THE TROLLEY COACH

POTENTIAL MARKET, CAPITIAL AND OPERATING COSTS, IMPACTS AND BARRIERS

TASK 2 REPORT
FOR THE
ELECTRIC TROLLEY BUS FEASIBILITY STUDY
DOT-UT-80037
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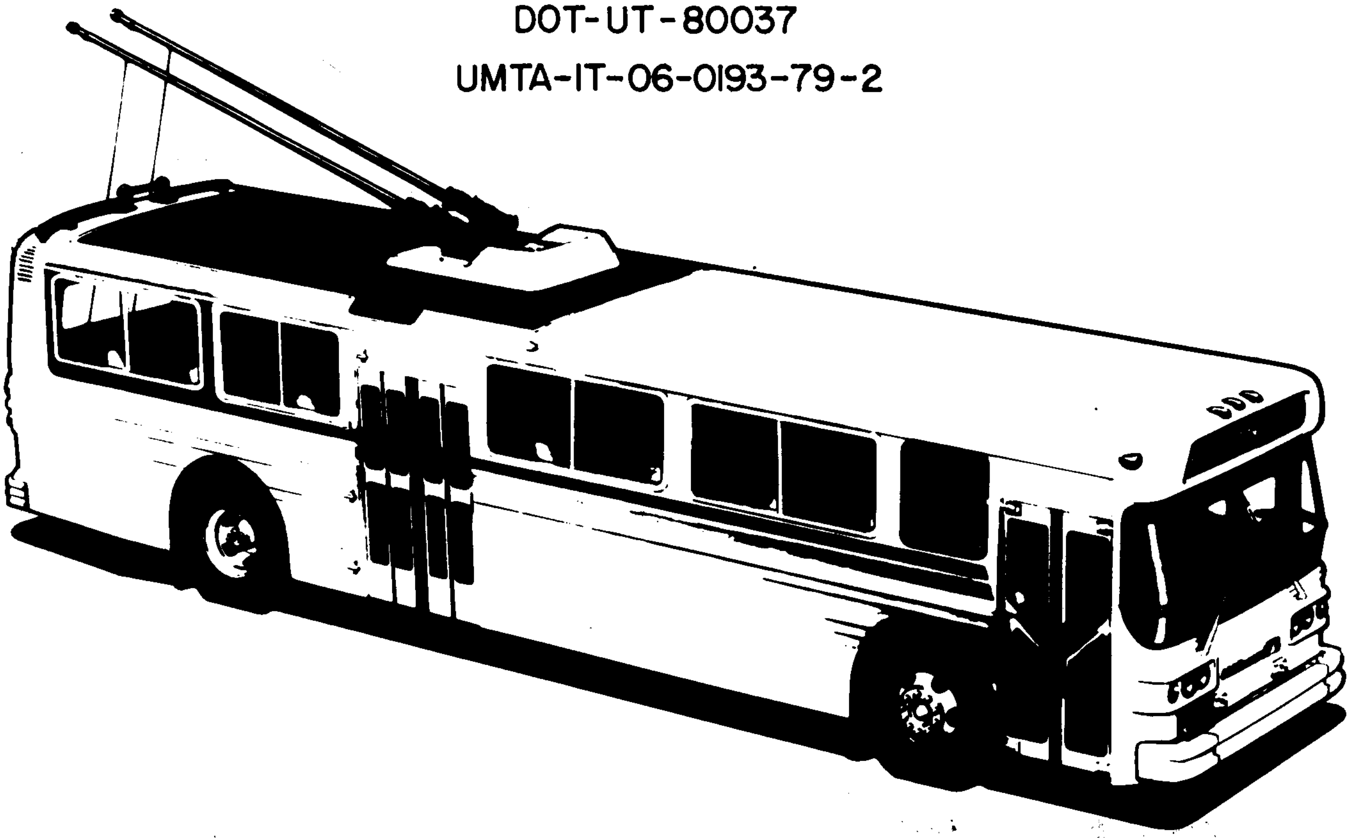

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U.S. DEPARTMENT OF TRANSPORTATION
Urban Mass Transportation Administration
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D I S C L A I M E R

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16. Abstract

This report contains a summary of the Task 1 report and an examination of the potential market for trolley coach systems in the United States. In support of this analysis, trolley coach capital and operating costs are estimated, and the impacts of trolley coach transportation on land use, community aesthetics and energy consumption are described. Potential barriers to trolley coach expansion are identified and pertinent conclusions from the study are presented.

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TASK 2 REPORT

FOR THE

ELECTRIC TROLLEY BUS FEASIBILITY STUDY

DOT-UT-80037

UMTA - IT-06-0193-79-1

U.S. DEPARTMENT OF TRANSPORTATION
Urban Mass Transportation Administration
Office of Policy, Budget and Program Development
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John D. Wilkins, Project Director

TABLE OF CONTENTS

Table of Contents (continued)

LIST OF TABLES

LIST OF FIGURES

SUMMARY OF TASK 1 REPORT - CHAPTERS 1.1 - 1.5

The development and current state-of-the-art of trolley coach technology and operations were investigated in depth during Task 1 of this effort. Although the study findings are detailed in a comprehensive task report, 1/ it is appropriate to briefly describe the scope and conclusions as background to the information presented in this Task 2 report.

The principal objectives of Task 1 were: 1) to collect up-to-date information on all aspects of trolley coach equipment and operational use to permit an assessment of this technology and its deployment, and 2) to identify promising areas for future research concerning trolley coach capabilities.

The starting point for Task 1 was compilation of a history of trolley coach transportation in the United States and elsewhere. Description of the current status of trolley coach usage was based on site visits and contacts with major transit operators and equipment suppliers in the United States and Europe. Each trolley coach subsystem was examined in detail to determine the present state-of-the-art for the various components. Operational and environmental aspects of trolley coach deployment were also evaluated. Based on the information gathered, the impacts of integrating trolley coaches into conventional transit operations were considered, and finally, areas for additional research were identified. Report coverage of each of these subjects is described in the following paragraphs.

Development and Status of the Trolley Coach

Usage of trolley coach systems began in the late 1880's, peaked in North America between the 1920's and 1950's, and then largely disappeared over the next twenty-odd years as high performance diesel buses became available and transit economics changed. A turning point was reached in 1970 when Toronto analyzed the comparative costs of trolley coaches and motor coaches and concluded that the trolley coach system should be retained. A new fleet of trolley coaches was built and the existing electrical systems were rehabilitated. This impetus led to the replacement of existing trolley coach fleets with new vehicles and programs for expansion in several cities. Increased interest in trolley coach deployment resulted from greater availability of capital for transit systems and a recognition of the opportunities for reducing environmental impacts and dependence on imported oil. The energy and environmental issues have also played an important role in the retention of trolley coach systems in Europe.

1/ "The Trolley Coach Development and State-of-the-Art", Task 1 Report for the Electric Trolley Bus Feasibility Study, prepared for U.S. DOT/UMTA, Office of Policy, Budget and Program Evaluation, under contract DOT-UT-80037, Washington, D.C., October 1979.

A description of trolley coach system development, the current situation and outlook for the future are detailed in the Task 1 report for the following cities:

Boston
Dayton
Philadelphia
Seattle
San Francisco
Edmonton
Vancouver
Toronto
Hamilton
Calgary

Trolley coach systems throughout Europe are also described briefly by country.

State-of-the-Art

Trolley coach state-of-the-art is described in terms of the vehicles and facilities in use in the United States, Canada and Europe. Specific electric propulsion systems, auxiliary mechanical components and vehicle bodies are pictured in the report and operating characteristics and dimensions are stated. Various types of power supply permitting off wire capability are also described. Power distribution equipment made by major manufacturers in the United States and Europe is described in detail, including several types of overhead wire support systems. Associated power supply equipment and operating characteristics are also covered.

Operational and Environmental Evaluation

To complete the description of current trolley coach systems, operational characteristics are specified and their impacts on the environment are estimated. These characteristics are presented with corresponding values for diesel motor coaches so that comparisons of these transit alternatives are realistic and in perspective. The topics covered in this study of operational use are the performance characteristics and speed, reliability, maintenance requirements, energy needs and the resulting impacts on air pollution and noise.

The conclusions of this investigation of operations in specific cities were that for typical urban routes, trolley coaches and diesel motor coaches can be considered to have identical performance.

There was evidence that trolley coaches have a slightly lower maintenance reserve requirement than motor coaches. With respect to environmental factors, trolley coaches contribute significantly less to air pollution than motor coaches; however, emissions attributable to motor coaches are a very small percentage of the overall. The sound intensity of trolley coaches is also significantly less than that for motor coaches, being indistinguishable from ambient street noise.

Energy consumption depends upon the operating environment and terrain as well as the vehicle propulsion system. Equivalent miles per gallon averages were obtained for trolley coaches and motor coaches in eleven cities.

Integration and Potential for Upgrading

Trolley coach service planning considerations were investigated in order to identify the impacts of integrating trolley coaches into existing transit operations. Most aspects of service are similar for motor coaches and trolley coaches, however, garage location can be more critical for trolley coaches so that off route operations are minimized. The impacts of introducing trolley coaches into existing transit operations are greatest in systems without electrical operations. As might be expected, the impacts on systems with existing electrical distribution infrastructures for rail operations are much smaller. All aspects of trolley coach integration were considered including route configurations, scheduling, operating and maintenance requirements, and personnel staffing levels and training.

The potential for upgrading trolley coach operations was examined in terms of the feasibility and costs of using various exclusive right of way configurations.

Identification of Research Needs

Evaluation of the information on current trolley coach equipment and operational experience led to the identification of the following areas in which further research may be successful in augmenting capabilities:

- Off wire capability
- Current collection for high speed operation
- Power control systems
- Routing control
- Passenger preference

CHAPTER 2.1

THE POTENTIAL MARKET FOR TROLLEY COACHES IN THE UNITED STATES

Introduction

This chapter details the potential market for trolley coaches in the United States, both with respect to the urban areas where trolley coaches could be utilized and the number of trolley coaches that could be employed in each area. The type of routes that are appropriate for trolley coach installation are described. The effect of changes in overall transit system size, fixed guideway expansion and changes in trolley coach technology are reviewed with specific estimates being made for articulated vehicles.

Approach

The market analysis described in this chapter was performed using the following procedure. Schedule information was obtained for all urban areas in which one or more primary transit operators require at least 225 vehicles to operate peak schedules. These urban areas were selected using the information on fleet requirements produced by UMTA. Thirty urban areas were found to have in excess of 225 vehicles.

The cutoff point of 225 vehicles was selected based on a minimum size for a practical trolley coach operation of 75 vehicles, excluding spares, and the assumption that it would be unlikely for a medium size transit system (a system with fewer than 500 vehicles) to have a service pattern that is sufficiently concentrated so as to utilize more than one-third of its vehicles on routes meeting the minimum density requirement, as described below.

Several transit systems in the 150-225 vehicle range were checked. None was found to have the potential for a trolley coach system of 75 or more vehicles. For example, the transit system in Richmond, Virginia, one of the highest density systems in the 150-225 vehicle group, would be able to utilize between 50 to 60 trolley coaches based on the density criteria described below. The next largest TC fleet was about 35 vehicles and the numbers dropped sharply beyond that. The route structure of cities in this size grouping was also not conducive to TC operation. Many lines have light density branches, which would not lend themselves to shuttle operation due to their close proximity to CBD's. It is estimated that if the fleet size restriction were eliminated and if light density branches were converted to shuttles an additional 900 to 1000 vehicles would be required. It should be pointed out that the existing trolley coach system in Dayton, Ohio does not meet the fleet size requirements.

The availability of a cost effective off-wire capability would eliminate the problem of light density branches and allow additional systems to achieve the minimum fleet requirements.

The schedule information was examined to determine those routes that met a minimum service density requirement of 120 or 140 two-way vehicle trips per weekday. 1/ The service density levels were chosen based on their relationship to service frequencies that we would expect to be suitable for trolley coaches. One hundred and forty trips per day, the basic system minimum, is equivalent to a midday headway of 15 minutes, peak headway of 10 minutes and evening headway of 30 minutes, with service operating from 6:00 a.m. to midnight. The 120 trip per day level, used to develop an estimate that would apply under more favorable conditions and to evaluate the sensitivity of the estimates is the equivalent of a 20 minute midday headway, 10 minute peak headway and 30 minute evening headway, given the same hours of operation.

Using the number of trips as a requirement rather than a peak or base headway enabled us to compensate for differences among systems with respect to the length of time that peak period service is offered and the level of evening service as well as the overall hours of operation. For example, a 15 minute midday headway may mean that this headway is operated between 9:00 a.m. and 4:00 p.m. or it may mean that this headway is operated between 11:00 a.m. and 2:00 p.m., with more frequent service being provided during mid-morning and mid-afternoon periods.

A study done by San Francisco Municipal Railway indicated that there were cost savings possible on lines with a peak headway of up to 15 minutes. However, San Francisco Muni has particularly favorable conditions for trolley coaches, including generally low peak to base ratios, an existing power system and low power rates. The Muni report recommended a high priority be given to trolley coach conversion for all lines having a five minute peak headway or better and lines having a peak headway of between five and ten minutes that either have a substantial amount of common routing with existing trolley coach lines or have steep grades.

It appears unlikely that there are a significant number of routes and locations where trolley coaches can be justified on purely economic grounds. Thus, the minimum density level becomes a subjective decision point that is based on an implied value of environmental factors and the potential for use of energy sources other than diesel fuel.

Routes included in the basic estimate (140 trips per day minimum) and the low density estimate (120 trips per day minimum) were selected based on the service over a major portion of the route achieving this service density. Where routes have branches or extensions, the route was not included unless the branch was sufficiently short relative to the length of the route to make the installation of wire feasible, or the main portion of the route was of sufficient length so that the route could be split into a trolley coach route and a feeder bus route. In this latter case, the vehicle requirements were adjusted downward to reflect the route splitting. In a few cases, a similar route splitting was assumed for routes operating through a CBD and having substantial differences in service level on the two legs.

1/ It should be noted that certain TC routes in Seattle do not conform to this criteria.

Routes that operated on freeways were excluded from these estimates, as were routes that operated in areas where overhead wires are restricted, including Manhattan and Washington. 1/ Express services were included where these services operated over the same route as the local service. In those instances where a different route is used, express services were excluded and vehicle requirements were adjusted accordingly.

System effects were taken into account in several respects. The minimum system size has already been mentioned. The effect of commonality of routing was examined in the evaluation and classification of routes. For example, there are several situations where routes that would not individually meet the minimum service density criteria have been included as a result of the use of common routing. In addition, isolated routes have been excluded in a few cases. Buffalo is a unique case, in that the number of routes that meet the basic density criterion would utilize less than 75 vehicles. Thus, Buffalo is only included in the low service density estimate.

A third route category was established, which included those routes that met either service density requirement but were in locations where the physical or institutional feasibility of installing wire is questionable. Most of these routes are in Manhattan or Washington. However, other such routes are in locations where a specific roadway such as a bridge that is part of a freeway, is in question.

Market Estimates

Table 2.1-1 shows the result of the route and system analysis described above. This table shows the number of vehicles required for service and the number of vehicles that would be purchased assuming a 10% or a 15% spare ratio.

The 10% spare ratio 2/ is reasonable for trolley coaches, based on the experience cited in the Task 1 report (page 203). The 15% spare ratio is useful for comparison with motor coach operations. Also, the availability of 80% UMTA fundings for vehicles has tended to encourage transit systems to operate with higher spare ratios.

These figures are shown for the basic service density situation (140+ trips per day) and incrementally for the low density situation and for the situation including special problems with respect to overhead wire.

The routes in each category for each city are shown in the Appendix. Routes of private operators in New York City are included with the routes under MTA jurisdiction (NYCTA, MABSTOA and MSBA) in the New York total. All routes in Northern New Jersey are grouped without regard to ownership. In both cases, the private operators rely on public agencies for the purchase of new equipment.

1/ The feasibility problems of trolley bus operation on mixed traffic freeways are discussed on Page 122 of Volume 1.

2/ Individual transit properties may desire to acquire additional vehicles over the stated 10% to allow for growth.

Table 2.1-1

Potential Market for Three Levels of Trolley Coach Service

	Basic Service (140+ Trips/Day)			Basic and Low Density Service (120+ Trips/Day)			Basic, Low Density and Special Problem Services		
	Vehicles Required for Service	Vehicles Purchased (10% Spare Ratio)	Vehicles Purchased (15% Spare Ratio)	Vehicles Required for Service	Vehicles Purchased (10% Spare Ratio)	Vehicles Purchased (15% Spare Ratio)	Vehicles Required for Service	Vehicles Purchased (10% Spare Ratio)	Vehicles Purchased (15% Spare Ratio)
New York	2713	2985	3120	2854	3139	3282	3878	4266	4460
New York	(2328)	(2561)	(2677)	(2453)	(2698)	(2821)	(3477)	(3825)	(3999)
Northern New Jersey	(385)	(424)	(443)	(401)	(441)	(461)	(401)	(441)	(461)
Chicago	1576	1734	1812	1617	1779	1860	1698	1868	1952
Los Angeles	740	814	851	838	922	964	838	922	964
Philadelphia	792 *	839 **	883 **	865 *	920 **	967 **	865 *	920 **	967 **
Detroit	342	376	393	448	493	515	448	493	515
San Francisco	426 *	400 **	434 **	446 *	423 **	457 **	446 *	423 **	457 **
SF Muni	(291) *	(251)**	(279)**	(307)*	(269)**	(297)**	(307)*	(269)**	(297)**
AC Transit	(135)	(149)	(155)	(139)	(154)	(160)	(139)	(154)	(160)
Boston	248 *	258 **	272 **	277 *	290 **	306 **	304 *	319 **	337 **
Washington	0	0	0	0	0	0	622	684	715
Cleveland	211	232	243	229	252	263	262	288	301
St. Louis	137	151	157	137	151	157	137	151	157
Pittsburgh	98	108	113	141	155	162	141	155	162
Minneapolis-St. Paul	236	260	271	276	304	317	276	304	317
Houston	97	107	111	97	107	111	97	107	111
Baltimore	435	479	500	435	479	500	435	479	500
Milwaukee	214	235	246	244	268	280	244	268	280
Seattle	52 *	57	60	62 *	68	71	62 *	68	71
Atlanta	147	162	169	164	180	189	164	180	189
Buffalo	0	0	0	82	90	94	82	90	94
Kansas City	74	81	85	74	81	85	74	81	85
Denver	77	85	89	98	108	113	98	108	113
New Orleans	306	337	352	306	337	352	306	337	352
Portland	82	90	94	136	150	156	136	150	156
Columbus	101	111	115	101	111	115	101	111	115
Honolulu	79	87	91	79	87	91	79	87	91
	9183	9988	10461	10006	10894	11407	11793	12859	13461

* Excludes vehicles required for existing trolley coach routes.
** Spares adjusted to reflect existing vehicle surplus.

The vehicle market estimates were adjusted to reflect surplus vehicles in Boston, Philadelphia and San Francisco. Thus, due to the large vehicle surplus in San Francisco, the number of vehicles required for service is larger than the number that would have to be purchased.

The most significant element of this estimate is the concentration of the potential use of trolley coaches in a small number of transit systems. Six urban areas of the 30 analyzed do not have a sufficient number of routes that meet either of the density criteria to support a 75 vehicle system. These are: Cincinnati, Dallas, Miami, Memphis, San Antonio and San Diego. Four transit systems account for a substantial majority of the trolley coach market in the remaining 24 urban areas. New York accounts for 25.6% of the market in the lowest (basic) estimate and 29.7% in the highest estimate, which includes Manhattan. Chicago accounts for 17.4% of the market in the lowest estimate and 14.5% in the highest estimate. Philadelphia and Los Angeles each account for between 7.2 and 8.4% in both estimates. No other system includes significantly more than 5% of the total market in any of the estimates. In total, the four largest systems account for 59.6% of the total market in the lowest estimate and 58.6% in the highest estimate. The highest estimate includes Washington, which is not included in the other estimates. In this estimate, the five largest systems, including Washington, are 63.9% of the total market.

According to a recent UMTA estimate, there are 48,479 transit buses in the United States. The potential demand for trolley coaches estimated during this study is between 9,988 and 13,461 vehicles. This represents a replacement of between 20.6% and 27.8% of the total number of transit buses. This number is substantially higher than the 6,504 trolley coaches in service in 1950, which was near the peak year for such vehicles.

It is also significantly greater than the 8,296 trolley coaches built between 1929 and 1954, the period of the greatest use. This difference is largely a result of the potential market in the four largest transit systems. Table 2.1-2 shows a comparison of past usage of trolley coaches with the estimated market. It can be seen that the market estimates for the four largest systems taken as a group range from 5 to 6.5 times that peak ownership, while for the 15 other systems in the market estimate where trolley coaches were formerly used, the market estimate is between 75 and 88% of the past peak ownership.

The trolley coach was obviously never a predominant mode of the four largest systems. Chicago and Philadelphia retained large streetcar systems until a relatively late date, while New York and Los Angeles were among the first areas where the diesel bus was adopted as standard. It must be pointed out that these market estimates are based on a much higher level of transit operator interest in trolley coaches than is presently being shown. At present, only San Francisco and Seattle are considering the purchase of additional trolley coaches. Their purchase would amount to between 308 and 368, 40 foot vehicles. Only one operator, Portland, Oregon, is considering a new TC system.

Trolley Coach Applications

In developing the market analysis described above, it has become apparent that the trolley coach is most generally applicable to line haul routes in densely settled urban areas. These routes may be radial to a CBD, feeder routes to high capacity rail systems or crosstown routes in dense areas. However, the common characteristic that they share is a high level of demand throughout the day that is common in densely urban areas and is not often found in suburban areas. These routes also tend to be entirely on surface arterial streets and to have fewer branches than do suburban routes. In addition, these routes generally serve established areas and are not likely to be extensively changed, which contributes to their suitability for trolley coaches. Even where extensive route revision programs have taken place, dense routes on major arterials tend to remain the same.

In several cases, a group of suburban routes taken as a whole has sufficient service density on the trunk portion, but branches and/or short turn trips produce a situation where a large part of the route mileage does not have sufficient service density to warrant trolley coaches. Also, suburban routes are more likely to utilize freeways and thus would not be suitable for trolley coaches.

In certain cities, routes with extremely steep grades are potential candidates for trolley coach operation. Most such routes are in San Francisco and Seattle and already have trolley coaches. In snowbelt cities, major arterials with very steep grades are uncommon due to their non-usability during winter months. A few minor routes in Pittsburgh have steep grades, but these routes do not have sufficient service to warrant trolley coaches.

Areas where there is a well defined separation between city and suburban services, such as Chicago, are more likely to have routes that are suitable for trolley coaches as the branch and extension problem is reduced.

CBD circulator routes may be appropriate for trolley coaches in a system where a large number of radial routes are equipped with these vehicles. Many CBD circulator routes do not have vehicles specifically assigned. Instead, the vehicles used on these routes also make peak period trips on radial routes. Thus the applicability of trolley coaches will depend upon the specific scheduling practices of the system, as well as the extent of common wire between a circulator route and radial routes in the CBD.

Table 2.1-2

Comparison of Past Trolley Coach Ownership and Estimated Market

	Peak Number of Vehicles Owned	Estimated Market	
		Minimum	Maximum
New York	200	2561	3999
Chicago	713	1734	1952
Los Angeles	110	814	964
Philadelphia	202	949 (b)	1077 (b)
Total of 4 largest systems	1225	6058 (b)	7992 (b)
15 other areas with past trolley coach systems (a)	4433 (d)	3343 (c)	3904 (c)
Total	5658	9401 (b,c)	11896 (b,c)

(a) Atlanta, Baltimore, Boston, Cleveland, Columbus, Denver, Detroit, Honolulu, Kansas City, Milwaukee, Northern New Jersey, New Orleans, Portland, San Francisco (Muni), Seattle.

(b) Includes 110 currently owned vehicles.

(c) Includes 502 currently owned vehicles.

(d) Excludes secondhand purchases in Boston, Cleveland and Milwaukee.

Factors Affecting Market Estimates

The market estimates described above were developed using a 40' (12 m.) trolley bus of current design without off wire capability and were based on current service levels and configurations. There are several potential changes that should be taken into account in using these estimates. Among these are:

- Potential transit system expansion including rail system expansion and busways
- Use of articulated trolley coaches
- Increased high speed capability
- Off wire capability

The general expansion of bus service is not likely to affect the potential for trolley coach utilization significantly. As described above, the routes that are the prime candidates for trolley coaches are in large urban areas with strong transit systems and serve portions of the area that are densely developed and generally already have a high proportion of travel by transit. In the large urban areas with strong transit, it is likely that growth in usage will result from expansion of the route structure either to serve newer suburban areas or to provide for non-radial travel that was previously poorly served. However, there are cetain urban areas where the transit system is relatively weak. In these cities there may be a potential for growth throughout the system, including the major routes. One example of such a system is Phoenix. This system uses only 130 vehicles to serve an urbanized areas of almost 900,000, while Portland, Oregon, which is slightly smaller, uses 435 vehicles. Among the larger cities, Detroit, Houston, Dallas and Kansas City, appear to have transit systems with overall growth potential which could result in increasing the potential market for trolley coaches identified in Table 2.1-1. There may also be several smaller cities where system size could increase sufficiently to warrant a trolley coach installation.

The effect of such usage increases on the potential for trolley coaches is hard to project, but it is likely that it would be only on the order of 500 to 1000 vehicles.

The effect of rail transit expansion is likely to be more significant and could reduce the potential for trolley coaches. The following cities have rail routes under construction that would replace surface routes that were included in the market estimate: Atlanta, Boston, New York, Baltimore, Washington and Buffalo. It is likely that the effect of rail systems in Atlanta and Buffalo would be to eliminate entirely the potential for trolley coaches in these cities. The overall effect of rail lines presently under construction would be to decrease the potential market for trolley coaches by between 350 and 750 vehicles. Other rail proposals, such as the Wilshire line in Los Angeles and the Geary Street light rail line in San Francisco would also preempt major trolley coach markets. In general, although a rail line may require high density feeder routes, the number of buses replaced by the rail service on the main route or routes will be significantly greater than the number of vehicles required for feeder service.

Busways are not likely to provide a significant market for the conventional trolley coach for several reasons. Review of the three largest existing busway operations reveals that none is suited to conventional trolley coach operation. All of these facilities serve a large number of low density suburban routes. While the Pittsburgh and Los Angeles busways have stations, most usage is from areas served by the surface street portions of the busway routes. Other types of busways would be more appropriate for trolley coaches. Several busway configurations were discussed in the Task 1 report (pages 243-247). The configuration that was most promising for trolley coaches was the one that included a central area subway. This type of system is not likely to be a significant factor in U.S. cities. Six of the eight urban areas of over two million population and five of the 17 urban areas of between one and two million have rail systems either in place or under construction. In ten of the twelve areas (except Cleveland and Miami) the rail system serves as its own central area distributor, thus largely eliminating the need for additional central areas construction. Even in Pittsburgh, where a major busway has been completed and a second one is under construction, the downtown subway will be exclusively for light rail use.

Many of the remaining urban areas are not likely to be well served by a system combining street operation and a central area subway. This system configuration is most appropriate for an area where travel distances are relatively short and most delay to bus movement occurs in a relatively small central area. In many urban areas, such as Los Angeles and Detroit, the need is to provide higher speed capability over long distances. Central area congestion is not as significant as in older cities in the Northeast, due to wider streets and lower development density in the core. It appears to us that there would only be four or five cities where this concept is at all applicable, and the likelihood of any such systems being developed in the near future appears to be quite small.

Another busway configuration that would be appropriate for trolley coaches would be a system in which the primary service area is tributary to stations on the busway. Although there have been some proposals for this type of system, it appears that rail modes are generally more appropriate in such situations.

Several aspects of vehicle and overhead wire design may affect the potential market for trolley coaches. These include: articulated vehicles, higher speed capability and off wire capability. Articulated vehicles could have a significant impact on the market for trolley coaches. The effect would be to reduce the number of vehicles required but to increase the total cost of vehicles produced. Table 2.1-3 shows an estimate of the number of articulated trolley coaches that could be used by individual transit systems. This estimate was made from the data used in making the estimate of the number of 40' (12 m.) vehicles. The routes selected in the initial estimate that operate a base headway of 8 minutes or less were considered to be potentially suited for articulated vehicles. Almost all routes selected in the initial estimate utilize a substantial portion of their total vehicle assignment throughout the day. Thus routes that are to be assigned articulated vehicles would have to be those that can utilize their greater capacity throughout the day.

Table 2.1-3

Articulated Trolley Coach Market Estimate
By Urban Area

	Basic Estimate Including 10% Spare Vehicles	Estimate with Special Problem Routes Including 10% Spare Vehicles
New York	1168	1952
New York	(1029)	(1813)
Northern New Jersey	(139)	(139)
Chicago	458	521
Los Angeles	180	180
Philadelphia	160	160
Detroit	91	91
San Francisco	221	221
SF Muni	(179)	(179)
AC Transit	(42)	(42)
Boston	43	43
Washington	0	234
Cleveland	41	41
Minneapolis-St. Paul	83	83
Milwaukee	52	52
New Orleans	82	82
	2529	3660

Articulated vehicles were assumed to replace 40' (12 m.) two axle trolley coaches at a ratio of one articulated coach for every 1.4 two axle coaches. The ratio is slightly less than the size difference, (60' (18 m.) in length as opposed to 40' (12 m.)) due to the space taken up by the articulation, the probability that articulated vehicles will have slightly lower schedule speeds due to longer stop times, and the slight reduction in scheduling efficiency when a smaller number of units is scheduled. An exception was made for San Francisco where it was assumed that all additional vehicles would be articulated, but that none of the current fleet would be replaced with articulated coaches.

The result of this analysis is to reduce the potential market derived in the basic estimate from 9988 40' (12 m.) trolley coaches to 6378 40' (12 m.) trolley coaches and 2579 articulated coaches, or a total of 8957 coaches. This represents a 10.3% reduction in the number of vehicles but 15.5% increase in the total cost for vehicles, based on the cost ratios shown in Chapter 2.2. The resulting fleet would consist of 71.3% 40' (12 m.) coaches and 28.7% articulated coaches. For the maximum estimate (using the 10% spare ratio) 12,859 40' (12 m.) coaches would be reduced to 7735 40' (12 m.) coaches and 3660 articulated coaches, a reduction of 11.4%. Articulated coaches would be 32.1% of the total fleet.

The articulated coach market is even more concentrated in the largest systems than is the total market. In the basic estimate, 39.9% of the market for articulated coaches is in New York, with the four largest systems accounting for 70.8% of the total. In the maximum estimate, 49.5% of the market for articulated coaches is in New York, while the five largest systems account for 79.5% of the total.

It should be pointed out that this estimate of the potential for articulated trolley coaches is based on the use of a fare system that would allow boardings at doors in addition to the front door, as well as on the use of vehicles with at least three doors. Without such a system design, it is likely that articulated coaches would have substantially higher stop times than two axle coaches, and would offer little or no operating cost advantage.

Higher speed capability would have little use on the type of routes that form the largest part of potential trolley coach applications. These routes are on arterial streets where speed limits are generally below the present maximum trolley coach speed.

Three classes of off-wire capability are identified in Volume 1. These classes are differentiated by range and performance levels. Two of these classes are not intended for off-wire operation in regular revenue service. It is unlikely that these levels of off-wire capability would affect the potential market for trolley coaches. In the analysis of potential routes, only two routes were found that had to be excluded due to being disconnected from a larger system. Thus, the use of off-wire capability for movement to and from garages would have minimal effect on the potential use of trolley coaches. Other uses of limited off-wire capability include movement in garages and emergency detours. The lack of off-wire capability for these purposes does not appear to be a significant deterrent to trolley coach usage.

The third class of off-wire capability is the hybrid vehicle or all service vehicle. Such vehicles are designed to operate in regular revenue service either as a trolley coach or using an internal power source. Range in the off-wire mode may be less than in the trolley coach mode, but is adequate for the service to be operated. A hybrid vehicle would permit the provision of through service on route extensions or deviations that with conventional trolley coaches would have to be operated as feeder routes with motor coaches. It would also be a suitable vehicle for routes where a trunk portion has sufficient density to justify the installation of wire but the individual routes do not. An hybrid vehicle could also reduce garage pull-in and pull-out times through the use of more direct routes, which would not normally be wired. The usability of this capability will vary widely from system to system. For example, Chicago, which is largely a grid transit system, would have very little use for off-wire capability. Pittsburgh, however, where the topography forces many routes onto a few streets approaching the core of the city, would have substantial use for such a vehicle.

In general, the question of the overall market for a vehicle with full off-wire capability is impossible to determine without a better knowledge of the characteristics of such vehicles. Vehicles with off-wire capability presently have higher initial costs, maintenance costs and energy consumption, due to greater weight, than a conventional trolley coach. This deficiency will continue to exist for any battery or internal combustion engine auxiliary power source. The potential market is dependent upon the amount of the cost penalty associated with this capability.

It should also be noted that vehicles with full off-wire capability were developed and commercially available in the 1930's, but that only one transit system, PSCT in New Jersey, made extensive use of such vehicles.

CHAPTER 2.2

TROLLEY COACH CAPITAL AND OPERATING COSTS

Introduction

This section is intended to provide the reader with insight as to the costs that are unique to TC installations and their relationship with motor coach costs. Sufficient detail is provided to allow the determination of new system costs, both capital and operating, which can be used in a present worth analysis. It must be pointed out that the data provided will only support a preliminary analysis. The material has been organized in a manner that does not require a technical background for its application. All costs indicated are in 1978 dollars unless otherwise noted.

The tendency of many previous comparisons of TC and motor coach costs has been to use current cost data and avoid any reference to life differences between the two vehicles. The appropriate course of action is to use life cycle costing as a basis of comparison. The following reasons can be cited:

- The time relationship of TC and MC maintenance costs can be ascertained only by comparing TC and MC fleets over their life span.
- The determination of MC capital costs must reflect that a second MC fleet will be required because of the TC's longer life.
- To the extent possible, comparisons should incorporate the varying cost differences associated with TC and MC energy consumption.

Capital Costs

Overhead Line Materials and Installation

Costs of Typical Tangent and Special Work Sections - Estimates of the installed cost of tangent TC overhead and the most common special work installations are provided in this section. The costs are derived from Seattle's current program to rehabilitate and expand its TC system. The costs provided must be qualified as follows:

- The price of overhead fittings is based on a quantity purchase covering 55 route miles.
- Installation was contracted and includes the following contractor costs:
  - Labor and fringe benefits
  - Equipment, operating and depreciation costs
  - Overhead, including supervision, operation of a stores function, etc.
  - Profit

- The estimates are not valid for small installations and extensions or work performed by an operation's own work forces.

Figure 2.2-1 indicates costs associated with typical special work installations. The installed costs of poles and line materials are indicated separately. The high cost of the poles relates to the fact that they must accommodate the high moment forces imposed by the overhead special work. Figure 2.2-2 indicates costs per mile for a typical tangent wire construction, including the costs for wood and steel poles and building eye bolts.

Capital costs for overhead facilities should also include line trucks and an inventory for poles and line hardware. The number of trucks is shown in Table 2.2-7 below. The cost incurred by Seattle was approximately $25,000 per truck.

Seattle Overhead Installation Costs - Seattle has rehabilitated its existing 28.6 mile system and is installing new extensions that will increase the route miles to 55. Actually, rehabilitation involves the installation of a completely new overhead and power supply system. The existing support structure was reused to the extent conditions allowed. The major costs of of rehabilitating the existing system are shown in Table 2.2-1.

Table 2.2-1

Cost of Rehabilitating Overhead Lines in Seattle
(in thousands of dollars)

	Costs as Bid		Costs Including Adjustments	
	Total	Per Mile	Total	Per Mile
Non-CBD Contractor Rehabilitation Costs (1)	$4,131	$144	$5,929	$207
CBD Contractor Rehabilitation Costs (2)	820	15	1,247	24
Hardware and Other Material (1)(3)	1,219	43	1,219	43
Total Overhead Costs		$202		$274
Ratio of Labor/Materials	4.1		5.9	

(1) The cost associated with 28.6 miles of rehabilitated overhead, including special work at intersections with new extension routes.
(2) The cost of the CBD network is allocated to the entire new system which is comprised of 55 route miles.
(3) The cost of purchasing wood and steel poles is included in the contractor's costs.

FIGURE 2.2-1

COST OF

TYPICAL SPECIAL WORK INSTALLATIONS

GENERAL DATA

- 4/0 WIRE EMPLOYED
- OHIO BRASS 4/0 HARDWARE EMPLOYED
- UTILITY RELOCATION COSTS NOT INCLUDED
- LIFE OF INSTALLATION, 30 YEARS
- ALL COSTS IN 1979 DOLLARS

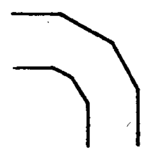
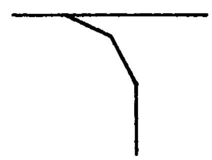
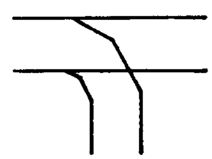
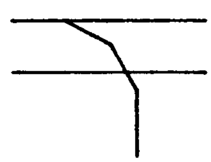
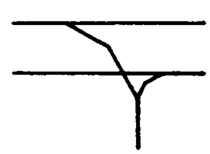
TYPE OF SPECIAL WORK	CONFIGURATION	COST
SINGLE 90° CURVE		LM&I: $4,500 Poles: $14,000
DOUBLE 90° CURVE		LM&I: 9,000 Poles: 17,000
SINGLE SWITCH		LM&I: 14,000 Poles: 24,000
DOUBLE SWITCH		LM&I: 34,000 Poles: 35,000
SINGLE SWITCH WITH CROSSOVER		LM&I: 20,000 Poles: 27,000
WYE		LM&I: 42,000 Poles: 33,000

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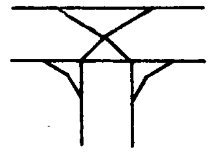
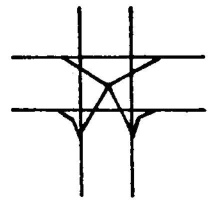
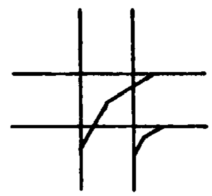
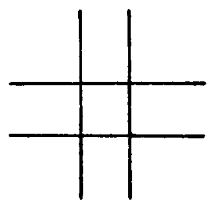
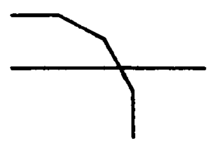
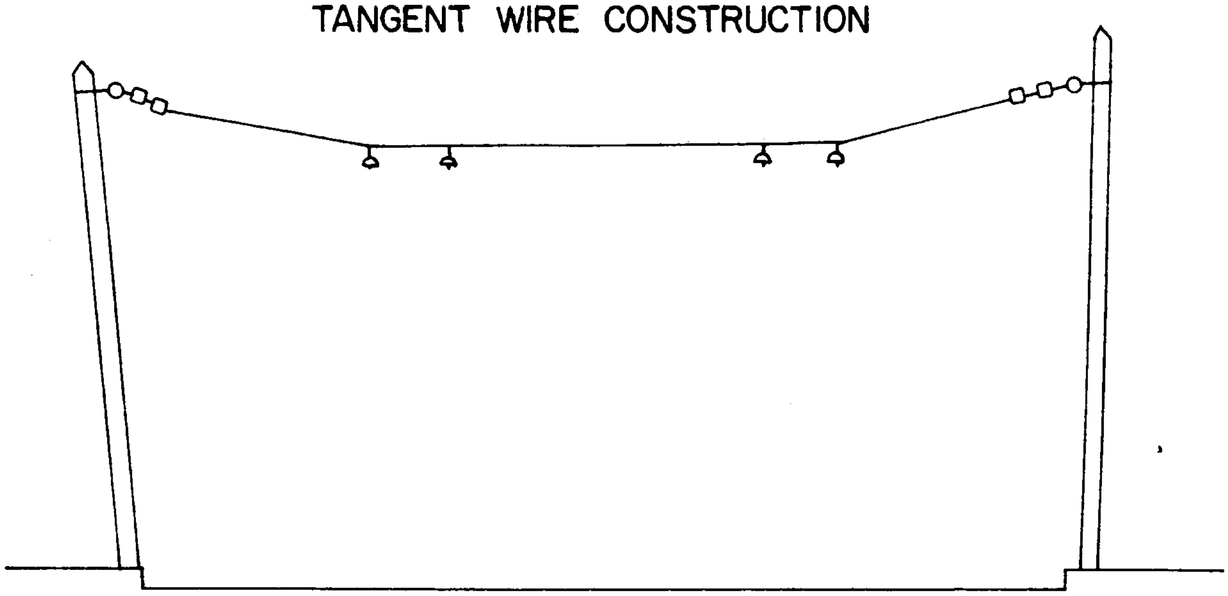
FIGURE 2.2-1 (CONTINUED)

TYPE OF SPECIAL WORK	CONFIGURATION	COST
"T" INTERSECTION		LM&I: $88,00 Poles: $58,00
½ GRAND UNION		LM&I: 140,00 Poles: 58,00
¼ GRAND UNION		LM&I: 77,00 Poles: 48,00
DOUBLE CROSSOVER		LM&I: 19,00 Poles: 13,00
SINGLE 90° CURVE WITH CROSSOVER		LM&I: 10,00 Poles: 16,00

LM&I = Line material and installation

Poles = Purchase price and installation of steel poles

FIGURE 2.2-2
COST OF
TANGENT WIRE CONSTRUCTION



TYPICAL TANGENT SPAN

GENERAL DATA:

- 50 Spans installed in an average mile
- 4/0 Feederless system employed using copper wire @ $.5883/Foot
- Incorporates the use of 5° - 12° curve segments
- Utility relocation cost not included
- Life of installation, 30 Years

COST PER MILE:

• Line material and installation using existing eyebolts and poles	$ 130,000
• All new poles - Wood (a)	$ 210,000
- Steel (b)	$ 380,000
• 50% New poles - Wood (a)	$ 170,000
- Steel (b)	$ 255,000
• All new eyebolts (c)	$ 210,000
• 50% New eyebolts (c)	$ 170,000

(a) Wood poles at $ 800 each installed

(b) Embedded steel poles at $ 2500 each installed

(c) Eyebolts at $ 800 each installed

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It should be indicated that the average ratio of contractor costs to material costs in Seattle was approximately 4.1:1 when the original rehabilitation contracts were let. This ratio, shown in Table 2.2-1, has since risen to 5.9. The reasons for this increase are as follows:

- It was originally intended that the support structure that served the old system would simply be reused. When construction work commenced, it was soon evident that the following extra work was required:

    - Some poles has deteriorated beyond the point of reuse and had to be replaced.
    - Many wooden poles had to be back-guyed to ensure that the contact wires remained at the proper height and tension.

- Areaways (basements of adjoining buildings that extend to the curb line) were discovered in many areas where new poles were required in the CBD. Extra work was required to install expensive pole foundations. The areaways had not previously been discovered, since they were not indicated on street maps or building plots.

- At the request of the building owners, some building bolts were not reused. Extra work was required to install new steel poles.

- Overtime work was required to retain the contractor's linemen. Typically these people are accustomed to working overtime hours and an inducement was required to keep them from migrating to other area jobs.

- Numerous unanticipated conflicts with utilities were encountered. Telephone and power lines, principally lateral service lines, had to be moved to provide required clearances.

The conclusion to be drawn and the reason for mentioning these problems is that total installation costs are extremely sensitive to efforts associated with the supporting structure. The estimation of detailed construction costs must be accompanied by a rigorous surveillance of construction environment as it pertains to:

- Pole condition,

- Pole location,

- Conflicts with utilities on joint use poles,

- Conflicts with utility laterals that must cross the contact wires with specific clearances.

The estimated costs must also be sensitive to the wage expectations of local electrical workers.

Substations

Feederless Substations - This type of substation typically has a low capacity, usually around 500 kw, and is installed at rather close intervals along a TC route. The rehabilitated and expanded Seattle TC system will have 26 substations for 55 unduplicated route miles or an average spacing of one station every two miles. Actual spacing on lines such as South Rainer Avenue varies between 6000 and 7000 feet (1800 to 2100 m.). The average spacing is higher due to crossfeeding in the inner portion of the system. The average distance would decrease if the system had a denser service pattern.

The substation is a self-contained unit which needs no building protection and only a small parcel of land. The unit can also be installed underground if adequate drainage is provided. Feederless systems can be used to support operations in the CBD provided adequate substation sites can be located.

Based on Seattle's experience, 500 kw stations required the following outlays in 1978 dollars:

- o Station equipment including AC switch gear, a 500 kw transformer, rectifier, DC switch gear (one circuit breaker and contacter), together with a housing for outdoor installation. --------------------------------$ 60,000
- o Contractor labor for installation --------------------$100,000
- o Site acquisition costs and security fence - Determined locally.

These data should be used primarily to establish the relationship between equipment and labor costs. Equipment prices should be verified with appropriate vendors. The equipment must have a heavy traction rating, 500 kw units should be capable of a 750 kw output for two hours and 1500 kw output for one minute. Contract installation charges can be determined by using a multiplier of 1.7 against total material costs.

Substations Supporting a Conventional Feeder System - Conventional feeder systems may be required in dense traffic areas or when an adequate number of sites cannot be obtained for feederless substations. A typical feeder system can be installed underground or attached to the overhead support poles. The former course of action greatly increases costs but may be mandated in certain areas by local undergrounding ordinances.

The decision to use a conventional feeder system, particularly in the CBD, may be influenced by the existence of an underground conduit system that supported a previous light rail or TC system, or excess conduit capacity obtainable from the local electric utility. Seattle opted for a conventional feeder system in the CBD principally due to the existence of conduit network that had supported the old TC system and the ability to reuse and secure long term leases on two existing substation sites.

The capacity of substations supporting a conventional feeder system is significantly greater. Seattle's two CBD substations will each have a capacity of 3000 kw. Even so, the space requirements are significantly less than substations of a previous generation which used rotating or early non-mechanical rectification equipment. Locations for large capacity central substations can include:

- Space leased in an electric utility CBD substation
- Space leased in basements or sub-basements of principal CBD buildings
- Specially designed structures

The costs associated with larger substation installation can vary widely due to the site location problems and the type of feeder system employed. Based on the Seattle experience, the following costs can be cited:

- Station equipment including transformers, AC switch gear and a 1500 kw rectifier requiring indoor installation---$45,000
- DC switch gear for each DC circuit ----------------------$12,000
- Contract labor multiplier ------------------------------ 2.5
- Installation of four 4" (10 cm.) plastic conduits with 500 MCM aluminum feeder cable --------$60/foot ($197/meter)
- Installation of two 500 MCM feeder cables on existing poles ----------------------------$15/foot ($49/meter)
- Site costs -----------------------------------Determine locally.

Again, local vendors should be contacted to determine current equipment prices. Local utility companies, both telephone and electric, can usually be consulted for a more precise conduit estimate. The cost of underground conduits varies considerably between CBD and non-CBD areas and between localities.

Required Substation Capacity - Generally stated, the required capacity is a function of the maximum number of TC's that will occupy a given route segment at any one time. The number of TC's is, in turn, dependent upon headway and average operating speed. The actual calculations are set forth in Task 1, Chapter 1.2. Using the formulas indicated in that chapter, the graphs in Figures 2.2-3 and 2.2-4 were constructed to indicate required capacity for one two-way route mile. The figures include a growth factor of 1.00 and 1.25, respectively. Both figures include loss and off-schedule factors of .25 and 1.3. The graph is used by selecting the minimum proposed headway and the average speed for the route segment under consideration.

As an example, we shall determine the capacity requirements for a feederless system on a route segment that is eight miles long, has a "best" headway of six minutes over the entire route segment, i.e. both directions, and operates at an average speed of 9 mph (14 kph). If the six minute headway were not in effect over the entire segment, an effective headway would have to be calculated.

Using Figure 2.2-4, which includes a growth factor of 1.25, the required capacity is 488 kw per mile (303 kw per km.). This would necessitate the installation of eight substations spaced one mile apart. The first station would be one-half mile from the end of the line.

Table 2.2-2 can be used as a check on substation spacing. To use this table, the number of vehicles in a one mile section must be determined. In the example, a six minute headway with an average speed of 9 mph (14 kph) translates into 3 vehicles. Using the diversity curve in Chapter 1.2, three vehicles in turn translates into 530 amperes. Using Table 2.2-2, for a 15% voltage drop, and interpolating between 400 and 600 amperes, we find that the substation spacing cited above is quite adequate.

The example cited above is based on the use of MRC controllers. If chopper controllers are to be used, power consumption can be reduced by 20%. It is assumed in the example that internal substation losses are countered by designing the unloaded voltage, i.e., the voltage at zero load, to be greater than the desired nominal voltage.

The maximum allowable distance between end of line and the first substation is approximately one-quarter of the distance cited in Table 2.2-2. In the example above, this distance would be one-half mile, which conforms with the table (10,000'/4 = 2500 or approximately one-half mile).

Table 2.2-2

Maximum Substation Spacing for 4/0 Copper Wire Feederless System

Ampere Load		Substation Spacing (feet/meters)	
Diversity Curve	RMS	10% Voltage Drop	15% Voltage Drop
400	600	8000/2438	11900/3627
600	900	5300/1615	8000/2438
800	1200	4000/1219	6000/1829
1000	1500	3200/ 975	4800/1463

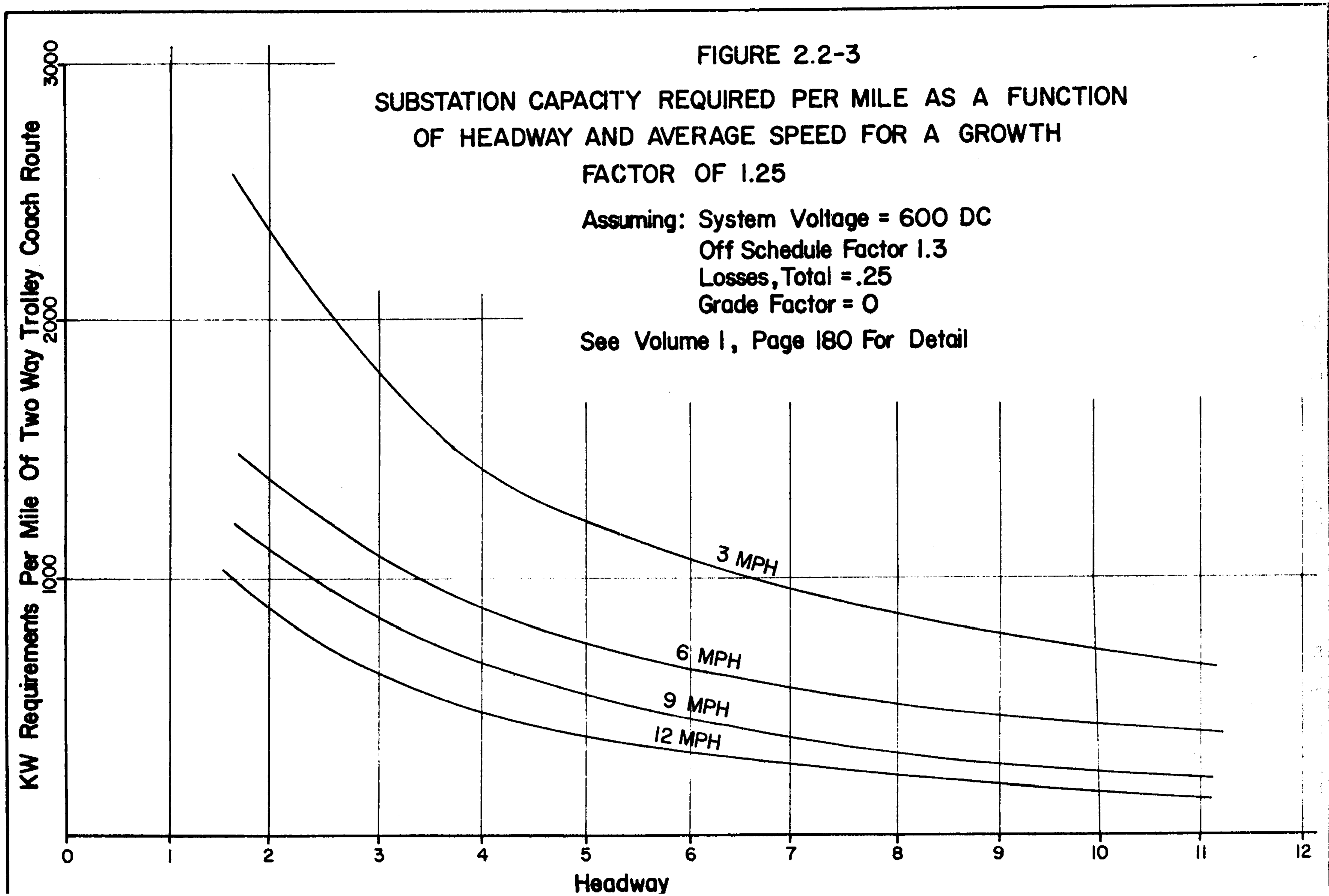
FIGURE 2.2-3
SUBSTATION CAPACITY REQUIRED PER MILE AS A FUNCTION OF HEADWAY AND AVERAGE SPEED FOR A GROWTH FACTOR OF 1.25
Assuming: System Voltage = 600 DC
Off Schedule Factor 1.3
Losses, Total =.25
Grade Factor = 0
See Volume I, Page 180 For Detail
KW Requirements Per Mile Of Two Way Trolley Coach Route
3000
2000
1000
3 MPH
6 MPH
9 MPH
12 MPH
0
1
2
3
4
5
6
7
8
9
10
11
12
Headway

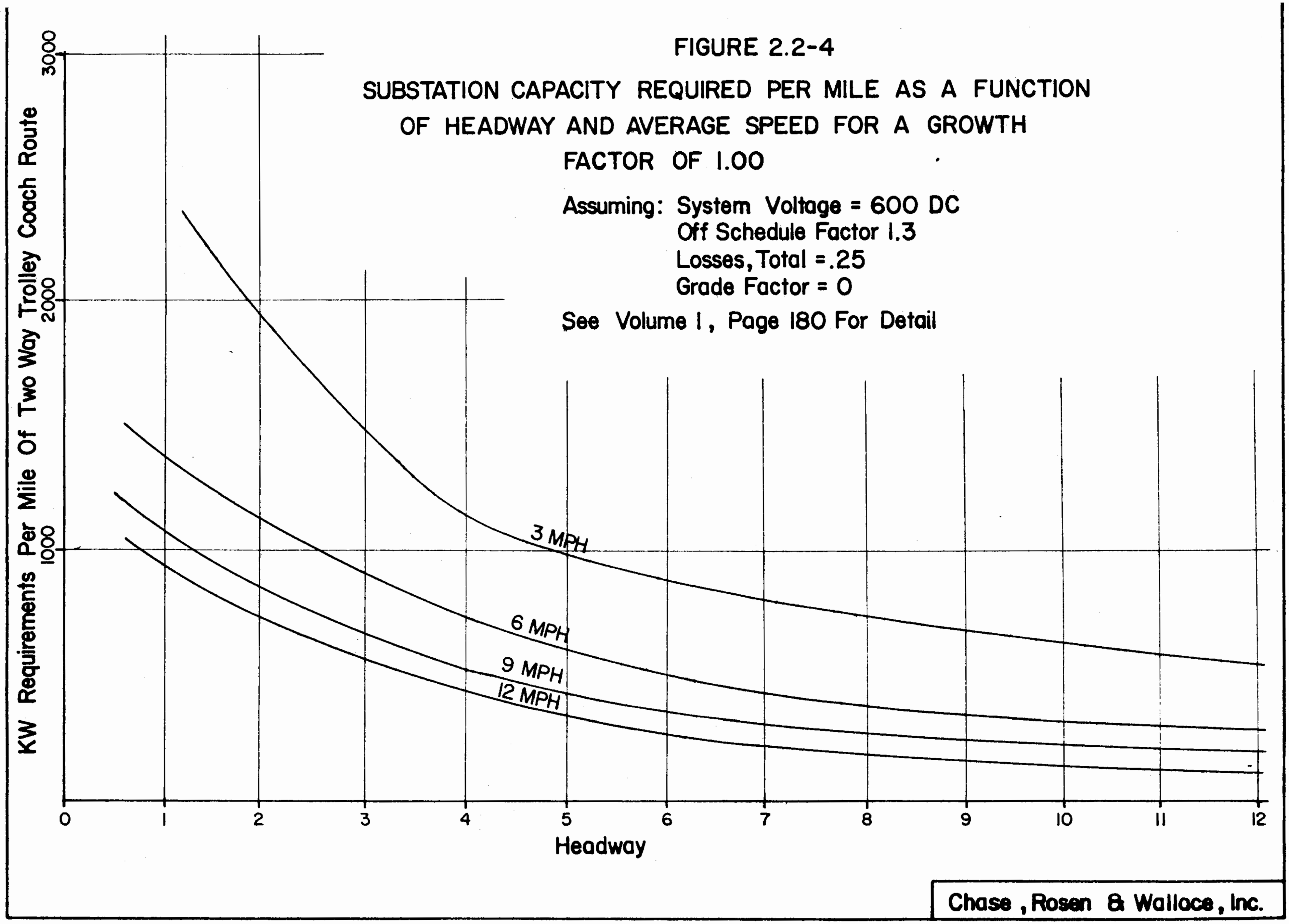
FIGURE 2.2-4
SUBSTATION CAPACITY REQUIRED PER MILE AS A FUNCTION OF HEADWAY AND AVERAGE SPEED FOR A GROWTH FACTOR OF 1.00
Assuming: System Voltage = 600 DC
Off Schedule Factor 1.3
Losses, Total = .25
Grade Factor = 0
See Volume I, Page 180 For Detail
KW Requirements Per Mile Of Two Way Trolley Coach Route
3000
2000
1000
3 MPH
6 MPH
9 MPH
12 MPH
0
1
2
3
4
5
6
7
8
9
10
11
12
Headway
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The design of a conventional feeder system is far more complicated. The capacity at a central substation is sensitive to the length and size of feeder circuits employed. The station must be sized to accommodate the proposed service plan and overcome feederline losses. The process of determining the optimum substation size and feeder network is an iterative process. Several circuit designs may be required before the optimum system is determined. The reader is referred to Task 1, Chapter 1.2, Power Supply for TC's, for a more detailed discussion.

Seattle Substation Costs - Table 2.2-3 indicates the installed costs associated with the Seattle program described above. The costs associated with the feederless substation include all required items. The CBD station costs do not include DC switch gear, but do include rehabilitation of the equipment previously employed. Installation costs cover the pulling of new feeder cable in existing conduits, although some small amount of new conduit was required.

Vehicle Costs

The cost history associated with recent TC purchases is shown in Figure 2.2-5. This figure indicates the prices associated with TC's using both new and rebuilt electrical equipment. The figure also indicates the prices of motor coaches in the time period between 1974 and 1979. The approximate ratio of TC to motor coach costs is 1.5:1. The cost of new-look TC's can be obtained by trending the data provided or by updating the history of new-look motor coach costs and applying the above factor. The cost associated with advanced design bus (ADB) TC's has yet to be established, but a rough estimate could be obtained by using the 1.5 factor. Trended estimates should add $17,000 (1979 dollars) for the wheelchair lift.

Based on the recent experience in Seattle, where the chopper was only $2000 more expensive than conventional MRC, chopper and resistor control costs are considered equal. If it is desired to purchase emergency off-wire capability, the following estimates can be employed:

- Volkswagen/generator package $15,000
- Battery package $ 8,000

The costs associated with recent articulated motor coach purchases compared to standard coaches have set a pattern of approximately 2 to 1. It is assumed that the same ratio would apply to anticipated TC's.

Facility Modifications

In terms of its overall size, shape and space required for maneuvering, the TC is identical to the motor coach. Facility modifications will be required only to accommodate the need for an overhead collection system. The nature of facility modifications are as follows:

Table 2.2-3

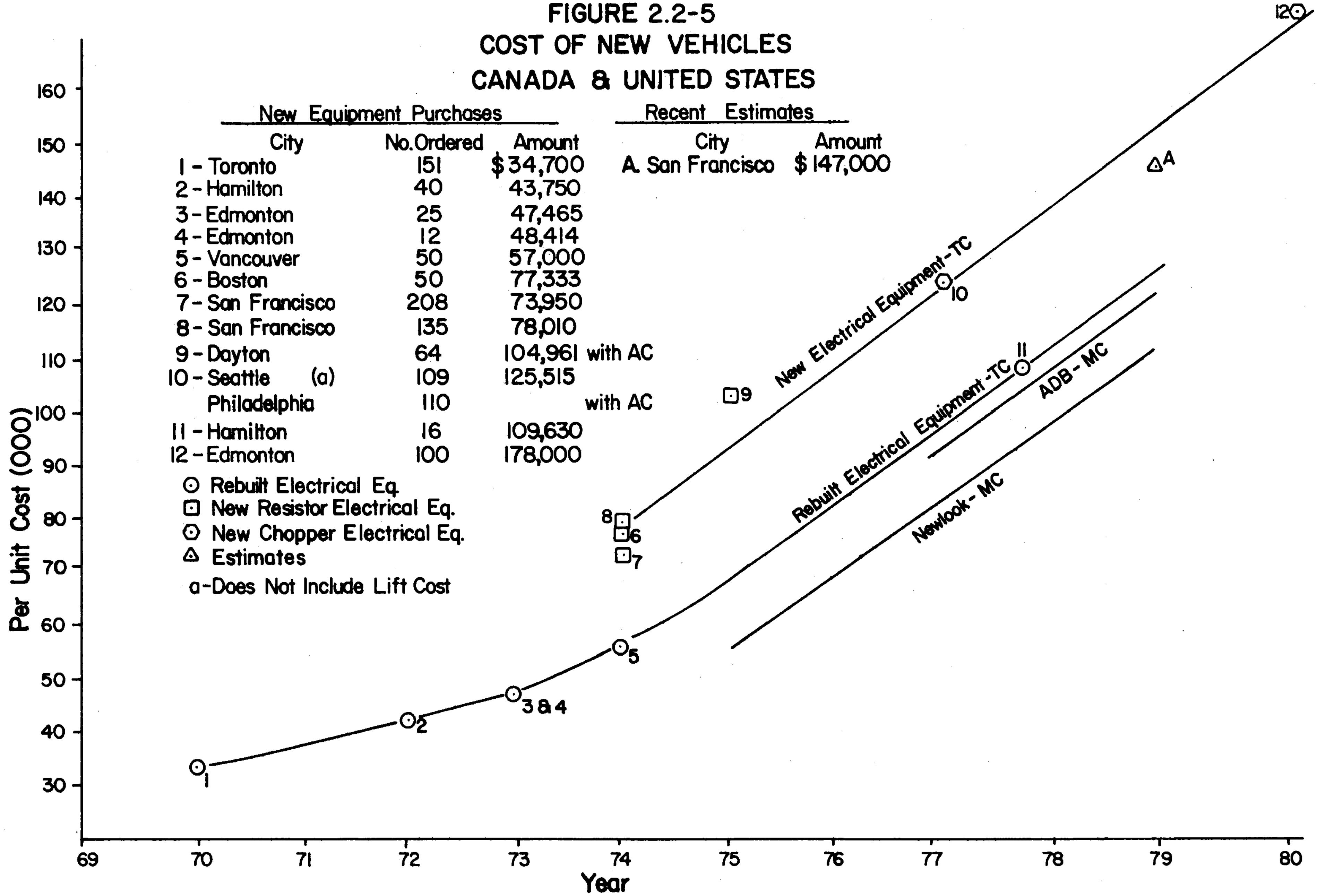
Costs of
Rehabilitating CBD Substation and Feeder System and
Installation of Feederless Substations
in Seattle
(in thousands of dollars)

	Costs			
	Total	Per Mile/Kilometer		
Non CBD-Feederless System				
Rectifier Equipment - 26 500 kw stations	$ 1,574	$ 28	(1)	$ 17
Installation - 20 stations	1,992	43	(2)	27
Site Acquisition or long-term lease - 23 sites	172	3	(1)	2
		$ 74		$ 46
CBD-Feeder System				
Rectifier Equipment - 4 1500 kw, excluding DC switch gear	$ 168	$ 3	(1)	$ 2
Installation of substations and rehabilitation of feeder system	949	17	(1)	10
Site Acquisition - 25 year lease on two sites	184	3	(1)	2
		$ 23		$ 14
Total Substation Costs		$ 97		$ 60

(1) Cost spread over 55 two-way wire miles, (88.5 km.). The CBD consists of 7.7 one-way wire miles.

(2) Per unit price multiplied times 24 and divided by 55. Further installation contracts remain to be let.

FIGURE 2.2-5
COST OF NEW VEHICLES
CANADA & UNITED STATES



New Equipment Purchases

City	No. Ordered	Amount
1 - Toronto	151	$34,700
2 - Hamilton	40	43,750
3 - Edmonton	25	47,465
4 - Edmonton	12	48,414
5 - Vancouver	50	57,000
6 - Boston	50	77,333
7 - San Francisco	208	73,950
8 - San Francisco	135	78,010
9 - Dayton	64	104,961 with AC
10 - Seattle (a)	109	125,515
Philadelphia	110	with AC
11 - Hamilton	16	109,630
12 - Edmonton	100	178,000

Recent Estimates

City	Amount
A. San Francisco	$147,000

⊙ Rebuilt Electrical Eq.
⊡ New Resistor Electrical Eq.
⊙ New Chopper Electrical Eq.
△ Estimates
a-Does Not Include Lift Cost

Source: References B,C,D

- Ceiling heights should be no lower than approximately 16' (5m.) to accommodate TC's in storage, servicing and inspection areas, although heights as low as 13' (4 m.) are workable. Typically ceiling heights in existing motor coach garages conform to this 16' (5 m.) requirement.

- Building entrances should also be 16' (5 m.) or greater in height.

- Existing washers that include roof and back brushes must be modified or new washers installed for TC's.

- In-line storage must be installed for TC's if it is not already employed.

Since requirements in this area will very greatly, no cost guidelines are provided. A more detailed discussion of this subject is found in Chapter 1.4. The costs associated with the installation of the Seattle coach yard will be available in late 1981.

<u>Staff Training</u>

Training is required for operating, supervisory and certain maintenance staff to illustrate the principal differences between motor coaches and TC's. Chapter 1.4 indicates the subjects that must be covered. It is assumed that this program could be completed in three days. The capital cost associated with this effort would equal three days pay for the staff involved.

Additional staff training may be required in other areas if sufficiently trained personnel cannot be recruited. The areas referred to are:

- Electronic systems - The use of solid state substation equipment or chopper propulsion systems will require the employment or training of persons to maintain sophisticated electronic systems.

- Contact wire systems - If experienced linemen cannot be recruited in sufficient numbers, an apprentice program would be required.

<u>Other Capital Cost Items</u>

Certain other costs must also be included. These are:

- Engineering - Costs associated with designing the new TC system and preparing the necessary construction documents. These costs normally run 10 to 20 percent of the costs identified above.

- Local taxes - Cost of sales tax, required permits and others, as locally appropriate.

- Construction inspection - Costs associated with inspecting contractor work to insure compliance with specifications. These costs normally run about 2% of the costs identified above.

- Management staff - Costs associated with the management of engineering and installation contracts.

Operating Costs

Vehicle Maintenance

The discussion of the vehicle maintenance function in Chapter 1.4 indicated that TC maintenance, excluding the servicing function, involved less effort when compared with the motor coach. Several examples were provided to document this point. In this chapter the cost relationships will be indicated and documented.

Many previous comparisons of TC's and motor coaches have employed maintenance costs shown in an operator's annual or monthly statement of expenses. This approach will not generally present a true picture of the cost relationships between the two vehicle types. The following reasons can be cited:

- The life cycle costs associated with the various fleets are ignored.
- The comparisons are made only for one period of time. Abnormal occurrences during this period can cloud the true cost relationship.
- The comparisons generally contrast the average costs of several motor coach fleets of varying age with a single TC fleet.

The first point is perhaps the most important. Comparisons of TC and motor coach maintenance costs should ideally include the following:

- The comparisons should be between fleets that were purchased at roughly the same time. Since a TC fleet's life cycle is greater than that of a motor coach fleet, the comparisons, ideally, should include a second motor coach fleet to replace the one purchased initially.
- The comparison should include the maintenance cost history from date of purchase for the fleets to be compared.

Unfortunately, the "real world" does not always provide the best possible data. Two comparisons are illustrated below to indicate the approaches taken by operators to support continued TC operation.

San Francisco - In the period of time between 1955 and 1960, the Municipal Railways of San Francisco (Muni) purchased over 300 Mack diesel motor coaches to replace gasoline powered White vehicles. The replacement was largely completed in 1960. Muni purchased its TC's, approximately 330 in number, between 1949 and 1951.

Between 1960 and 1969 Muni's coach fleet consisted almost entirely of new Mack motor coaches. As shown in Table 2.2-4 and Figure 2.2-6, trolley coach costs per mile (CPM) were less in this entire period. This is in spite of the fact that the TC fleet was older and had accumulated greater mileage. During the initial phase-in of the Mack's in

Table 2.2-4

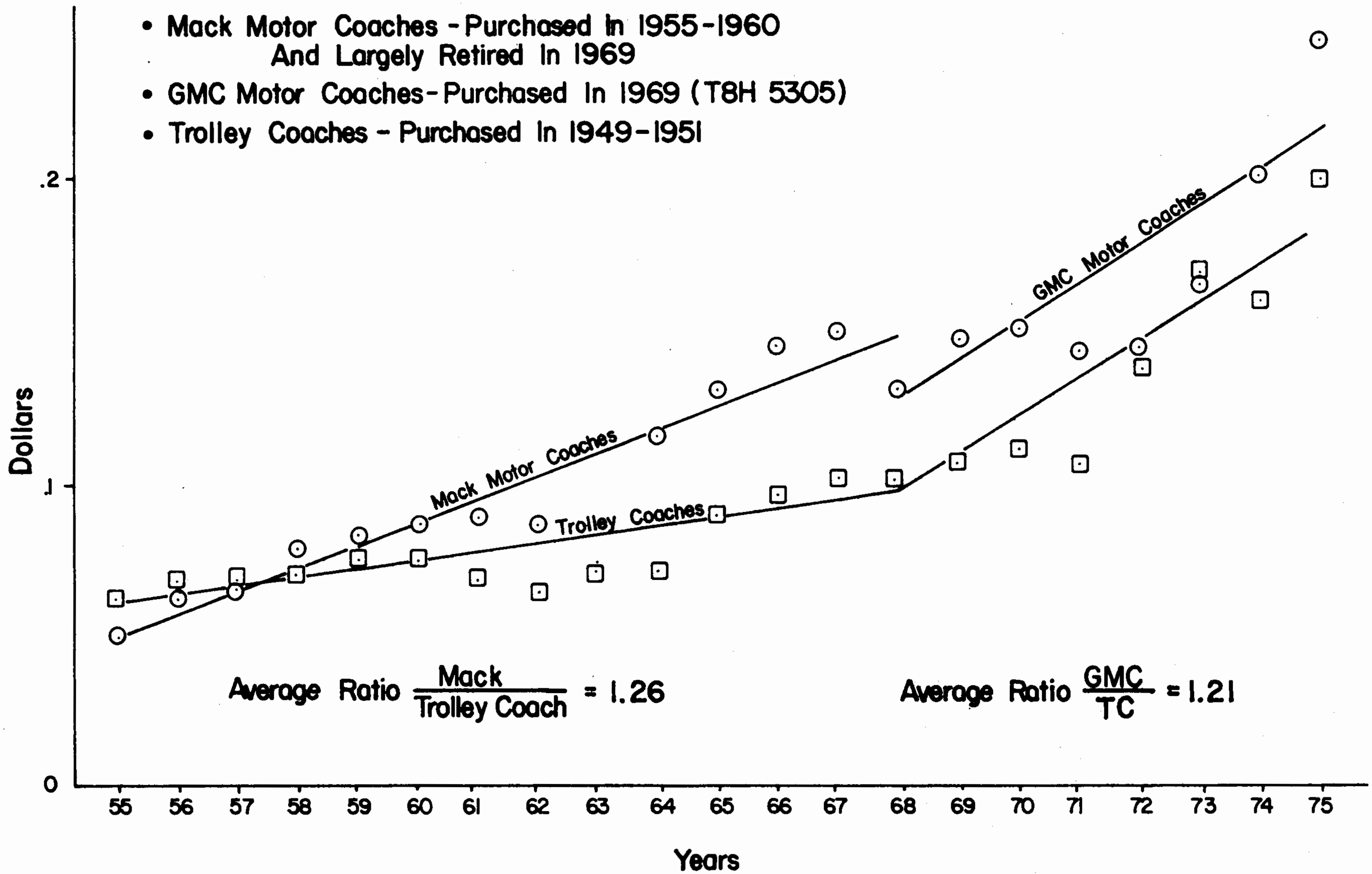
Trolley and Motor Coach Maintenance Costs
San Francisco

Year	Mack Motor Coach	GMC Motor Coach	Marmon Trolley Coach
	Cost in Cents Per Mile/Per Kilometer		
1955-56	.049/.030	--	.061/.038
1956-57	.061/.038	--	.065/.040
1957-58	.067/.042	--	.064/.040
1958-59	.078/.048	--	.070/.044
1959-60	.082/.051	--	.076/.047
1960-61	.087/.054	--	.073/.045
1961-62	.088/.055	--	.068/.042
1962-63	.085/.053	--	.063/.039
1963-64	.072/.045	--	.070/.044
1064-65	.114/.071	--	.070/.044
1965-66	.130/.081	--	.088/.055
1966-67	.144/.089	--	.085/.053
1967-68	.149/.093	--	.100/.062
1968-69	.130/.081	--	.100/.062
1969-70	--	.145/.090	.104/.065
1970-71	--	.149/.093	.110/.177
1971-72	--	.142/.088	.105/.065
1962-73	--	.142/.088	.135/.084
1973-74	--	.164/.102	.168/.104
1974-75	--	.200/.124	.158/.098
1975-76	--	.246/.153	.198/.123

FIGURE 2.2-6

TROLLEY AND MOTOR COACH MAINTENANCE COSTS

SAN FRANCISCO



Source: Reference D

1955 and 1956, the combined CPM for both motor coach types was less than TC CPM. This is probably due to the lower costs associated with the new Mack fleet. It is surprising to note during the White fleet's final phase-out years, 1957 through 1959, the trolley coach fleet became economical to operate. In the period 1955 to 1968, the average ratio of motor coach to TC CPM is 1.26:1.

Between 1969 and 1975 the motor coach fleet consisted of 390 new GMC T8H-5305 coaches and approximately 100 of the older Macks. In all years except 1973 the TC's were still the most economical fleet. The average ratio of motor coach to TC CPM in this period dropped to only 1.21:1.

It should be noted that Muni has separate maintenance departments for electric vehicles, both TC and LRV's, and motor coaches. This fact minimizes the cost allocations that must be made between these vehicle types. The cost allocations between LRV's and TC's is also minimal, since most of the TC costs are incurred at two maintenance locations that accommodate only the latter vehicle. This situation greatly enhances the reliability of the cost comparisons.

Toronto - In the late 1960's, the Toronto Transit Commission (TTC) performed an in-house study to determine if it was economical to replace its aging TC fleet. The TTC approach was slightly different in that they chose to look at CPM as a function of accumulated fleet miles rather than calendar year costs. The results are shown in Figure 2.2-7.

The comparison, conducted in 1969, was between the TC fleet of 150 vehicles and a fleet of 150 GMC TDH-5301 coaches. Since each fleet accumulated mileage over a different span of time, all costs were revised to reflect 1969 costs. The results indicate that after 25 million fleet miles (40 million fleet km.), the difference between the two curves stabilized. In the range of 25 to 50 million miles (40 to 80 km.), the average CPM ratio of motor coaches to TC's was about 1.40:1.

Toronto maintains a fleet accounting system for maintenance costs. Although this does not eliminate all cost allocations, it does enhance the reliability of the cost comparison.

Vancouver - BC Hydro and Power Authority purchased two 50 vehicle TC and motor coach fleets in 1975 and 1976. The recent cost experience with these fleets is shown in Table 2.2-5 and Figure 2.2-8. Although this is a point of time comparison, rather than life cycle, it does show the cost relationship for two fleets of similar age in the initial years of service. The previous two examples do not portray similar information. The ratio of CPM for motor coaches to TC is 1.27:1.

Conclusions - Although the data employed was not ideal in the strictest sense, it can be concluded that TC's do enjoy maintenance cost advantage over motor coaches. Based on the above comparisons, the ratio of motor coach to TC costs varies between 1.21:1 and 1.40:1. We feel that 1.3:1 would be a prudent value to use in any comparative studies. The maintenance of a new TC fleet would be developed by first determining similar costs for a comparable motor coach fleet, using local cost experience, and then applying the above factor.

FIGURE 2.2-7

TROLLEY AND MOTOR COACH MAINTENANCE COSTS
TORONTO

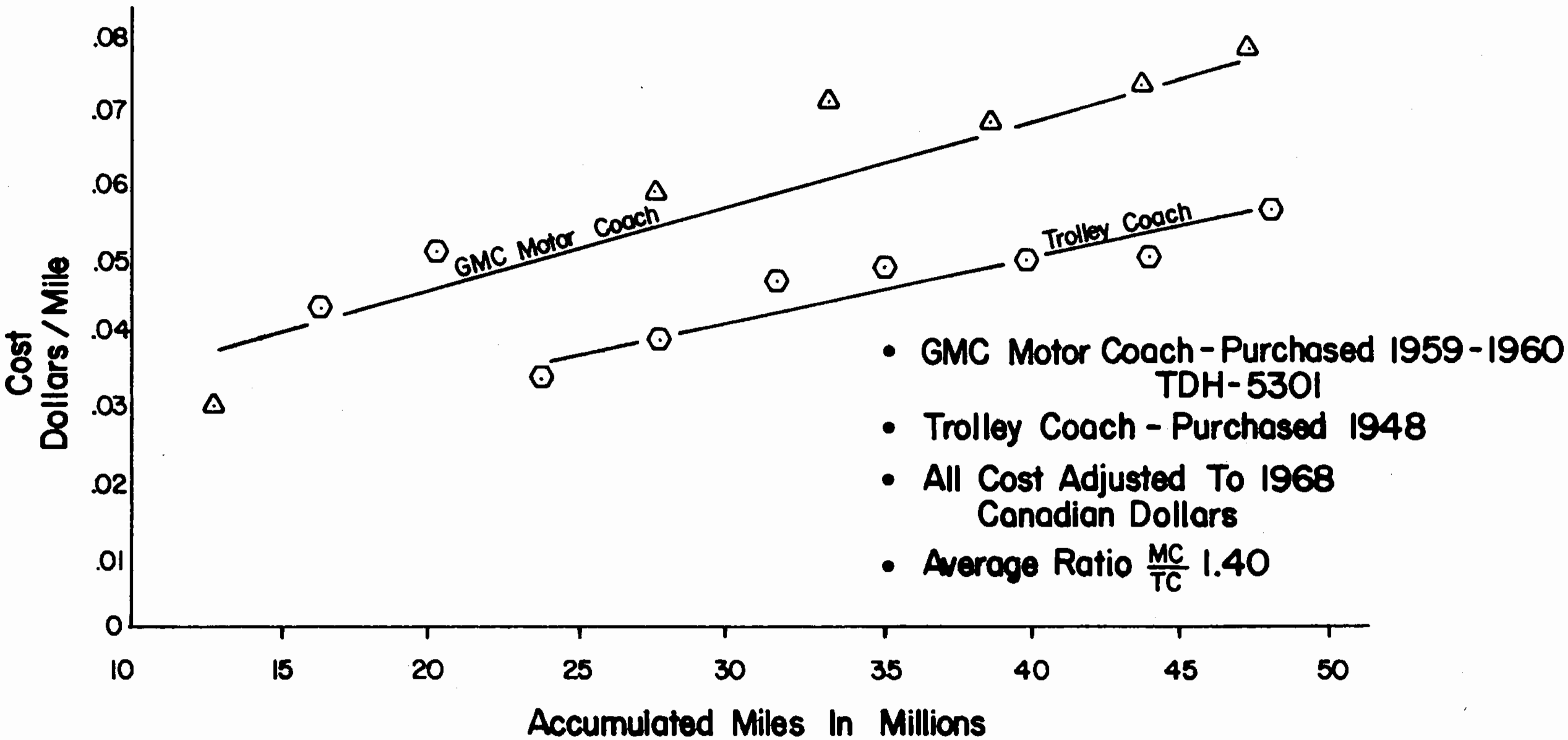


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Table 2.2-5

Comparison of Fleet Maintenance Costs
Vancouver

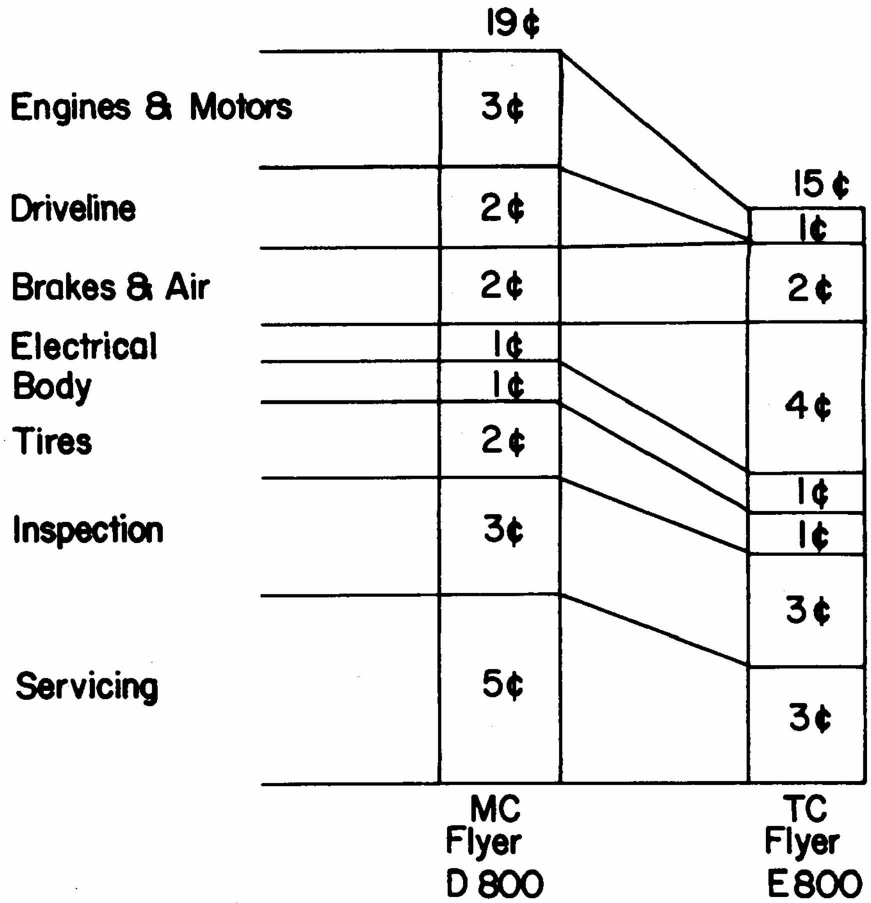
	Costs for the 12 Month Period Ending 3/31/78			
	Total Cost		Cost Per Mile	
Costs - Maintenance	Flyer D800	Flyer E800	Flyer D800	Flyer E800
Engines/Motors	$57	$16	$ .03	$ .01
Drive Line	47	3	.02	--
Brake and Air	49	23	.02	.02
Suspension	8	2	--	--
Electrical	26	48	.01	.04
Body	32	17	.01	.01
Tires	34	16	.02	.01
Inspections	69	39	.03	.03
Costs - Servicing	111	33	.05	.03
Total	$439	$191	.19	.15
Ratio MC/TC CPM			1.27	

Fleet Data

Year purchased	1975	1975-76
Number of units	50	50
Accumulated fleet miles (000)	5,010	2,440
Average yearly mileage per Vehicle (000)	45	25
Annual fleet mileage (000) 12 mo. ending 3/31/78	2269	1261

FIGURE 2.2-8

COMPARISON OF FLEET MAINTENANCE COSTS (1)
VANCOUVER



(1) - Based on fleet costs for the 12 month period ending 3/31/78

Source: Reference F

Vehicle Servicing Costs

It was stated in Chapter 1.4 that the time required to service TC's is generally less than that for motor coaches. The cost experience of several TC operators was reviewed to document this statement. The results are shown below in Table 2.2-6.

Total servicing costs for each mode were divided by the number of coaches operated rather than the number of revenue miles generated. Vehicle servicing is generally undertaken only once a day or is a function of the number of pull-ins. Comparisons using costs in cents per mile are valid only if both vehicle types accumulate approximately the same amount of mileage. Typically TC's are assigned to routes that have low average speeds and therefore accumulate fewer miles for a given time period than motor coaches.

Table 2.2-6

Relationship of TC and Motor Coach Servicing Costs

City	Ratio-Average Annual Vehicle Servicing Costs, Motor Coach/Trolley Coach
San Francisco	1.44
Vancouver	1.88
Philadelphia	2.22
Average	1.85

Approximations of per vehicle servicing costs on a new TC system can be obtained by determining the annual per vehicle servicing costs associated with the existing motor coaches and dividing by 1.9. The net annual reduction in servicing costs is obtained by multiplying the number derived above times the number of new TC's required and subtracting the resulting amount from a similar figure derived for the motor coaches to be replaced.

Overhead Line and Substation Maintenance

The costs associated with this function are highly labor dependent. Since labor rates vary across the country, it is not practical to use another system's established cost unless it can established that similar rates of pay and work practices are to be employed. An alternative course is to estimate staff requirements and apply local labor and fringe benefit rates. Table 2.2-7 has been provided to aid in determining staff requirements on new TC systems.

The principal maintenance efforts required on new systems will consist of:

- Repair of damage caused by vehicular traffic.
- Overhead changes required by new highway construction, redevelopment and so forth.

Table 2.2-7

Personnel Requirements for Substation and Overhead Line Maintenance on New TC Systems

One Way Wire Miles	Line Crew Personnel	General Foreman	Office Staff	Substation Personnel	Total Personnel	Line Trucks
30	4	1	--	--	4	2 (A)
40	4	1	--	--	5	2 (A)
50	4	1	--	--	5	2 (A)
60	8	1	--	1	10	2
70	8	1	--	1	10	2
80	8	1	--	1	10	2
90	12	1	1	1	15	3
100	12	1	1	2	16	3
110	12	1	1	2	16	3
120	16	1	1	2	20	4
130	16	1	1	2	20	4
140	16	1	1	2	20	4
150	16	1	1	2	20	4

Line Crews: One Foreman/Lineman
Two Linemen
One Groundman/Driver/Helper

(A) One truck to be used as a spare.

Substation Personnel:

It is assumed that for 50 one-way wire miles (80 km.) or less, the capabilities for substation maintenance would be provided by one of the line crew or by personnel from the vehicle maintenance department if chopper equipment is to be obtained. It is assumed that state-of-the-art conversion equipment is employed.

Source: Current operator practices.

- Repair of damage caused by dewirements.

- Construction inspection during the installation period.

As the system advances in age, renewal activity related to system wear will be undertaken in conjunction with periodic inspections of the wire system. This effort may require additional personnel.

Material and supplies required for this function have been found to average approximately 20% of labor and fringe benefit costs on established systems. New systems should experience a slightly lower amount.

Electric Power Costs

Power costs vary quite widely across the country. San Francisco has a very favorable rate, since the city has its own hydro generating facilities. Eastern TC operators pay a substantially higher rate. The costs determined for comparison studies must be sensitive to local power rates.

Commercial power rates are based on two factors: (1) the maximum power requirement for the system and (2) the total power consumption. The first factor determines the demand charge which has the effect of charging the user for a portion of the fixed generating costs. The second factor charges the user for the variable costs based on total usage.

The maximum power usage can be estimated by employing the Diversity Curve, shown in Table 1.2-7 in Chapter 1.2 of the Task 1 report. The curve would be used as follows:

- Determine the maximum number of vehicles in service during either the morning or afternoon peak and thus solve the equation below.

  Ampere Requirements = 80 (max. buses) + 810

- Multiply the total ampere requirement times line voltage, normally 600 volts, and divide by 1000. The result will be an estimate of the maximum kilowatt demand.

Power consumption can be determined in the following manner:

- Estimate the amount of revenue mileage including both pull-out/pull-in and on-line service, for weekdays, Saturdays and Sundays.

- Expand these data to represent a typical month.

- Multiply this monthly mileage times an average consumption rate. Typical consumption rates are shown in Table 1.3-11 in Chapter 1.3.

With regard to the last step, consumption in areas with hilly terrain or Northern climates will tend to be higher.

The estimates derived above are for TC's equipped with an MRC cam controller. If a chopper controller is employed, both the total demand and consumption can be reduced by about 20%.

Having determined both the demand and consumption, the local power company can be consulted to determine the appropriate commercial rate. It should be noted that in the past, power rates were often set as a result of negotiations between the utility and the transit operator. In many instances historical precedents are also a determining factor. For a preliminary cost the prudent course would be to use an established commercial rate.

Having estimated a typical month's power charge, it should be converted to CPM. The net change in power costs can then be determined by comparison with the CPM costs for the motor coach fleet which is currently operating on the proposed TC routes.

Transportation Costs

In line with our conclusions in Chapter 1.3, that TC's and motor coaches have similar performance and can be treated as interchangeable, transportation costs will be assumed to be identical. It should be noted that in reviewing operating financial statements, TC CPM is usually more than motor coach CPM. This is due to the fact that the latter vehicle is in service on routes that have a higher average speed than TC routes. Thus the CPM is lower.

Relationship Between Principal Costs

Vancouver performed a present-worth study in 1978 to determine what course of action should be taken to replace its aging TC fleet. The results of this study are shown in Table 2.2-8, along with the principal assumptions employed. This table points out the relationship between some of the principal costs associated with TC's. Unfortunately it does not reflect all of the start-up costs associated with a new system.

The generalized statement has often been made that savings in TC fleet maintenance are offset by overhead maintenance. In other words, total TC maintenance costs are about equal to motor coach maintenance costs. Table 2.2-8 verifies this statement. On a present-worth basis, TC maintenance was $34,360 million versus $33,490 million for motor coaches, approximately the same cost.

The difference in vehicle costs is also minimal owing to the TC's longer life. The vehicle life cited is somewhat greater than present experience in this country. Vehicle life on U.S. systems is probably closer to 24 years for TC's and 12 years for motor coaches, as evidenced by recent operator experience.

The principal factor influencing TC retention in Vancouver is the cost savings associated with energy consumption. Vancouver has advantageous power rates which produce an effective cost per kilowatt hour of only 2.9¢. The energy savings for TC's are likely to be less in other areas that depend on non-hydro power sources. Power rates in the Eastern

Table 2.2-8 *

Trolley Coach vs. Motor Coach Costs

Summary of Present Worth
(in thousands of 1978 dollars)
Vancouver

	Trolley Coaches	Motor Coaches	TC Savings
Vehicle Purchases (1)			
1980-83	$36,500	$24,440	
1995-98	-	13,850	
Sale: Flyer TC's	-	-800	$ 990
Special Capital Costs (2)			
TC Overhead	570		
Diesel Garage		2,230	
TC Substations	1,060		600
Regular Maintenance (including servicing)			
TC Overhead	11,470		
TC Vehicles	22,990		
Diesel Vehicles		33,490	-970
Vehicle Fuels			
TC Energy	19,230		
Diesel Oil		29,430	10,200
	$91,820	$102,640	$10,820

(1) Purchase of: 262 TC's at $150,000 1980-83
317 MC's at $ 83,000 1980-83
317 MC's at $ 83,000 1995-98

(2) Includes required improvements to overhead and substations if TC's are retained and the addition of fueling and new garage facilities for replacement motor coaches.

Vehicle Life: TC 30 years; Motor coach 15 years
Inflation rates: 7.75% to 6.25% 1979-82 5.75% thereafter
Interest Rates: 7.75% to 7.00% 1979-82 7.00% thereafter
Span of PW Study: 1980-2012

* These results were obtained from a Present Worth study conducted in 1978 by the British Columbia Hydro and Power Authority in Vancouver.

United States, for example, are significantly greater. Recent rates in Boston, Philadelphia and Dayton have averaged 7, 3.5 and 4 cents per kilowatt hour, respectively. The current trend in diesel fuel oil prices might make electrical rates more attractive, but other fuels generally follow the trends established by the oil market.

Electric propulsion does offer a non-quantifiable advantage in that it draws on a variety of fuel sources and, additionally, during the lifetime of a TC system major shifts can be made in the fuel sources employed for the generation of power. The motor coach, on the other hand, is wedded to a continuing flow of diesel fuel oil.

The relationship between new system capital costs and operating costs can best be illustrated by a hypothetical example. Let us assume that total capital costs, exclusive of vehicles, average $450,000 per route mile and that operating costs favor TC operations by an amount of 5 CPM. If the life of the physical plant is 30 years, then the cost per year per mile is $15,000. If this amount is amortized on a CPM basis, 300,000 (15000/.05) vehicle trips per mile must be operated annually. This translates into approximately 1000 two-way or 500 one-way trips for a typical weekday. For a 16 hour service day, an average headway of 1.9 minutes would be required. For a cost effective system Figure 2.2-9 indicates this relationship for varying capital costs and a operating cost savings.

Although this is only a hypothetical example, it is readily apparent that only new systems with extremely high service densities and a favorable power rate can be completely cost effective.

<u>Conclusions</u>

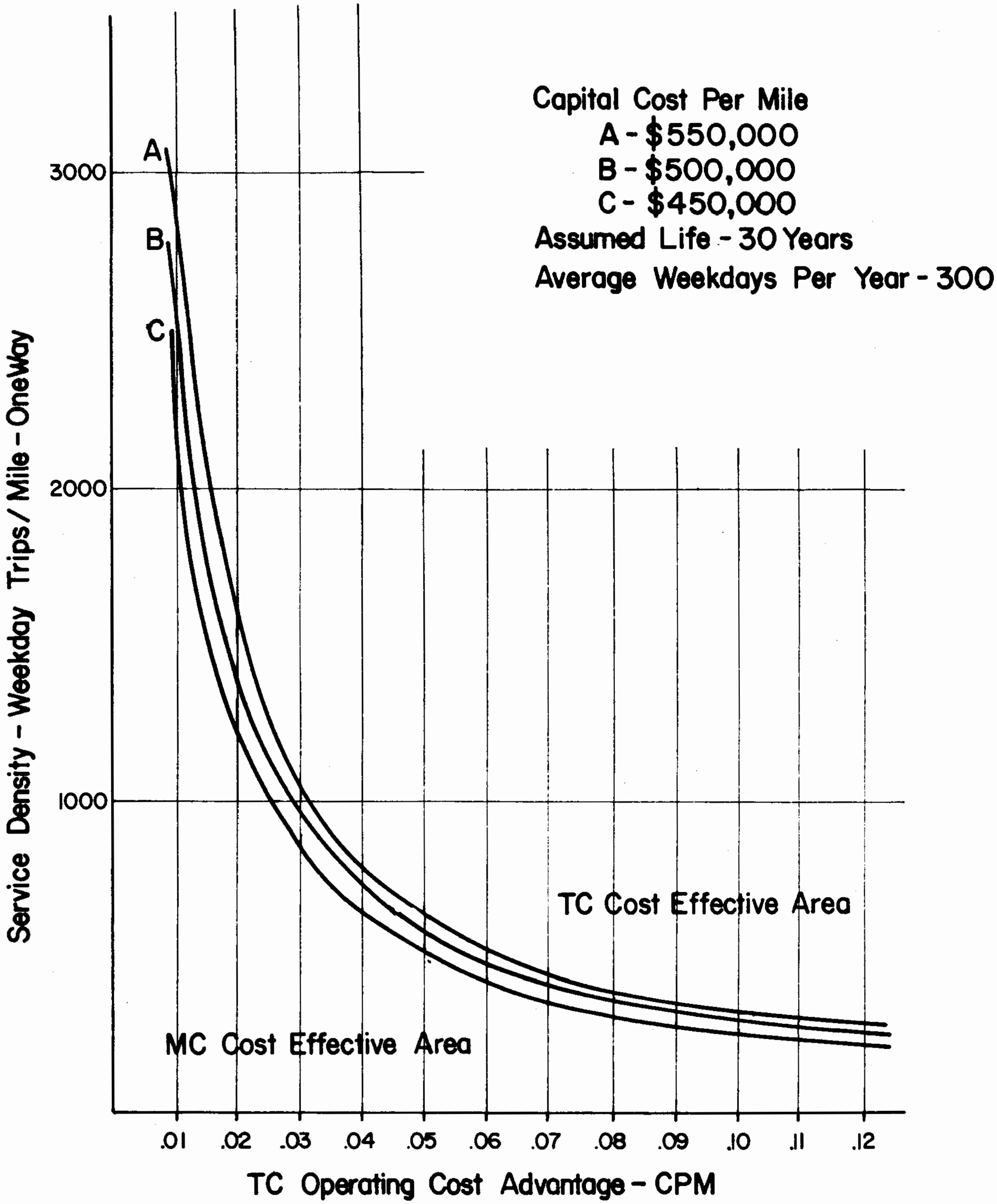
There are two general conclusions that can be reached concerning TC costs. These are:

(1) In most instances it is economical to replace older fleets and renew existing TC systems. Operating and fleet replacement costs will be similar for both vehicle types and energy costs will be the principal factor determining which vehicle is more economical. This is particularly true in cities such as Seattle and San Francisco that have major routes transversing steep grades.

(2) New systems will not generally be cost efficient when compared to motor coach operation. The costs associated with the power distribution system, when amortized over a 30 year life, will not generally be offset by TC operating cost savings. Cities that have favorable power rates and a high service density, such as San Francisco, may provide a cost effective environment for a new TC system.

FIGURE 2.2-9

RELATIONSHIP OF TC OPERATING COST SAVINGS TO CAPITAL COST



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The relationship between diesel oil costs and electric power rates is presently very dynamic. Some estimates do indicate a widening gap favoring electric propulsion. Unfortunately the capital costs associated with new TC systems are also increasing due to inflationary pressures. The effect of these two changing situations is difficult to judge. Should their interaction lead to increased cost savings for the TC, it would become cost effective on systems with lower service densities.

The TC has advantages that are not quantifiable but can weigh heavily in TC vs. MC decisions. Principally the TC has environmental advantages in that it does not pollute and is far less noisy. These qualities can have a significant impact wherever there are concentrations of transit vehicles, such as in the CBD or at regional terminals. A further advantage is the TC's ability to draw on a variety of fuel sources.

CHAPTER 2.3

THE IMPACT OF TROLLEY COACHES ON LAND USE, COMMUNITY AESTHETICS AND ENERGY CONSUMPTION

Introduction

This chapter includes a description of the impact of trolley coaches on land use, the visual impact of overhead wires and the effect of a major expansion of trolley coach operation on national energy consumption. The impact on land use is minimal, as the trolley coach does not have any unique characteristics that cannot be duplicated by another vehicle type. The effect on overall energy consumption is also shown to be very small, due to the relatively small number of vehicles involved. The visual impact of overhead wires is a relatively minor problem and is often offset by the noise and air pollution effects of motor buses.

Land Use

Development activity in any community is a function of local economics, available labor and a variety of other factors. Transit service can affect the pattern of this development in certain situations. The transit mode employed must be:

- Perceived as a permanent element,
- Able to accommodate significant traffic volumes, and
- Able to provide travel time savings when contrasted to competing modes.

Trolley coaches generally will not have any significant impact on land use over that which would have occurred if motor coaches were employed. TC's are not a permanent fixture when comparisons are made with heavy rail and some light rail facilities. The overhead lines make them more permanent than a motor coach service, but the degree of permanency is a relatively minor item when contrasted to the size of major developments and their required investment level.

TC's operating in a normal urban environment will accommodate the same traffic level as motor coaches. Further, TC's will offer approximately the same travel time. Chapter 1.3 demonstrated that the performance characteristics of the two vehicles are almost identical.

The only situation where trolley coaches have capabilities that differ from motor coaches is the ability to more readily be utilized in underground facilities. However, any configuration of routes that may be developed utilizing such facilities could be duplicated using the light rail mode. The trolley coach in this situation has the advantage of lower construction costs due to the elimination of street trackage.

Visual Impacts of Overhead Lines

Many existing TC installations were designed and constructed with little thought given to minimizing the visual intrusion created by the overhead lines. A sample review was made of existing installations to identify and categorize the major visual impediments. This is accompanied by a list of practices that can be employed to improve the aesthetics associated with TC overhead networks.

Aesthetic Problem Areas

Major problem areas identified by sampling a variety of street environments are as follows:

- Feeder networks - Above ground feeder networks were found to be a visual impediment in many areas. The problem is most significant (1) near central substations where the number of feeder lines on a given street is the greatest and (2) in areas where utilities are installed underground.

- Major intersections - The use of special work at key transit intersections has a definite impact on aesthetics. The degree of visual pollution increases directly with the number of switches and crossovers installed.

- Support poles - In non-CBD areas, the inability to maximize joint use of poles with utility companies increases pole requirements and contributes to the visual clutter.

- Span wires - Span wires can become a greater source of visual pollution on wide thoroughfares where their presence is highlighted. Many systems have installed spans at shorter intervals than necessary, further degrading local aesthetics.

- Contact wires - The presence of contact wires is highlighted when they are installed close to the center of a street and when there is no background into which they can blend.

Practices to Improve Aesthetics

There are several steps that can be taken to improve the aesthetics of TC overhead and reduce or remove the more significant impediments. They are:

- Feeder systems - Feeder networks can be undergrounded to achieve a significant visual improvement. In new systems the feederless concept can be employed, thereby eliminating the need for a feeder network.

- Major intersections - There are a limited number of steps that can be taken to reduce the visual clutter that can occur at the junction of several TC routes, including:

- Install the contact wire as close to the curb lane as the wire configuration will allow. Such an arrangement will allow the overhead to blend into the background as shown in Figure 2.3-1. Additionally, installations of switches outside the intersection limits will also reduce special work concentrations and the accompanying visual clutter.

- If the intersections occur in open areas, trees can be planted along the curb line to provide a backdrop.

- Lay out TC lines and emergency routings, to the extent possible to avoid complex junctions in the heart of the CBD. Complex junctions, if necessary, could be moved to the periphery of the CBD where they are less obtrusive.

- The use of one-way pairs in the CBD will also reduce visual clutter at intersections.

Figure 2.3-1

Illustration of how to minimize the visual impact of contact wires by installing them close to the curb with special work installed at or near the intersection limits.

o Poles - Several actions can mitigate the impact of support poles:

- In CBD and other areas that have storefront commercial activity, building bolts can be employed to eliminate poles.

- Maintain maximum pole spacing unless street conditions dictate otherwise, i.e., horizontal and vertical curves, driveways and so forth.

- The use of wood poles should be eliminated in areas where they have a significant impact on aesthetics. Such areas include commercial areas, areas with underground utilities, and open space areas.

- Increase the number of joint use poles by negotiating attachment agreements with local utility companies. The joint use of poles for street lighting, for example, could greatly reduce the total number of poles required separately for each system.

- The avoidance of complex intersections will also greatly reduce the clutter of poles at these locations.

o Span wires - The impact of span wires can be reduced by installing modern bracket arms that have a free flowing form. Figure 2.3-2 shows such a treatment in Toronto. Maximizing pole spacing, as noted above, will also reduce the impact of span wires.

o Contact wires - The recent installation of a transit mall on Granville Street in Vancouver, as shown in Figure 2.3-3, indicates one way of reducing the visual impact of both contact and span wires. Trees were planted along the mall which was built with slight reverse curves. This treatment greatly minimizes the impact of TC overhead. The impact of contact lines on streets lined with either trees or buildings can be minimized by installing them as close to the side of the street as possible. This treatment causes the contact wires to blend into the background when viewed on the horizon.

Aesthetics as a Barrier

There have been recent instances where the TC has been rejected or proposed for removal because of the impact of overhead lines. A synopsis of some of these cases follows.

Seattle - During the preliminary planning stages, an environmental assessment was made of the program to rehabilitate and extend the TC network. During this process residents of Madison Park expressed concern about the reinstallation of TC overhead in their neighborhood. Apparently it was felt that plans to underground utilities in the community would be adversely affected by the return of TC's. The community's views were acknowledged and plans to reinstall TC's on Route 11 were withdrawn.

Figure 2.3-2

An installation of "freeflowing" bracket arms. Photo by Toronto Transit Commission from North American Trolley Coach Association.

Figure 2.3-3

View showing trolley coaches on the Granville Transit Mall in Vancouver

A proposed extension of Route 10 via East Boston Street to Route 9 was also rejected by local residents. In this case, however, it is not clear if it was the TC or simply a new transit service that was rejected.

San Francisco - During the early 1970's, plans were made to beautify Market Street in the CBD area. The project was devised as a result of the construction of the Market Street subway, which would remove all streetcars from surface operation in the CBD. Original plans called for removal of all TC overhead at the time streetcar operation was moved underground. Such an action, it was felt, would add greatly to the street beautification. The principal alternatives considered to replace TC's on Market Street were:

- Terminate routes 5, 6, 7 and 21 at the location they intersect at Market Street (see Figure 1.1-10 in Chapter 1.1) and convert route 8 to diesel. Service on route 8 would have to be increased to provide sufficient capacity to transport route 5, 6, 7 and 21 patrons to the CBD.

- Reroute routes 5, 6, 7 and 21 to alternative routes to reach the CBD and convert Route 8 to diesel.

The analysis of these alternatives indicated that both air and noise pollution would significantly increase, negating the reduction in visual pollution. Additionally, patrons were inconvenienced by the imposition of transfers, additional travel time, and poorer accessibility to CBD destinations.

Based on the analysis, it was decided that TC's would remain on Market Street. The presence of overhead wire had a lesser impact than high density motor coach operation.

Hamilton - The recent extension of the King Line was intended to serve the adjoining Borough of Stoney Creek. During the planning stages, several councilmen voiced disapproval of TC's because of the instrusion of overhead wire and its impact on the desire to underground all utilities. There was also a dispute as to the location of the new terminal in Stoney Creek.

The problems were not resolved and the new extension now terminates at the city line. One can only speculate, but if it had been a motor coach extension, it is quite likely that the transit route would now be serving Stoney Creek.

Conclusions - It is difficult to extract hard and fast conclusions from three examples, but the following observations are offered:

(1) Resistance to TC overhead develops when utilities have been undergrounded or efforts are underway to accomplish that end.

(2) The impact of TC overhead is greatly outweighed by increase in both air and noise pollution caused by diesels in high traffic areas.

Off-Wire Operation

The availability of vehicles that can operate off wire on a regular basis could improve the aesthetics of TC operation by allowing the removal of certain overhead facilities. The technology to support this type of operation is in place and improvements are currently being tested. Present off-wire operations consist of:

- Berliet ER100 - These vehicles are presently used in off-wire operations in Lyon, France. The off-wire capability is used daily and involves a substantial portion of the total route.

o Daimler-Benz OE305 and OE305G - These vehicles are designed for significant off-wire operation and are equipped with automatic rewiring which adds significantly to the vehicle's versatility. These vehicles are presently being tested in Esslingen (Stuttgart), West Germany. The reader is referred to Chapter 1.2 for a more detailed discussion of off-wire capabilities.

The availability of vehicles with significant off-wire capabilities, equipped with an automatic rewiring feature, leads to the following types of considerations that improve aesthetics:

(1) Wiring on lightly used branches and special work at their junction with the main route can be eliminated.

(2) CBD wiring and the accompanying concentration of special work can be eliminated. This capability is made possible by the speed at which the automatic rewiring feature works.

Off-wire capability does not come without drawbacks. The capability adds to vehicle costs, approximately $30,000 ($20,000 propulsion and $10,000 automatic rewire) and increases maintenance costs. A trade-off analysis would have to be conducted to determine costs incurred and costs saved (overhead not required). The use of diesel engine off-wire capability in central areas will also increase noise and air pollution in these areas.

It should be pointed out that UMTA is presently funding a Flywheel Bus Program, which is directed toward the deployment of vehicles with significant off wire capabilities. These vehicles would not have the adverse environmental side effects associated with diesel assisted off wire capability.

Energy Consumption

A popular argument for conversion to electric powered transportation technologies is their positive impact on petroleum conservation. Depicted in Table 2.3-1 are the energy impacts resulting from the conversion of the previously-defined basic service market from diesel motor coach to electric trolley coach. As indicated, this would entail a large scale replacement of 9,183 motor coaches with electric trolley coaches. The resulting annual savings in diesel fuel is estimated at 86.77×10^6 gallons, and the estimated increase in electric power consumption is 1.27×10^9 kwh.

Assuming the most optimistic estimate of the electric trolley coach market, annual diesel fuel savings are estimated at 111.70×10^6 gallons, and the estimated increase in electric power consumption is 1.63×10^9 kwh.

Given current U.S. oil consumption in the range of 20 million barrels per day, which translates to $401{,}500 \times 10^6$ gallons per year, even the most optimistic estimate of conversion from diesel motor coach to electric trolley coach would yield a savings in fuel consumption amounting to 0.00028 of the national total. To the extent that additional electricity requirements are generated by fuel oil, (approximately 15% on a national basis) even this savings is reduced.

Table 2.3-1

Energy Impacts of Basic Service Market Conversion from Diesel Motor Coach to Electric Trolley Coach

City	1 Basic Service Market (Vehicles)	2 Average Annual (a) Miles/Vehicle	3 (1 x 2) Annual Veh.-Miles (Millions)	4 Motor Coach MPG	5 (3 ÷ 4) Annual Diesel Fuel Reduction (Million Gallons)	6 Additional Electricity Needed (b) Million kwh
New York/New Jersey	2,713	33,226 (c)	90.14	3.67 (c)	24.56	360.56
Chicago	1,576	40,591	63.97	3.31	19.33	255.88
Los Angeles	740	36,149	26.75	4.47	5.98	107.00
Philadelphia	792 (d)	28,540 (e)	19.78	3.28 (e)	6.03	79.12
Detroit	342	36,817 (f)	12.63	3.41 (f)	3.70	50.52
San Francisco	291	28,723	8.36	2.80	2.98	33.44
Oakland	135	33,805	4.56	4.96	.93	18.24
Boston	248	32,000 (g)	7.94	3.94	2.02	31.76
Cleveland	211	31,982	6.75	3.87	1.74	27.00
St. Louis	137	32,448	4.45	3.87	1.15	17.80
Pittsburgh	98	43,242 (h)	4.23	4.09 (h)	1.03	16.92
Minneapolis/St. Paul	236	30,832	7.27	3.91	1.86	29.08
Houston	97	46,566	4.51	3.98	1.13	18.04
Baltimore	435	31,492	13.70	3.53	3.88	54.80
Milwaukee	214	39,927	8.54	4.73	1.81	34.16
Seattle	52	46,596	2.42	4.67	.52	9.68
Atlanta	147	41,621	6.12	3.99	1.53	24.48
Kansas City	74	32,000 (i)	2.36	4.00 (i)	.59	9.44
Denver	77	34,269	2.63	4.55	.58	10.52
New Orleans	306	29,523	9.03	3.26	2.77	36.12
Portland	82	43,067	3.53	4.49	.79	14.12
Columbus	101	32,602	3.29	4.15	.79	13.16
Honolulu	79	55,108	4.35	4.06	1.07	17.40
Totals	9,183				86.77	1,269.24

Thus, from the perspective of national conservation of petroleum products, conversion to the electric trolley coach technology would be insignificant.

Nonetheless, the electric trolley bus may have an energy advantage of relevance in particular situations. First, if a region has an excess of electric generating capacity from nonpetroleum sources, so that marginal demand to power the system is readily available, the electric trolley coach would have an advantage. (It is doubtful that any region is so fortunate.) Second and more significant, the conversion from diesel fuel to electric power generation does introduce an element of flexibility in terms of ultimate energy source. Stationary generating facilities are capable of being designed to use a variety of energy sources, including oil, natural gas, hydro, coal, nuclear, and more esoteric fuel sources. In the foreseeable era of energy shortages, it appears prudent to place a high value on flexibility. Thirdly, in tight supply markets for diesel oil, systems with significant TC operations are less vulnerable to service disruptions than systems totally dependent on motor coaches.

Footnotes to Table 2.3-1

(a) Derived from Transit Operating Report for Calendar Fiscal Year 1975, American Public Transit Association, Washington, D.C., 1977.

(b) Assumes electric energy consumption rate of 4 kWH per mile. For energy efficiencies greater or less than this, this column can be scaled up or down appropriately. At 3.5 kWH per mile the total electricity needed for the basic service market would amount to 1.265.71 million kWH.

(c) These factors were derived from NYCTA statistics, as reported to APTA.

(d) Although the basic service market estimate for Philadelphia is 792, only 693 represent conversion from motor coach to TC, the remaining 99 results from potential streetcar to TC conversion.

(e) These factors were derived from SEPTA's City Division, as reported to APTA.

(f) These factors were derived from City of Detroit statistics, as reported to APTA.

(g) Since the MBTA did not report to APTA in sufficient detail to compute this number, 32,000 miles was assumed.

(h) These factors represent all Port Authority of Allegheny County operations.

(i) Kansas City did not report to APTA, so these factors are estimated.

CHAPTER 2.4

BARRIERS TO TROLLEY COACH EXPANSION AND POSSIBLE UMTA POLICIES

Introduction

This chapter describes the various barriers to expansion of trolley coach operation in the United States, as well as possible UMTA policies with respect to trolley coach expansion. The discussion is divided into five areas:

- Costs and Financing
- Availability of Equipment and Components
- Institutional Barriers
- Management and Operational Factors
- Community Acceptance
- Other UMTA Policies

Cost is by far the most significant barrier to trolley coach expansion. The historical description in Chapter 1.1 has shown that the decision to discontinue trolley coach operation was largely based on costs. The other barriers to expansion of trolley coach systems are relatively unimportant, as compared to cost. The most severe barrier is the local laws restricting the use of overhead wire current collection systems that exist in New York City and Washington, D.C.

Cost and Financing

The capital and operating costs of trolley coach systems have been described in Chapter 2.2. The significant variables identified were energy cost and the density of service. The unknown factor in the analysis of cost is the relationship between the cost of diesel fuel and the cost of electric power, both for individual situations and considering a future time frame. However, given current costs, the expansion of trolley coach systems appears to be economically viable only in a few areas, such as San Francisco, which have very low electric power costs and a high density of service. The cost differential between trolley coach and motor coach operation could change if diesel fuel increases in price at a higher rate than electric power.

Costs

There are two areas in which government policies can affect the cost of trolley coach operation. One of these is the area of electric power rates. Historically, electric railway and by extension, trolley coach systems, have been able to purchase power at rates that were generally more favorable than the prevailing industrial or commercial rate. This was largely due to the interrelationship between the two industries during their growth periods. Electric railways were the first large users of electric power. In many cases, the commercial sale of power was an outgrowth of the railway power supply. In other cases, favorable power rates could be obtained due to the electric railway being a large enough user so that operation of its own generating facility was a feasible option.

This historical precedent for favorable power rates still applies to certain transit systems, particularly those with extensive rail transit operations. However, any system not presently using electric vehicles will need to negotiate new power rates. This applies to 14 of the 22 systems shown in Chapter 2.1 as potential trolley coach users. Even those systems that have existing power rate structures may need to have these modified to satisfactorily utilize feederless substations, with the large number of low volume supply points required.

Electric power rates for large volume users are generally based on a combination of the amount of power used and the peak demand for power. Unit rates generally decline with increasing volume. All of these elements are intended to approximate in the rate structure the cost of producing and distributing electric power. However, all rate structures are to a large extent arbitrary. For example, the demand charge (a charge based on the peak demand for power) can reasonably reflect the need to size a particular part of the distribution network for peak loads, but does not reasonably reflect the cost of producing power during peak periods. This cost is a function of total system demand rather than the peak demand of any one user.

The discussion is intended to demonstrate that electric power rates as do most utility rates reflect an arbitrary allocation of costs among various user groups. This allocation is largely the responsibility of state regulatory agencies with the U.S. Department of Energy having some influence. The Public Utility Regulatory Policies Act of 1978 sets Federal standards for utility rate structures and stipulates, among other things, that elimination of declining block rates must be considered by state regulatory bodies in future rate determinations.

If the Federal government intends to expand the use of electric propulsion in the transit industry, as part of a nationwide energy policy, an appropriate action might be to provide incentives to the electric utility industry, which would yield favorable power rates. Action in this area would not only promote TC expansion, but aid urban rail systems and intercity railroad electrification.

A specific example of the type of arrangement required to encourage the use of trolley coaches is the power rate agreement obatained for the rebuilt Seattle system from the city-owned power department. The entire system will be treated as a single power consumer for billing purposes, thus obtaining the advantages of a volume rate, even though power is fed to a large number of small substations.

It must be pointed out in this discussion that trolley coach systems will generally have peak demands that coincide with, rather than complement, overall power system peak demand periods. Thus, the expansion of trolley coach systems will not serve to level out power demand.

The second aspect of cost that can be influenced by government actions is directly under the control of UMTA. This is the treatment of the capital funding of trolley coach systems under the various UMTA programs. The treatment of trolley coach systems that are replacements for motor coaches as eligible only for bus replacement funding would provide the lowest level of support for trolley coach expansion. Incremental costs of trolley coach systems would have to be funded locally or utilize operating assistance funding. The opposite approach, treating all components of trolley coach programs as eligible for discretionary funding would tend to encourage trolley coach expansion, as the local agency would not be constrained by the funds it would normally expect to receive on the standard formula allocation basis.

Several intermediate approaches are possible. One is to make discretionary funds available for wire and other trolley coach related fixed plant such as substations, but to require all vehicles be treated as bus replacements. A more liberal approach would be to make the incremental cost of trolley coaches over an equivalent number of motor coaches eligible for discretionary funding. The approach to be used in deciding the appropriate mix of funding for trolley coach projects will depend upon the desirability of trolley coach expansion from a Federal point of view.

Financing

The cost of the basic 10,000 vehicle trolley coach system described in Chapter 2.1 is estimated to be approximately $3 billion. This includes $1.5 billion for vehicles and an equal amount for wire. This cost is based on an estimate that approximately 3000 two-way miles (4800 km.) of wire would be required to utilize a 10,000 vehicle fleet. The estimate of wire mileage is based on an average vehicle density (peak vehicles per mile of line) of 3. For existing systems, vehicles per mile of line range from 1.7 in Seattle to 4.4 in San Francisco. On an annual basis, assuming a 10 year conversion program, the total cost would be 300 million dollars per year. Approximately one-third of this cost would be offset by a reduction in motor coach purchases, thus producing a net cost of $200 million per year. If all of this cost is eligible for Section 3 funding, the Federal share would be $160 million and the local share would be $40 million. This represents approximately 11.6% of Section 3 funds available in fiscal 1982, or 5.4% of all transit assistance (Section 3 and Section 5) fundings.

The incremental cost of the 10,000 vehicle trolley coach system would be, however, a substantial part of the discretionary funding available for bus systems. The $160 million is 62.7% of the $255 million in Section 3 funds allocated for bus capital improvements.

The local share of trolley coach financing should not be a major problem for most urban areas. The incremental vehicle cost is offset by longer vehicle life. The local share of the cost of wire installation may be offset by reduced operating costs. Using the approach shown in Figure 2.2-9, the operating cost savings required to offset overhead wire costs will range from 5¢ to 44¢ per vehicle mile, for service density levels of between 420 and 70 one-way trips per day (140 and 840 two-way trips). This range of service densities includes the minimum used as a cutoff point in developing a basic trolley coach market and extends up to the highest single route densities found outside of Manhattan. However, the local share of such expenditures represents only 20% of these amounts, or a range of 1.2¢ to 9¢ per vehicle mile. This level of expenditure is within the range of potential operating cost reductions resulting from conversion to trolley coach operation.

Financing of expanded trolley coach operation will not require any long term commitments as does, for example, fixed guideway financing. The $200 million per year financing level would be sufficient to produce viable operations in ten cities in the first year, assuming an average initial installation of 30 miles (48 km.) of wire and 100 vehicles. This size system would be viable even without future expansion. From a different point of view, the expenditure of $400 million, two years worth of funds, would be sufficient to install a large trolley coach system in Chicago as well as a smaller system in an area such as Minneapolis-St. Paul or add to the existing system in San Francisco.

Other Cost-Related Issues

One argument can be raised with respect to expansion of trolley coach systems is the potential diversion of funds from other projects. A likely tradeoff would be the installation of trolley coaches as compared to an expansion of transit service. Such a tradeoff analysis would generally indicate that trolley coach installation would produce greater benefits in terms of reduced petroleum consumption and thus decreased local air pollution as shown in the following example. However, the expansion of motor coach service would produce a benefit in terms of increased mobility that would not result from trolley coach installation in replacement of existing transit service. The high cost of new trolley coach installation argues against its use in an uncertain expansion of transit service area. Incremental expansion of existing service is best accomplished with motor coaches since it is likely to have relatively low utilization.

From the point of view of energy tradeoffs, consider the following example. If the expanded motor coach service attracts two trips per mile operated and that one-half of these trips are diverted from automobiles, then one fewer automobile trip would be made per transit mile operated. Assuming an average trip length of five miles, and fuel consumption of 20 miles per gallon, automobile fuel consumption would be reduced by 0.25 gallons per bus mile, but fuel consumed by buses would increase by the same amount, at a bus consumption rate of four miles per gallon, resulting in no net change in petroleum usage. This hypothetical expanded transit service would have to divert twice as many automobile trips in order to save as much petroleum as would be saved by conversion of an established transit route to trolley coaches.

Another cost related issue is the question of the long term life of a trolley coach system. It may be argued that an energy storage system for vehicle propulsion, such as a battery or flywheel system, would provide the benefits of the trolley coach without the expense and disadvantages of installing an extensive network wire. However, no such vehicle of suitable performance is currently commercially available, although experimental storage systems have a history as long as electric propulsion. The initial findings of UMTA's "Study of Flywheel Energy Storage" indicated that flywheel assisted TC's have lower operating costs than non-assisted TC's. The viability of this finding is soon to be tested by employing the technology on a prototype vehicle.

If a vehicle using an energy storage power source is developed to the point of being commercially available, it is highly probable that such a vehicle would be used at least initially to replace motor coaches on lines that are not suited to trolley coach operation in order to achieve the savings associated with a non-petroleum-dependent energy source. These represent approximately three-fourths of all transit buses. Trolley coach replacement would most likely occur only when the vehicles are life expired, thus resulting in a small loss due to premature retirement of the overhead wire.

A final issue is the claim in several studies that trolley coaches have an advantage over motor coaches in that additional usage is generated, thereby increasing revenues. There has been no systematic study of such assertions. The only evidence presented has been in a San Francisco study. This study is based on a vehicle type change in a corridor where there are many closely parallel routes and does not address the question of whether the usage changes indicated represent shifts among routes in the corridor or represent overall usage changes. This question will not be settled until the research described in Chapter 1.5 is performed.

Availability of Equipment and Components

The availability of vehicles and parts is largely a function of the size of the market. Based on past experience with other low volume transit vehicle purchases, such as Chicago's propane-powered buses in the 1950's, a production rate on the order of 200 vehicles per year, if maintained over a substantial period of time without frequent design changes, would be sufficient to assure supplier participation. Such a market size would be obtained if New York, Chicago or a combination of Los Angeles and Philadelphia were to undertake a long-term policy of replacement of motor coaches with trolley coaches. Without this type of commitment, it is likely that vehicle suppliers will treat each trolley coach order as a unique event and charge all tooling costs to the order. In such a situation, it would be necessary for two or more transit systems to develop joint purchase programs in order to obtain favorable prices. It appears that a purchase of at least 200 vehicles is required in such cases, as was done for the recent Seattle and Philadelphia purchase.

The availability of spare parts should not present any severe problems for current generation vehicles or for any new systems. Problems that trolley coach operators have experienced in the past were largely a result of the continued use of coaches with Westinghouse electrical equipment after Westinghouse discontinued the manufacture of equipment and parts. In addition, many coaches were built by manufacturers such as Marmon-Herrington and Pullman-Standard. These firms all discontinued production of trolley coaches in the mid 1950's. Current generation coaches have been built by firms that also built large numbers of buses using the same body design. Body parts will be as available for these trolley coaches as they are for buses made by the same company. Electrical components have been made by General Electric except for the Randtronics chopper control. GE has continued to be active in the trolley coach market. The chopper control uses relatively few unique parts, being assembled largely from standard industrial components. Thus, parts are likely to be readily available for it, without the cost and delay problems that may occur when there is only one source.

Overhead fittings and current collection hardware are presently largely supplied by Ohio Brass. This firm has continued to actively support its trolley coach products. It manufactures a wide range of similar hardware for electric railway, mining and electric power transmission uses. If Ohio Brass discontinues its trolley coach line, many items will still be available. Additionally, several European firms manufacture similar overhead fittings and current collection hardware, which are generally compatible with U.S. systems. Systems that decided to purchase the K&M elastic system are assured of a continued supply, since this firm supports a large number of European and other operators.

Institutional Barriers

The primary institutional barrier to trolley coach expansion is the local ordinances prohibiting the use of overhead wire electric distribution systems throughout the Borough of Manhattan in New York City and in the central area of Washington, D.C. To our knowledge, no such restrictions exist in other areas although there may be certain locations where such restrictions apply to specific streets. There are 26 transit systems identified as potential locations of trolley coach expansion in Chapter 2.1. Four of these presently operate trolley coaches. Fifteen others, including New York City, formerly used these vehicles. New York City utilized them only in the Borough of Brooklyn. Four systems seriously considered trolley coaches to the extent of ordering vehicles, borrowing a demonstrator vehicle or building a short-lived experimental route. It is likely that none of these systems, except New York City, have any regulatory or legal obstacle to trolley coach use. St. Louis, Houston and Washington, D.C. were the only cities identified in Task 1 in which the transit system never seriously considered the use of trolley coaches. In St. Louis and Houston it is unlikely that there would be any legal problems with these vehicles, as both cities had extensive street railway operation using overhead wire.

State laws with respect to trolley coaches vary. Most states do not consider them to be motor vehicles although there are some exceptions. These laws do not appear to present any problem with respect to their operation. All of the systems identified in Chapter 1 are in states where trolley coaches have been operated in the past with the exception of the District of Columbia.

Federal Highway Administration motor carrier regulations at present explicitly exclude trolley coaches as not being motor vehicles (49CFR-390.1). No definition of motor vehicle is included in the NHTSA motor vehicle safety standards. One problem has been encountered with present design trolley coaches. These vehicles have been equipped with pneumatic control connections between the accelerator pedal and the cam controller. This system was apparently developed in response to motor vehicle Safety Standard #124. This standard requires that accelerator controls return to the idle or shutoff position if damaged or if pressure is released by the driver. Although it is unlikely that the application of this standard to trolley coaches would stand a legal challenge based on the precedent set by FHWA, the manufacturer decided to abide by it. This system has, however, been less satisfactory in operation than was the older mechanical connection using cables. This problem is unique to the cam controller and will not be encountered in the most recent designs utilizing chopper control and electric transducer for control of the chopper.

This problem does raise the question of the more general applicability of the motor vehicle safety standards to trolley coaches. This question should be resolved, although at present it appears to have little practical impact.

Management and Operating Factors

Certain aspects of management and operations may act as barriers to trolley coach expansion. Among these are the requirement that trolley coach systems must be designed. The service design principles have been described in Chapter 1.4 of the Task 1 report. Systems with straightforward route structures, such as Chicago, will generally require less in the way of service design than would a system with numerous branches and deviations such as Baltimore.

During the design phase, management personnel must be assigned to supervise and work with the design engineers. Negotiations and meetings with utility companies and local traffic departments will be required to cover such subjects as joint use of poles, location of poles, relocation of traffic lights, and so forth. During the construction phase, the operator will have to supervise construction inspection staff to ensure proper installation.

Trolley coaches have generally been more highly regarded by transit maintenance management than by transportation department management. The trolley coach reduces flexibility of operations in several ways that may be significant on some systems. Vehicles are not universally assignable to all routes. Thus it becomes impossible to assign a driver to a run that is partly on a motor coach route and partly on a TC route unless a vehicle change is scheduled. A branch or deviation cannot be added to a TC route to serve a specific demand unless the demand is sufficient to justify wire installation. Express service is precluded unless demand is sufficient to justify express wire on the headway and running times permit scheduling of non-interferring service. Appropriate service design will tend to minimize the effect of these constraints on system operation and service quality. For example, a timed transfer scheme at an outlying terminal point can minimize the effect of not providing through service as well as improve the system's ability to serve local trips in outlying places.

The need for greater management attention also applies to service disruptions. Restoration of wire is an additional management function. Rerouting and cutback opportunities are generally severely restricted for trolley coach as compared to motor coach operation.

One UMTA requirement may also have an impact on trolley coach operation. The use of wheelchair lifts on routes with high service frequencies can be much more disruptive to a trolley coach system than to a motor bus system. This is a result of the inability of trolley coaches to pass one another unless the poles on the stopped vehicle are lowered. Similar problems will be encountered for lifts on light rail vehicles and may occur in certain transit priority applications, such as contraflow lanes.

Community Acceptance

Overall, community acceptance of the trolley coach has been good. In several cities, including Dayton, San Francisco, and Seattle, the initial impetus for retaining trolley coaches came from community groups. There have also been community activity to restore trolley coach operation in several cities where it has been totally or partially discontinued. Much of this activity has been in Portland, Oregon, and Seattle, Washington, but it has also occurred recently in Milwaukee and New York City.

Experience with respect to specific route proposals has been mixed. Certain route extentions in Edmonton were supported by local residents on the basis of their being operated with trolley coaches. Negative reaction to specific route extensions has been enumerated in Chapter 2.3 for several locations.

In general, it is likely that community acceptance will be favorable for trolley coaches. The reaction to specific routes is likely to be less predictable. Factors that are likely to influence this reaction are:

- Service density - The visual impact of trolley coaches is present whether or not vehicles are operating. The effects of noise and air pollution from motor coaches vary with the frequency of service.

- Maintenance - The amount of noise and air pollution, particularly visible smoke and odor, produced by a motor coach is directly affected by the quality of maintenance. Areas with generally poor motor coach maintenance are more likely to be receptive to trolley coaches.

o Effect on underground installation of utilities - The installation of trolley coaches in an area that is attempting to obtain the removal of overhead utility lines or has recently undergrounded utilities may produce substantial opposition. This has happened in both Seattle and Hamilton.

o Familiarity - There is a tendency for people to oppose the unfamiliar. Thus trolley coach extensions in areas where systems already exist or new trolley coach installations in cities where a nearby city has such vehicles are likely to be more acceptable than new systems in areas where the whole idea of a trolley coach is only a distant memory.

Other UMTA Policies

Certain UMTA policy areas other than the ones previously mentioned concern the use of trolley coaches. One of these is the inclusion of trolley coaches in alternatives analysis. The present policy states that an alternatives analysis must be performed for any corridors in which fixed guideway facilities have been proposed. It would be inappropriate to consider trolley coach overhead wire as a fixed guideway, as its sole function is to provide electric power to a vehicle that operates in mixed traffic. However, trolley coaches should be considered in certain fixed guideway proposals. As has been mentioned, the trolley coach is capable of being utilized in underground facilities that would otherwise require rail vehicles.

The type of system described in Chapter 1.4 of the Task 1 report with surface street operation in outlying areas and a central area subway is particularly suited to trolley coach operation. Trolley coaches can either be used to reduce the total cost of the project or can be used to expand the number of street routes that provide through service into the subway, thus reducing the need for transfers. A trolley coach system may also be used as an interim step to utilize a short section of exclusive guideway until a longer section is completed. This type of alternative is appropriate for areas where the need for exclusive guideway is greatest in a relatively small core area, and where no simple route can develop sufficient usage to be viable as a rail facility.

CHAPTER 2.5

CONCLUSIONS

The following conclusions can be drawn from this review of trolley coach development.

(1) The trolley coach has been a workable technology for transit application for over 40 years. However, certain recent improvements in technology have made the trolley coach a more attractive option. The most significant improvement has been chopper control, with a resultant reduction in power consumption on the order of 20% and a much smoother ride quality.

(2) Direct operating costs of trolley coaches are likely to be somewhat lower than the cost of operating motor coaches. This cost reduction is largely a result of recent increases in the cost of diesel fuel, and may not exist where electric power costs are high. Maintenance costs tend to be equal as the lower vehicle maintenance cost for the trolley coach is offset by the cost of wire maintenance.

(3) In general, it is economical to retain trolley coaches on existing systems, as longer vehicle life offsets the higher cost of the trolley coach.

(4) The cost of overhead wire installation is the most significant barrier to new trolley coach systems, making them appear uneconomical on a strict cost accounting basis. Systems with especially high service density and low power costs are exceptions.

(5) Expansion of trolley coach operation will produce small though real decreases in overall air pollution and petroleum consumption. These small improvements, however, are likely to be larger than improvements in air quality and energy source utilization resulting from other transit expenditures. Local air quality in central areas may be significantly improved.

(6) There is a definite advantage to trolley coach expansion in terms of long term flexibility of energy source use, and long term reliability of energy supply.

(7) Given present energy policy, UMTA should maintain a basically neutral position on trolley coach expansion. The initiative for such expansion should originate at the local level. The criteria for review of trolley coach proposals should be largely based on the proposed service density. The use of a service density measure will assure that the investment in overhead wire will be utilized effectively.

(8) The use of a trolley coach alternative in certain fixed guideway alternatives analysis studies should be encouraged. This alternative is most appropriate for relatively short distance corridors where underground construction is required to penetrate a central area.

(9) The expansion of trolley coach operations may be a useful component of a long term policy to increase the use of electricity as an energy source for transportation, along with energy storage vehicles and railroad electrification.

A P P E N D I X

ROUTES SELECTED FOR TC OPERATION BY URBAN AREA

ROUTES SELECTED FOR TC OPERATION BY URBAN AREA

NEW YORK

Basic Group

NYCTA: B1, B2, B3, B4, B5, B6, B7, B8, B9, B10, B11, B12, B13, B14, B16, B17, B20, B21, B22, B23, B24, B25, B26, B31, B35, B36, B37, B38, B40, B41, B42, B44, B45, B46, B47, B48, B49, B52, B53, B54, B55, B56, B57, B58, B59, B60, B61, B62, B63, B64, B65, B67, B68, B69, B70, B75, B77, B78, B83, Q1, Q2, Q3A, Q4, Q4A, Q5, Q5A, Q5AB,Q12, Q13, Q14, Q15, Q16, Q17, Q17A,Q26, Q16, Q27, Q28, Q36, Q43, Q44, Q44A, Q44VP, Q49, Q75, Q76, Q88.

MABSTOA: BX1, BX2, BX3, BX4, BX6, BX9, BX10, BX11, BX12, BX13, BX15, BX16, BX17, BX20, BX22, BX26, BX27, BX28, BX31, BX35, BX37, BX38, BX40, BX41, BX42, BX55.

Green: Q6, Q7, Q8, Q9, Q10, Q11, Q22, Q35, Q37, Q40, Q60.

Jamaica: Q110, Q111/113, Q112.

Queens: Q25/34, Q65, Q65A, Q66, Q67.

Steinway: Q101, Q102, Q103, Q104.

Triboro: Q18, Q19A, Q19B, Q23, Q29, Q33, Q38, Q39, Q72.

MSBA: N4, N6.

Low Density Group

NYCTA: S1, S2, S3, S6, S102, S103, S107, S109.

MABSTOA: BX5, BX25, BX54.

Triboro: Q45, Q47.

Special Problem Group

NYCTA: B39, M15, M22, M27, M31.

MABSTOA: BX29, BX30, BX33, BX34, M1, M2, M3, M4, M5, M6, M7, M10 M11, M13, M14, M16, M17, M18, M19, M20, M21, M26, M28, M29, M30, M32, M100, M101, M102, M103, M104, M106.

Avenue B and East Broadway: M8, M9.

Routes Selected for TC Operation by Urban Area (continued)

NEW YORK - NORTHERN NEW JERSEY

Basic Group

Newark: 1, 5, 13, 14, 18, 21, 23/44, 24, 25, 27, 29/60, 31, 34, 39

Jersey City: 9, 44, North Boulevard, South Boulevard, Broadway, Montgomery and West Side, Lafayette and Greenville, Bergen Avenue, Central Avenue.

Low Density Group

Newark: 9

Paterson: 74

CHICAGO

Basic Group

CTA: 1, 3, 4, 5, 7, 8/42, 8A, 9/45, 11, 12, 15, 16, 18, 20, 21, 22, 24, 25, 27, 28, 29, 30, 34, 35, 36, 37, 38, 39, 43, 44, 47, 49, 49A, 49B, 50, 51, 52, 52A, 53, 53A, 54, 54B, 55, 56, 56A, 59, 60, 62, 62X, 63, 64, 66, 67, 68, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 84, 85, 85A, 87, 88, 90, 91, 92, 93, 94, 95, 96, 97, 103, 106, 111, 112, 126, 131, 152, 155

Low Density Group

CTA: 31, 41, 48, 57, 86, 110

Special Problem Group

CTA: 153, 156, 157

LOS ANGELES

Basic Group

SCRTD: 2, 3, 4, 5, 6, 7, 9, 12, 26, 28, 29, 39, 42, 44, 47, 50, 75, 83, 85, 89, 91, 93, 94, 95, 201

Low Density Group

SCRTD: 8, 41, 49, 92, 422, 426, 436

Routes Selected for TC Operation by Urban Area (continued)

PHILADELPHIA

Basic Group

SEPTA:	2, 3, 5, 6S, 15, 17, 20, 23, 26/S, 33, 39, 42, 46, 47, 48, 50, 52, 53, 54, 56, 59B, 60, 61, 88, A Local, B, C, D, E, G, H, K, L, N, R, Y, XH.

Low Density Group

SEPTA:	7, 12, 31, 40, 43, 73, J.

DETROIT

Basic Group

D-DOT:	Chene, Clairmount, Crosstown, Dexter, Fenkell, Fort, Grandbelt, Grand River, Gratiot, Greenfield, Hamilton, Mack, Michigan, Vandyk-Lafayette, Vernor, Woodward.

Low Density Group

D-DOT:	Baker, Cadillac-Harper, Chicago-Davison, Joy Road, Linwood, Oakland, 7 Mile East, Warren, Wyoming.

SAN FRANCISCO

Basic Group

SF Muni:	2, 10, 11/14, 15/42, 18, 19, 24, 25, 26, 28, 31, 35, 38, 45, 51, 55, 71/72.
AC Transit:	15, 40/43, 51/58, 57, 72, 80/81/82, 83, 88.

Low Density Group

SF Muni:	32, 36, 41, 53.
AC Transit:	53.

Routes Selected for TC Operation by Urban Area (continued)

BOSTON

Basic Group

MBTA: 1, 9, 11, 15, 17, 22, 23, 29, 32, 34, 35/36/37, 41, 43, 44, 45, 66, 69, 77, 80, 83, 87, 88, 89, 93, 101

Low Density Group

MBTA: 10, 25/26, 28/30, 96, 100.

Special Problem Group

MBTA: 57, 111.

WASHINGTON, D.C.

Special Problem Group

WMATA: 30/32/34/36, 40, 42, 50/52/54, 60/62, 70/71, 80, 90/92/94, A2/4/6/8, B2, B6, D2/4/8, G2, G4/6, H2/4, J1/2/4/6, K4, L1/2/4/5/7, M6, N2/4/6, P2/7, S1/2/3/4/5, T4/6, U2/4/6, V2/4, X2/4/6, Y6/8/9.

CLEVELAND

Basic Group

GCRTA: 1, 3, 6/6A, 10, 12/13, 14, 15, 16, 19, 20/20A/20B/21, 22, 26, 32, 79, B.

Low Density Group

GCRTA: 2, 8, 28

Special Problem Group

GCRTA: 55/55A

Routes Selected for TC Operation by Urban Area (continued)

ST. LOUIS

Basic Group

BSDA: 20, 30, 32, 70, 91, 93, 94, 95, 559X/560.

PITTSBURGH

Basic Group

PAT: 51C, 54C, 71, 73, 75, 76, 81C, 82, 88, 91A.

Low Density Group

PAT: 11D, 11F, 16B, 16C, 16D.

MINNEAPOLIS-ST. PAUL

Basic Group

MTC (Mnpls): 4, 5, 6, 9, 10, 17, 18.

MTC (St. Paul): 3, 14, 16, 21.

Low Density Group

MTC (Mnpls): 12, 19, 22.

HOUSTON

Basic Group

HOUTRAN: 10, 10/66, 44, 80, 82.

BALTIMORE

Basic Group

MTA: 1, 3, 5, 6, 7, 8, 10, 13, 15, 19, 20, 21, 23, 28, 44.

Routes Selected for TC Operation by Urban Area (continued)

MILWAUKEE

Basic Group

MCTS: 10, 11, 12, 14, 15, 18, 19, 23, 27, 51, 60.

Low Density Group

MCTA: 21, 22, 31, 35, 54, 80.

SEATTLE

Basic Group

METRO: 11, 15/18/21, 19/24/33.

Low Density Group

METRO: 5.

ATLANTA

Basic Group

MARTA: 3, M8, 10, 11, 13, 14, 19, 20, 23, 25, 35.

Low Density Group

MARTA: 17, M20

KANSAS CITY

Basic Group

KCATA: 25, 31, 39, 56, 71.

BUFFALO

Low Density Group

NFT: 3, 4, 5, 8, 10, 13, 24, 25.

Routes Selected for TC Operation by Urban Area (continued)

DENVER

Basic Group

RTD: 3, 6, 13, 14/15, 40.

Low Density Group

RTD: 8.

NEW ORLEANS

Basic Group

NOPS: 2, 3, 5, 6, 9, 10, 12, 13, 14, 15, 16, 18, 20, 21, 22, 23, 25, 26, 29, 31, 32, 33, 34, 35, 80, 81, 91, 92.

PORTLAND

Basic Group

Tri-Met: 9, 14, 19, 21, 53.

Low Density Group

Tri-Met: 3, 8, 12, 26.

COLUMBUS

Basic Group

COTA: North High-Main, East Broad-West Broad, Cleveland-Livingston, Indianola, Sullivant-Mt. Vernon.

HONOLULU

Basic Group

COH: 1, 2, 3, 4, 6.

R E F E R E N C E S

CHAPTER 2.1

A. A Directory of Regularly Scheduled, Fixed Route, Local Public Transportation Service, U.S. Department of Transportation, Urban Mass Transportation Administration, Washington, D.C., July 1979.

B. Schedules of transit routes operating in the areas indicated in Table 2.1-1.

CHAPTER 2.2

A. Summary of various cost documents associated with the rehabilitation and expansion of Seattle's trolley coach system, Municipality of Metropolitan Seattle, Seattle, Washington.

B. "Trolley Coach News", various issues.

C. Log of Motor Coach Purchases, Urban Mass Transportation.

D. The Environmental and Economic Feasibility of Trolley Coach Expansion, Carl Natvig for San Francisco Municipal Railway, July 1978.

E. "Economic Comparison, Trolley Coach vs. Diesel Bus", Toronto Transit Commission, Equipment Department, April 1969.

F. "Cost Control Statements", BC Hydro and Power Authority.

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CHAPTER 2.3

A. "Analysis of Operating Alternatives for Market Street Trolley Coach Lines", San Francisco Municipal Railway, June 1973.

B. "Trolley Coach News", various issues.

C. Transit Operating Report for Calendar Fiscal Year 1975, APTA, Washington, D.C. 1977.