the past in countering any attempts to reduce or remove trolley bus operations. The proponents promote the "tasteful eloquence" of the "graceful, quiet, pollution-free vehicle." City Transit, the original transit operator, has successfully resisted numerous attempts to abandon trolleys (*1*). There is a belief that the trolleys have a uniqueness that percolates to a uniqueness in the city itself. The pro-trolley sentiment often surfaces in the press. An article about a study showing no significant difference in measurable air pollution between trolley buses and motor coaches was headlined "Diesel Bus Emissions Bigger Health Threat, Study Says" (*3*).

The problems with the current Dayton system actually stem from the earlier success of City Transit in retaining trolley operations during an era of general trolley decline in the United States. City Transit purchased vehicles and, in particular, overhead at bargain prices from systems that were phasing out trolleys, so that they were able to extend trolley service for much less than if new equipment had been used (*1*). Now, however, there is a need to either abandon the trolley service or completely replace the hodgepodge of overhead hardware, much of which is obsolete. In addition, the trolley buses (TBs), which are actually modified motor coach (MC) equipment, are deteriorating much faster than anticipated and will have to be replaced before they are 12 years old at a cost currently estimated to be 40 to 60 percent greater than that of an MC.

Thus in January 1986, the MVRTA sought technical assistance regarding the future of its TB system and certain technical aspects of the TB operation.

MVRTA staff had been asked by their Board to examine possible future options for its TB and MC operations, particularly in view of Reagan Administration plans to dismantle

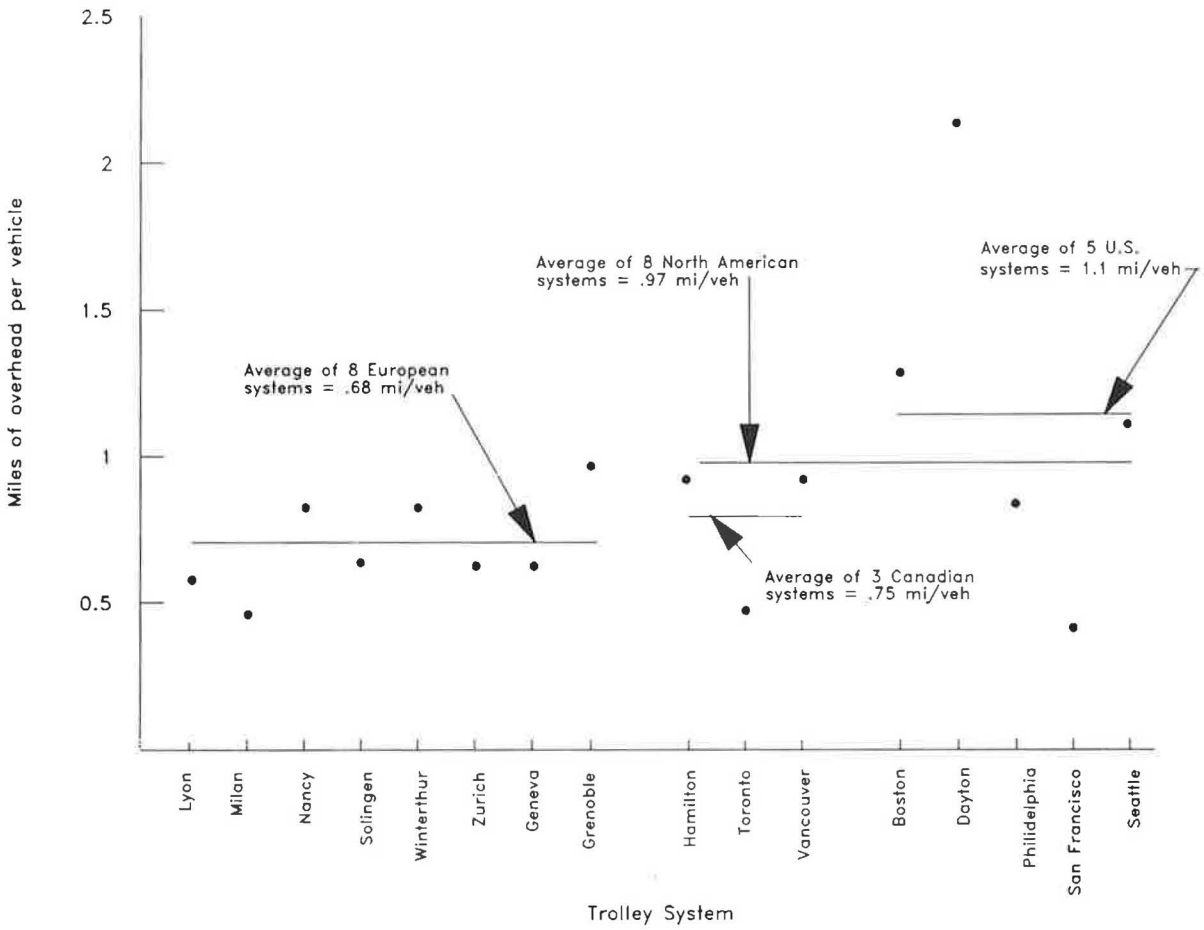

FIGURE 1 Ratio of miles of overhead wire per trolley bus.

the current UMTA operating assistance program and to reduce and reorganize capital funding programs. A contract was let to conduct a study originally designed to focus on technology and the options provided by advanced TB equipment and overhead and to examine how the MVRTA TB system could be optimally configured to meet local transit goals within existing and future financial constraints. As the study progressed it became clear that although advanced technology provides considerable options for both TB and MC, the overriding consideration for the future of the TB system is a financial one and that this needed to be accurately presented to the Board.

BACKGROUND INFORMATION

The study took into account the following basic information regarding the local transit system:

1. The MVRTA system currently consists of combined TB and MC operations.
2. The TB and MC operations are not independent; that is, there is considerable overlap of the TB and MC routes.
3. The TBs are deteriorating faster than anticipated. In the past a TB was assumed to have a useful life of 20 to 25 years, which compensates for its initial higher cost than that of an MC (useful life, 12 years). A 20-year life is appropriate for equipment designed and engineered as TBs. It does not apply to TBs that are in fact modified MCs. MVRTA TBs, which are modified MCs, will have to be replaced before they are 12 years old at a cost that is 40 to 60 percent greater than that of an MC.
4. The TB overhead is being refurbished by MVRTA because it is quite old and badly deteriorated.
5. The TB power distribution system (PDS) will, in the near future, be operated and maintained by MVRTA because the current operator, Dayton Power and Light (DP&L), no longer wants to supply the needed dc power. Much of the PDS needs to be replaced, and a plan has been developed for completely rebuilding it; the work will be under way soon.

From this information it is apparent that MVRTA is currently in the position of purchasing a completely new TB system (i.e., TBs, overhead, and a PDS owned and operated by MVRTA). It is therefore important to examine all possible options regarding the future TB and MC systems that it will operate; the MVRTA board must make a build or no-build decision. (The no-build option involves removal of the overhead, dismantling of the PDS, and divestiture of the TBs.)

Compounding the problem is the current UMTA capital grants program, which includes formula funds for fixed-guideway transit, including trolley bus operations. Thus, MVRTA currently receives an annual appropriation of about $6 million because it has a trolley bus system.

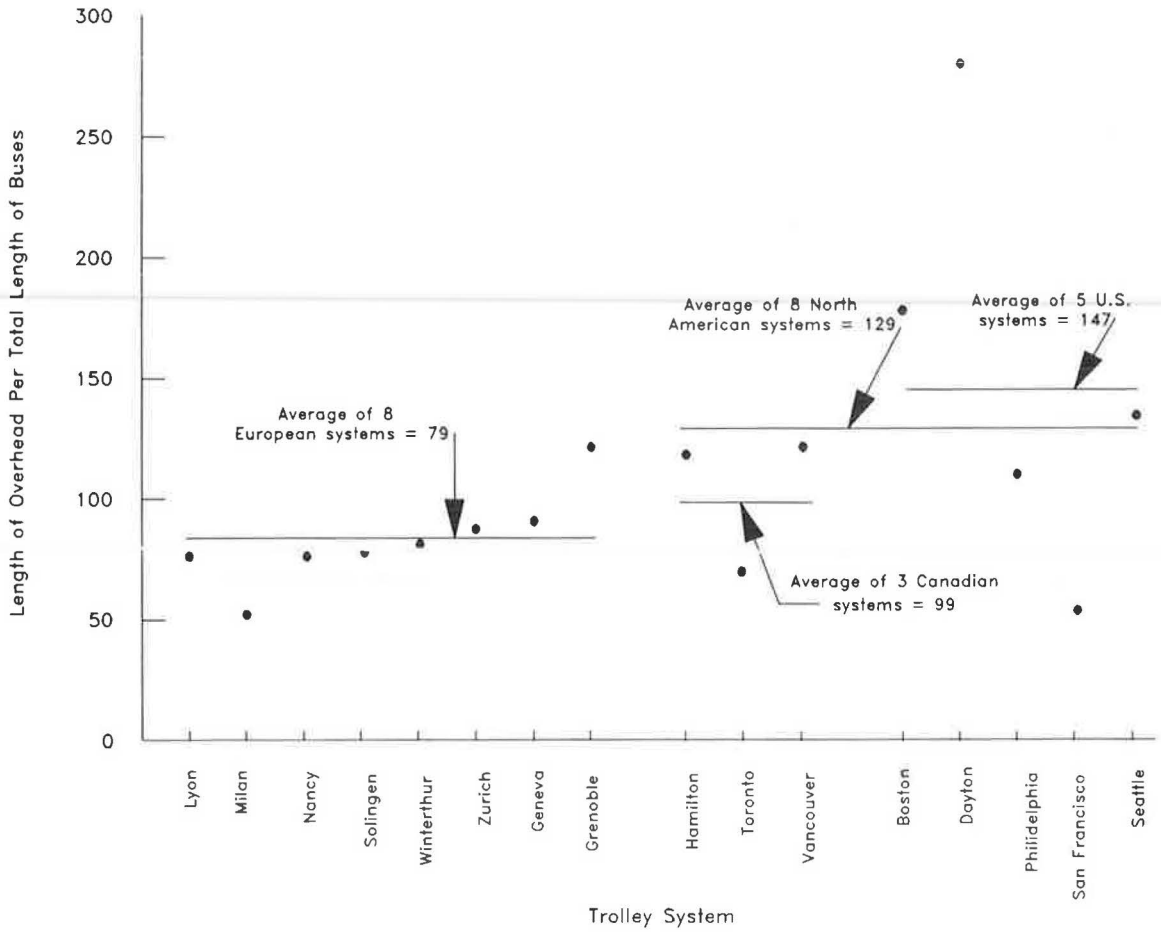

FIGURE 2 Ratio of length of overhead wire to length of trolley bus.

INITIAL APPROACH

The initial study scope involved the following steps:

1. Identify a set of feasible TB/MC system alternatives,
2. Estimate the costs of these alternatives,
3. Examine future funding scenarios, and
4. Determine the impact of each funding scenario on each system alternative with particular reference to the local fiscal responsibility.

Preliminary discussions with MVRTA staff regarding TB route changes or consolidations, or both, revealed that (a) there are no major route changes that can be made solely on the basis of service-level improvements and (b) route consolidations, without total elimination of some routes, do not have a major impact on the extent of the TB overhead network.

Further, even if MVRTA replaces the TBs, the overhead, and the PDS, UMTA funding may not continue at existing levels to support this commitment. The TBs have an expected useful life of 15 years; the overhead and the PDS have an expected useful life of 40 years. As a consequence, the technical considerations must be viewed in the context of future federal capital funding reductions and the potential need for increased local funding to make up for potential capital shortfalls.

Therefore, the issue for MVRTA is not one of simply identifying TB system alternatives but, more importantly, determining the cost implications of these alternatives, especially those that will encumber future MVRTA funds. A major aspect of the cost implications is the actual operating and maintenance (O&M) costs of the TB and the MC systems; moreover, there was considerable disagreement in Dayton regarding these costs.

As a result a decision was made to focus on developing detailed cost estimates and examining the cost implications of a selected set of alternative system configurations based on MVRTA data and reports. Particular emphasis was given to estimating the O&M costs for both the TB and MC systems.

Selecting Alternative System Configurations

There are a large number of potential TB/MC system options that can be examined, particularly from the standpoint of operations. However, in view of time and resource limitations

and because it was determined that a small number of alternatives would provide adequate representative information, five alternative system configurations were defined and examined. These are status quo, all-diesel (MC) system, consolidated diesel (MC) system, state-of-the-art consolidated trolley bus system, and a state-of-the-art trolley bus system replicating the existing system. These will be described in more detail.

Alternative 1: Status Quo

For the status quo alternative the existing TB/MC system would continue to operate. In particular, MC vehicles would be as currently configured; TB vehicles would be standard vehicles with solid-state control and auxiliary power units; the total fleet size would not change.

The overhead network would remain the same; MVRTA would proceed with its refurbishment program, aimed at replacing the entire overhead equipment over the next 40 years. MVRTA would also proceed with the installation and operation of the PDS currently being proposed.

Alternative 2: All Diesel

For the all-diesel alternative the TBs would be eliminated and the overhead system removed; the TBs would be replaced by an equal number of MCs. This one-for-one replacement does not take into account the existing route or equipment duplication. Elimination of the TB system would require reimbursement of funds to UMTA as well, because the TBs have not reached their design life.

Alternative 3: Consolidated Diesel System

The consolidated diesel system is similar to the system under Alternative 2 but includes a reduction of the MC fleet, which can be brought about because of the current duplication between TB and MC routes and equipment.

Alternative 4: State-of-the-Art Consolidated TB System

The consolidated system with state-of-the-art trolley bus equipment includes a reduction of the TB overhead network to include only those routes judged by MVRTA staff and the consultants to have enough traffic to justify TB operation. The reduced overhead would be totally rebuilt using state-of-the-art technology. The PDS rebuilding plan would be modified to take into account the reduced TB system. Dual-propulsion vehicles would be obtained to maximize the use of the reduced overhead system. The size of the new fleet would be optimized to take advantage of the consolidation of the routes.

Alternative 5: State-of-the-Art Full TB-MC System

The state-of-the-art full TB system would not change the existing TB network. The overhead and PDS would be totally rebuilt over a 5-year period with state-of-the-art technology. The vehicles would be replaced with a chopperless trolley similar to the E.H.M. Developed by BBC in Switzerland.

Table 1 provides a summary of the details for each of the five feasible alternatives.

Costing the Alternatives

O&M Costs

O&M costs were obtained using the MVRTA 1984 Section 15 data submittal (not the UMTA Section 15 report). These data are prepared annually by transit authorities that receive federal assistance and provide a wealth of information. The costs by category were entered onto a spreadsheet template so that allocations for joint expenses and estimates of the alternative scenarios could be made easily. The completed spreadsheet also provides a simple and quick means for assessing the sensitivity of allocation assumptions as well as potential changes in individual cost items.

Costs were calculated per revenue hour and per revenue mile. In the case of joint expenses reported by MVRTA in the Section 15 data submittal, allocation estimates were based as follows:

1. In general, joint expenses were divided on the basis of annual revenue vehicle hours, which yield a factor of 0.37 for trolley bus and 0.59 for motor coach; the balance of vehicle hours is dial-a-ride service.
2. Expenses in the General Function and General Administration categories were divided between operations and maintenance on the basis of Section 15 data: 70/30 for trolley buses and 78/22 for motor coaches. They were then divided according to item 1 above.
3. Servicing and fuel for service vehicles in the Expenses category were divided 80/20 (trolley bus/motor coach).
4. Maintenance of buildings and grounds in the Expenses category was divided 50/50 (trolley bus/motor coach).

Alternative 1: Status Quo Analysis of the MVRTA Section 15 data indicated that on a per-revenue-hour basis the TB costs slightly more to operate than the MC ($40.85 versus $40.21); on a per-revenue-mile basis the cost is $3.73 versus $2.80. For this study the number of revenue operating hours for both systems was assumed to be at the 1985 level: 191,108 hr for the TB system and 307,166 hr for the MC system.

It should be pointed out that the MC fleet had an average age of 8.5 years and the TB fleet had an average age of 7 years in 1984. The fleet size is assumed to be 133 MCs and 65 TBs. Also, MVRTA has a higher-than-average spare ratio for MCs because spare MCs are required to provide tripper and back-up service on TB routes.

Alternative 2: All Diesel For Alternative 2 the O&M costs were calculated using the 1984 Section 15 data as a base with

TABLE 1 ALTERNATIVE SERVICE AND OPERATING SCENARIOS

	BUS EQUIPMENT	TROLLEY OVERHEAD	POWER DISTRIBUTION SYSTEM	NON-REVENUE VEHICLES
1. Status Quo	133 MC; 65 TB (New TBs to be purchased as planned)	Refurbished as per current plans.	Total rebuild with state of the art equipment	Same as 1985
2. All Diesel Fleet	198 MC; one to one replacement of TBs	Completely removed	Completely removed	Reduced by 75%
3. Consolidated Diesel System	193 MC; reduction due to duplication of services	Completely removed	Completely removed	Reduced by 75%
4. Consolidated Trolley Bus (with State-of-the-Art Equipment) and MC System	146 MC; 47 TB	Reduced overhead to 55 mi.; rebuild over 5-year period	Total rebuild of reduced (50%) system with state-of-the-art equipment	Reduced by 50%
5. Full Trolley Bus (with State-of-the-Art Equipment) and MC System	133 MC; 65 TB Use chopperless TBs	Rebuild entire system over a 5-year period with state-of-the-art equipment	Total rebuild with state-of-the-art equipment	Reduced by 50%

Note 1: Maintenance facility requirements are assumed to remain the same.

Note 2: O&M staff changes have not been estimated directly. However, in estimating O&M costs pro rata O&M changes were assumed as a result of changes in service.

adjustments to represent the actual cost of MC and TB operation more accurately. The adjustments are needed because of certain anomalies at MVRTA that have the effect of weighting O&M costs in one direction or another. For example, the pick process for operator job selection affects operating costs because senior operators tend to choose the MCs and MC routes over the TBs, resulting in a disproportionately higher labor cost for the MC system. The net effect of normalizing these costs was the lowering of the O&M costs on a per-revenue-hour basis. In an all-diesel system the O&M cost per revenue hour of service is estimated at $38.73. This estimate is generally conservative because it does not take into account any potential savings from an optimization of an all-diesel system by route consolidations and reduction of the fleet size. The total fleet is assumed to be 198 MCs. In this alternative the number of operating hours was assumed to be the same as the total for MC and TB operations in Alternative 1 (498,274 hr).

Alternative 3: Consolidated Diesel System This alternative assumes an all-diesel system, but with fewer MCs than Alternative 2. Duplication inherent in the existing TB and MC system is eliminated. Again, Section 15 data form the basis for O&M cost estimation for this alternative. The MC fleet size is reduced to 193 vehicles and the total number of operating hours is reduced to 469,399 hours.

Alternative 4: State-of-the-Art Consolidated TB System For the state-of-the-art consolidated TB system it was assumed that consolidation would have the following results:

1. Total number of revenue vehicle hours would be 349,403 for MC and 146,946 for TB.
2. Total fleet would consist of 146 MCs (includes 20 percent spares) and 47 dual-propulsion TBs (includes 20 percent spares). Vehicles are all assumed to have wheelchair lifts and air conditioning.
3. Fuel consumption would be 4.21 mpg for MCs and 4.13 kW-hr/veh-mi for TBs. This assumes no change in energy consumption from current levels, even though the air conditioning unit has been added. It was assumed that the energy saved through a solid-state control system would be equivalent to the air conditioning energy consumption.
4. Average speed would be 14 mph for MCs and 11 mph for TBs.
5. Overhead would consist of 55 mi of one-way wire.

Alternative 5: State-of-the-Art Full TB-MC System Alternative 5 combines the existing overhead network, fleet size, and route scheme with the state-of-the-art equipment assumed for Alternative 4. O&M costs were estimated using appropriate information from Alternatives 1 and 4.

Table 2 summarizes the O&M costs for each alternative using 1986 dollars.

Capital Costs

The vehicles are all assumed to be equipped with air conditioning and wheelchair lifts. MC costs are assumed to be $160,000 per vehicle based on recent bid data. TB costs are assumed to be $246,000 per vehicle based on a recent 10-vehicle bid to MVRTA. A state-of-the-art trolley equipped with an alternative power unit (APU) is assumed to cost $221,400 based on manufacturer's data. A dual-propulsion vehicle was estimated at $261,130 for a 47-vehicle order based on a manufacturer's quote for a 100-vehicle order.

For the PDS, the full system 1986 overhead network cost is assumed to be $10,720,000 according to the engineer's estimate from MVRTA. The reduced (consolidated) system cost is assumed to be $4,500,000 (on a pro rata basis).

Based on data supplied by MVRTA the overhead cost per one-way mile is assumed to be $138,993 when installed by MVRTA and $155,693 when installed by a contractor. It should be noted that these estimates are low when compared with similar programs in other cities. For example, in San Francisco, 5.3 mi of overhead refurbishment cost an average of $334,500

TABLE 2 O&M COST PER ALTERNATIVE

	TROLLEY BUS		DIESEL BUS	
ALTERNATIVE	$/veh-mi	$/hr	$/veh-mi	$/hr
1	4.00	43.76	3.00	43.07
2			2.97	41.49
3			2.88	40.36
4	4.41	48.54	2.88	40.36
5	4.00	43.76	3.00	43.07

per one-way mile; in Seattle, a recent bid for 1.7 one-way mi of downtown rerouting ranged between $405,000 and $700,000 per one-way mile. Nonetheless, the lower MVRTA estimate was used for Alternative 1. For Alternatives 4 and 5, the cost of overhead replacement was assumed to be $350,000 per one-way mile.

The other capital expenses were based on capital expenditure projections from MVRTA and the estimated life of the equipment; they are assumed to be $555,000 per year.

Each alternative was costed and the net present value was computed assuming a 3.5 percent inflation rate and a 5 percent interest rate. With regard to equipment life span, MCs were assumed to last 12 years; TBs, 15 years; a PDS substation, 40 years; and the overhead, 40 years. A service vehicle for the trolley system was assumed to have a life of 6 years. The vehicle replacement schedules were determined for each alternative taking into account the current age and condition of the existing fleet.

The total cost (in 1986 dollars) of each alternative on an annual basis is as follows:

Alternative	*Amount ($)*	*Percent Above Lowest-Cost Alternative*
1	44,708,000	13
2	40,979,600	4
3	39,554,000	0
4	45,352,600	15
5	44,883,300	13

On a systemwide level, the TB costs more than the MC. The range varies between 13 and 15 percent; an examination of the incremental cost of replacing 65 trolley buses with 65 diesel buses reveals that the difference is even more pronounced; it reaches 20 percent.

Funding Scenarios

Funding scenarios were determined by combining these separate scenarios for capital grants with two scenarios for O&M operating assistance. The results of five of the six possible combinations are presented; the sixth was deemed too unlikely to be considered.

The first capital grant scenario assumes that no further capital grants will be available beginning in fiscal year 1987. The amount apportioned to MVRTA through fiscal year 1986 was assumed to be spent during 1986–1989, as is the current schedule.

The second capital grant scenario assumes that the capital grant program will be reduced progressively to 30 percent of its current level over a 5-year period. The reduction of funds was assumed to begin in 1987 and to continue until the limit was reached. The minimum value was then assumed for the remaining years. It was further assumed that adjustments would be made to the funds allocated after fiscal year 1987 at the rate of 0.5 percent per year.

Both of the foregoing scenarios assumed that the local share was 10 percent. A third scenario, with a funding schedule similar to the second but with a local share of 30 percent, was also retained in the evaluation.

The two operating assistance scenarios included in the proposed 1986 MVRTA budget were used in this funding analysis. The first scenario assumes a relatively constant O&M operating assistance level into the future and the second assumes a federal pullout over the next 5 years.

For each scenario combination, the net present worth (NPW) of the capital and O&M funding was calculated. Then the shortfall (if appropriate) in each scenario was computed for each system alternative for both capital and O&M expenditures. Finally, the annualized increase of local participation (to make up for the shortfall) was calculated. It should be noted that this method is approximate, because it only takes into account the withdrawal of federal assistance. State assistance may increase or decrease as well.

Table 3 summarizes the findings of the costs and funding analyses. It clearly shows that the trolley bus alternatives are more costly to the local taxpayer in the long run (within the set of assumptions that was developed). These findings, although not surprising in view of the lack of factors advantageous to the trolley bus in Dayton, point out the high cost of retaining the trolley bus in Dayton. Moreover, the current state of the TB system equipment is such that all of it must be replaced, resulting in the need for a substantial commitment of capital now (the major portion being federal funds) and into the future (when federal funds may be greatly reduced). Therefore there is considerable risk (fiscal) to the local populace if a decision is made to replace the trolley bus system.

There are three issues that have been used to illustrate the nonmonetary advantages of the trolley bus: reduced pollution, reduced noise, and less dependence on fossil fuel. Although this study did not examine these issues in detail (and they should be taken into account in the ensuing policy deliberations in Dayton), other studies, including one in Dayton (*4, 5*) have shown that pollution and noise are of negligible impact. Although these concerns are real, research, development, and demonstrations are taking place to improve the operability and to reduce the nuisance associated with the diesel engine. These

TABLE 3 ANNUALIZED INCREASE IN LOCAL FUNDING NECESSARY FOR EACH SCENARIO

	Funding Scenario				
	1	2	3	4	5
Annualized Supplemental Amount To Be Raised per Alternative ($)					
1	6,908,085	8,074,088	1,947,266	10,966,330	6,005,512
2	4,961,813	6,127,816	995	9,020,058	4,059,240
3	4,960,819	6,005,929	0	8,898,171	3,937,353
4	7,488,207	8,654,310	2,527,388	11,546,452	6,585,633
5	8,183,264	9,349,267	3,222,445	12,241,509	7,280,690
Annual Difference When Compared with Cheapest Alternative ($)					
1	1,947,266	2,068,159	1,947,266	2,068,159	2,068,159
2	995	121,887	995	121,887	121,887
3	0	0	0	0	0
4	2,527,388	2,648,281	2,527,388	2,648,281	2,648,281
5	3,222,445	3,343,337	3,222,445	3,343,337	3,343,337

developments are related to engines, transmissions, on-board storage, emissions control, and noise abatement. Further analyses are necessary to determine the impact of these three nonmonetary issues on the situation in Dayton (*6*).

CONCLUSIONS

The analyses have shown quite conclusively that at MVRTA the O&M costs for the trolley bus system are higher than the O&M costs for the motor coach system. This is true despite the fact that the motor coach is used to supplement the operation of the trolley bus. Moreover, the projected cost (O&M and capital) of the trolley bus system is higher for each of the alternative funding scenarios considered in this study.

If the federal share of operating and capital assistance is reduced as proposed by the Reagan Administration, the budget shortfall will have to be made up by local sources. In the examination of system alternatives that include trolley bus operations, the shortfall was estimated to be from $2 million to $3.5 million more (annually) than for the system alternatives that do not include trolley bus operations.

These analyses are preliminary and further study should be undertaken. For example, the overhead cost estimates prepared by MVRTA are significantly lower than contract amounts in other U.S. cities. Further analysis of these estimates should be made in order to more fully understand the nature of these differences and to establish real costs of overhead replacement in Dayton. In addition, a detailed inventory and an engineering evaluation of the existing overhead system should be conducted in order to determine what would be reusable in a rebuilt trolley bus system.

Finally, it should be noted that the MVRTA bus system is an assembly of systems that, in the past, have competed with one another. Retaining a trolley bus operation in Dayton will require (a) a restructuring of both trolley bus and diesel coach service, and (b) a full integration of the trolley bus system.

REFERENCES

1. F. C. Dyer. The Dayton Experience. In *Special Report 200: The Trolley Bus: Where It Is and Where It's Going*, TRB, National Research Council, Washington, D.C., 1983, pp. 10–11.
2. B. J. Cudahy. *A Century of Service: The Story of Public Transportation in North America* (supplement to *Passenger Transport*). American Public Transit Association, Washington, D.C.
3. *The Journal Herald* (Dayton, Ohio), Friday, Jan. 24, 1986, p. 37.
4. J. D. Wilkins et al. *The Trolley Coach Development and State of the Art: Task I Report for the Electric Trolley Bus Feasibility Study.* Chase, Rosen & Wallace, Inc., Alexandria, Va., Oct. 1979.
5. *Trolleys vs. Diesels: The Air Pollution Perspective.* Regional Air Pollution Control Agency, Jan. 1986.
6. D. Dunoye. *Update of the Status of the European and U.S. Trolley Bus Industry.* UMTA, U.S. Department of Transportation, Dec. 1985.

Publication of this paper sponsored by Committee on Transit Management and Performance.