U.S. Department of Transportation
Office of the Secretary of Transportation

Dallas Fixed Guideway Rapid Transit Mode Analysis

Executive Summary

March 1983

TECHNOLOGY SHARING REPRINT SERIES

Prepared for
City of
Dallas, Texas

DALLAS FIXED GUIDEWAY RAPID TRANSIT MODE ANALYSIS

EXECUTIVE SUMMARY

Submitted To

CITY OF
DALLAS, TEXAS

By

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MARCH 25, 1983

Note:

This document is the executive summary of a major study of fixed guideway modes and their applicability. The full study, entitled Dallas Fixed Guideway Rapid Transit Mode Analysis: Final Report, has been released to the National Technical Information Service, Springfield, Virginia 22161 for sale to the U.S. public. The full study's stock number is PB84 178508, and it costs $37.00 a copy at this writing (Price code A22).

PREFACE

This Executive Summary of the Dallas Fixed Guideway Rapid Transit Mode Analysis is submitted to the City of Dallas by Lea, Elliott, McGean /DeLeuw, Cather, a Joint Venture, and its associated consultants.

The Consultant has received helpful information and guidance from many people in the course of this effort. We appreciate the responses of the Dallas City Council and the Dallas Area Rapid Transit Authority Board. We would especially like to acknowledge the contributions of the following people:

- City of Dallas
  - Charles Anderson
  - Mildred Cox
  - Del Crouser
- Dallas Area Rapid Transit Authority
  - Maurice Carter
  - George Bonna
  - David White (Consultant)
- Texas State Department of Highways and Public Transportation
  - John Blain
- WED Transportation Systems Inc.
  - Jud Perkins
  - Dick Wiedenbeck
  - Dan Welsh
- Japan Ministry of Construction
  - Takashi Yajima
- Hitachi, Ltd.
  - Yutaka Sugihara
  - Hidetoshi Arakawa
  - Masakazu Ishikawa
  - Atsushi Ikio
- Urban Transportation Development Corporation
  - George Pastor
  - Marsden Burger
  - Ed Ries
  - Dan Braund

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EXECUTIVE SUMMARY

This Executive Summary presents an overview of the relevant findings of the Dallas Fixed Guideway Rapid Transit Mode Analysis. It is intended for those interested in the results of the study investigations; consequently, it does not include the supporting analyses and engineering. These can be found in the referenced sections of the Final Report.

This Executive Summary consists of five parts. Section 1.0, Study Objectives, describes the purpose and objectives of the study. Section 2.0, Study Approach, explains the methods used to conduct the evaluations and produce the findings. Section 3.0, Prototypical Evaluation, presents key issues of vehicle procurement, system operation, and urban integration for each of the five modes studied. Section 4.0, Corridor Analysis, summarizes the engineering requirements of the modes in both a rail and highway corridor, and presents the capital, operating and maintenance, and total annual costs for all modes in each of the two corridors. Section 5.0 summarizes a discussion in the Final Report about a decision making process for transit mode selection.

1.0 STUDY OBJECTIVES

The Dallas Fixed Guideway Rapid Transit Mode Analysis was conducted for the City of Dallas at the specific request of the Dallas City Council. The purpose of this study was to determine the relative feasibility and costs of a straddle-beam monorail system in typical Dallas corridors, compared with four other fixed-guideway modes: ICTS, light rail, pre-metro, and rapid rail.

The primary study objectives were: 1) to prepare a comprehensive evaluation of straddle-beam monorail technology as it currently exists, 2) to make a point-by-point descriptive comparison of the monorail mode with the four other modes, 3) to compute and compare total costs for all modes in both a highway and rail corridor alignment, across a range of capacity levels, and 4) to present the information to the City and the DART Board to aid in the assessment of potential transit modes for Dallas.

2.0 STUDY APPROACH

To accomplish the study objectives, the work was divided into two major parts: 1) Prototypical Evaluation and 2) Corridor Analysis. The first part was designed to evaluate procurement, system operation, and urban integration-related strengths and weaknesses for all modes. The second part was structured to estimate mode performance and capital, operating and maintenance, and total costs in the specified corridors.

The prototypical evaluation involved a number of steps: 1) collecting technical data on all modes, to develop a current and consistent data base; 2) preparing evaluation criteria to judge the modes; 3) comparing all modes and identifying potential key issues; 4) investigating each key issue by study team members; 5) identifying of those key issues of most concern to decision makers in Dallas, and 6) estimating unit cost data for use in the corridor analysis.

The corridor analysis consisted of: 1) definition of the mode alignments and profiles for a highway and rail corridor; 2) developing an operations plan, including a demand profile and service periods, for each alignment; 3) defining trackwork/beamway configuration and guideway support systems and other physical facilities; 4) estimating total capital costs; 5) estimating operating and maintenance costs; 6) estimating total annual costs; and 7) preparing a (hypothetical) fare analysis. All costs were computed for each of the five modes that were feasible in the two typical alignments for the four peak passenger capacity levels.

2.1 MODES

Five modes were evaluated: 1) straddle beam monorail, 2) Intermediate Capacity Transit System (ICTS), 3) light rail, 4) pre-metro, and 5) rapid rail. They are shown in Figure 2-1.

There are currently two potential suppliers of straddle-beam monorail; WED Transportation Systems, Inc. has an existing system at Disney World (Mark IV) and a concept for urban transit service (Mark V). Hitachi Ltd. has an existing system (Tokyo-Haneda), a new vehicle undergoing final testing at Kitakyushu, and three urban systems currently under design or construction. The investigation of monorail focused on these examples.

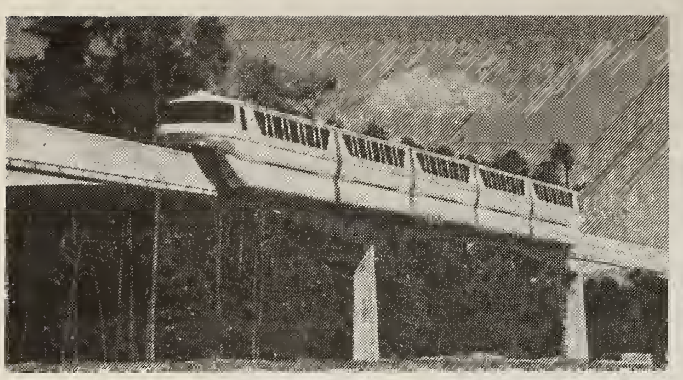
For ICTS, a fully automated system under development by the Urban Transportation Development Corporation (UTDC), the investigation focused on results from vehicle testing at the Kingston, Ontario test track and specifications for contractually committed projects in Vancouver, Detroit, and Toronto.

For light rail, the Duwag U-2 vehicle and associated components, currently in operation in San Diego, Calgary, and Edmonton was selected as a typical vehicle. Light rail was defined as operating only at-grade, except for necessary grade crossings at railroads and major arterials. For pre-metro, the same light rail vehicle (Duwag) was used. The difference between light rail and pre-metro is that pre-metro would operate in semi-exclusive, generally elevated, right-of-way. Finally, for rapid rail, the new Budd vehicle for the Miami and Baltimore systems was used as a typical example of the mode.

2.2 ALIGNMENTS

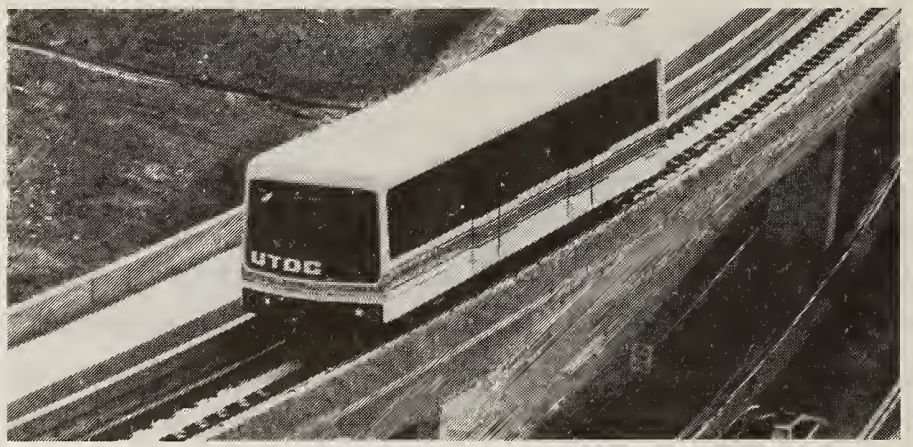
Three alignments were developed. The first was generic and prototypical, so that procurement, operational, and urban integration issues could be addressed, and unit costs could be developed in advance of the total cost

FIGURE 2-1
MODES INVESTIGATED



MONORAIL - WED, MARK IV

MONORAIL - HITACHI



ICTS

RAPID RAIL

LIGHT RAIL / PRE-METRO

estimation tasks. The remaining two alignments, one in a highway corridor and one in a railroad corridor, were developed so that operations and costs could be assessed in a more specific implementation environment.

The highway and rail corridor alignments are shown in Figure 2-2. Their vertical profiles are summarized in Figure 2-3. These alignments have 20 stations and are approximately 26 miles long. The highway corridor follows the Stemmons Freeway in the north and the South Central Expressway and the Hawn Freeway in the south. The rail corridor follows the MKT Railroad in the north and the Southern Pacific Railroad right-of-way in the south. These alignments are representative of the land uses, development intensities, right-of-way availability, geometric constraints, patronage levels, and adjacent street traffic volumes that would be encountered in all corridors in Dallas.

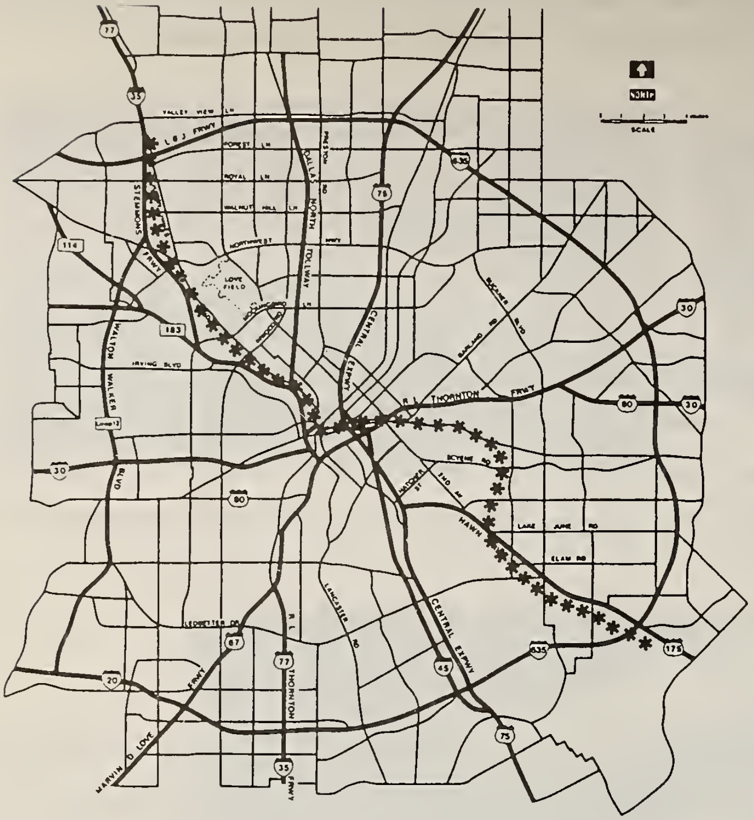
3.0 PROTOTYPICAL EVALUATION

This section summarizes the major findings from the analysis of potential key issues identified as part of the prototypical evaluation phase of the study effort. These major findings are described below in three sections:

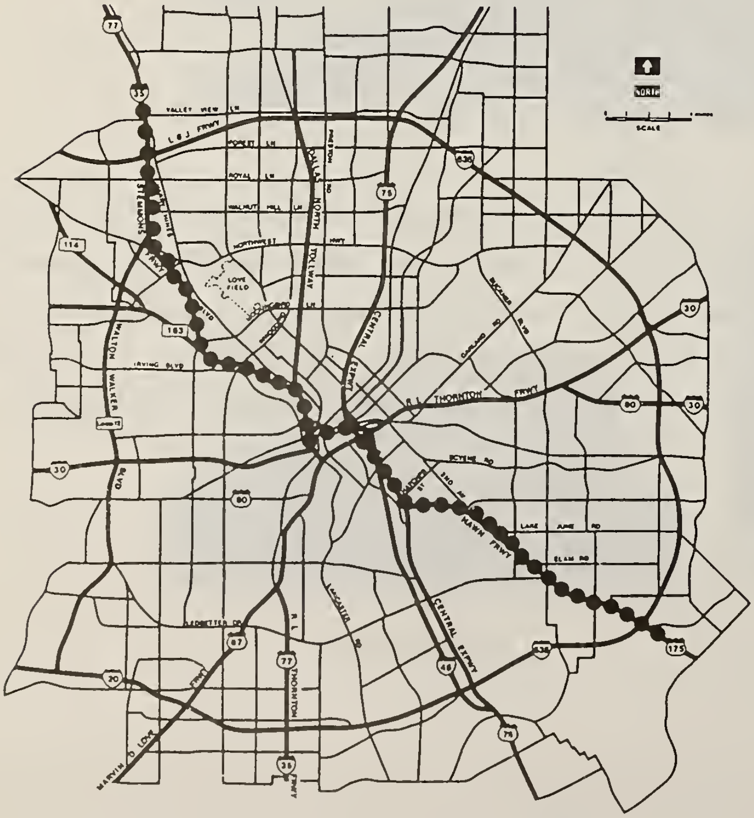
1) Procurement Issues
2) System Operation Issues
3) Urban Integration Issues

Nineteen evaluation criteria were identified and used to evaluate each of the modes. The following discussion summarizes the information presented in Section 5.0 of the Final Report, and focuses on those issues which are considered to be key issues for decision makers in Dallas. All system issues are discussed here; cost information is presented in Section 4.0.

FIGURE 2-2
CORRIDOR HORIZONTAL ALIGNMENTS

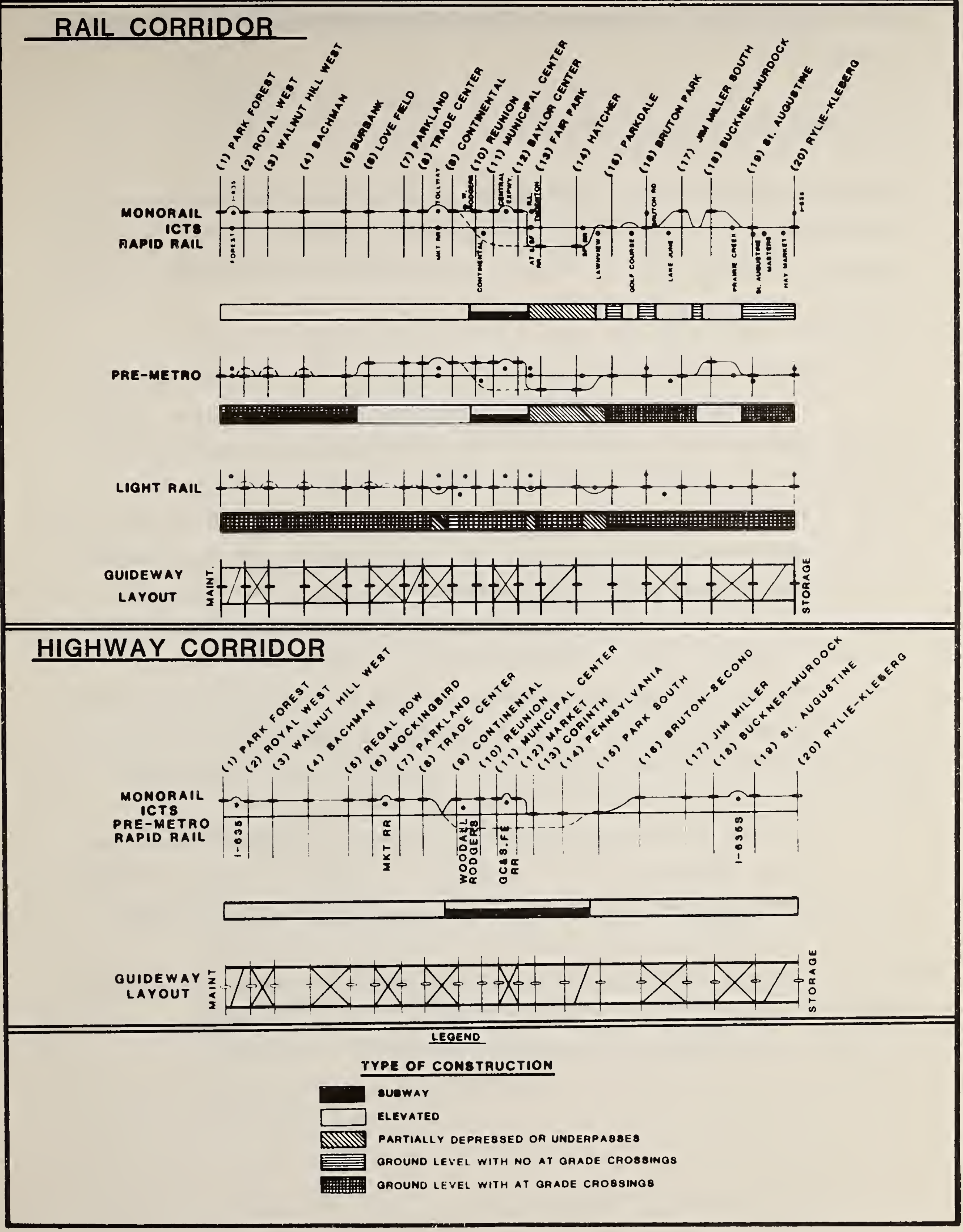


RAIL CORRIDOR



HIGHWAY CORRIDOR

FIGURE 2-3
CORRIDOR VERTICAL PROFILES



3.1 PROCUREMENT ISSUES

Four evaluation criteria were considered under this heading: 1) Maturity of System Technology, 2) Sources of Supply, 3) Significant Risk Items, and 4) Design Life.

3.1.1 Maturity of System Technology

A key consideration in selecting among the modes is the performance record of the technology. Specifically, how much operating history has the equipment developed, and in how many applications similar to those being considered in Dallas.

- Rapid rail, light rail, and pre-metro are accepted as mature technologies based on their extensive service histories in North America and throughout the world in hundreds of applications.

- Both the existing WED Mark IV and the Hitachi-Haneda systems are also mature technologies in their particular applications. These designs are not appropriate for transit use in Dallas. A monorail system for Dallas would be a new design.

- Neither the WED Mark V concept nor the new-design Hitachi system for Kitakyushu is in passenger service, although the latter is currently being tested and the system is under construction.

- ICTS is a fully automated system for which considerable test-track testing has been performed. However, actual passenger service experience with ICTS will not begin until late 1984.

Maturity of system technology is considered to be a key issue for decision makers.

3.1.2 Sources of Supply

In making a mode decision, one must be assured that equipment for the mode selected can be procured competitively both initially and in the future.

- There are approximately 26 manufacturers of light rail vehicles and 33 manufacturers of rapid rail vehicles in the Americas, Europe, and Japan. For most recent U.S. urban transit projects, there have been two to ten bidders. Thus competitive bids and future availability of compatible vehicles and equipment is virtually assured.

- There are only two potential suppliers of straddle beam monorail systems: Hitachi Ltd. and WED Transportation Systems, Inc.

- Hitachi is currently designing and/or constructing three new monorail systems in Japan, but has not formulated specific plans for marketing its monorail system in the U.S. It has, however, successfully entered the U.S. rapid rail vehicle market, and provides a range of transit vehicles in Japan and elsewhere.

- WED has designed and constructed monorail systems at Disneyland (Mark III) and Disney World (Mark IV). Recently it has decided to market its transportation equipment, including monorail, for other applications. It has a Mark V monorail system concept for urban use, but has not completed design, engineering, prototype fabrication, and qualification testing.

- The current Hitachi and Disney Mark V monorail systems are not compatible: Hitachi vehicles can not operate on a system designed and constructed for WED, and vice versa. Thus, price competition would exist on the initial procurement, but would be unlikely on subsequent procurements, unless one manufacturer were to make major adaptations to make his design compatible with that of the other.

- Although the WED and Hitachi monorail designs both derive from a single original design (Alweg), there are no legal relationships between the companies, or other restrictions, which would preclude them from bidding against each other in a competitive procurement.

- Any procurement of the ICTS system would involve a single supplier, UTDC; therefore, no price competition would exist.

Source of supply is considered to be a key issue for decision makers.

3.1.3 Significant Risk Items

Whenever new transit equipment is placed in service, there is risk that the program may be delayed, and revenue operations degraded by failures until the new equipment is properly "debugged". This criterion identifies any such risk associated with the five modes.

- Provided that standard, off-the-shelf designs are specified, the risks associated with rapid rail, light rail, and pre-metro are well understood, because of the extensive service histories of the equipment.

- The WED Mark V monorail is a new conceptual design, based on the existing Mark IV equipment. Numerous aspects of the Mark IV would require redesign and/or replacement in the Mark V. Whenever multiple adaptive redesigns such as this are undertaken simultaneously, there is risk of cost impacts and program delay due to unforeseen developments with those elements which will require a redesign or replacement. The magnitude of this risk is uncertain, and cannot be definitively assessed until final design of the Mark V is completed.

- The new Hitachi monorail system is currently being tested. It appears that this monorail could be deployed in the U.S. in an urban application with minimal change and risk.

- There is a relatively high risk of cost impacts and implementation delays with ICTS because it incorporates significant technological advancements which have not been tested in revenue service.

Procurement and technology risk is considered to be a key issue for decision makers.

3.1.4 Design Life

Because of the large capital investment required, any public transit system must incorporate hardware which can operate at a high level of performance for many years.

- Vehicles for rapid rail, light rail, and pre-metro are typically designed for a 30-year life, and, in the past have often operated well in excess of this period.

- In the judgement of the Consultant team, the WED Mark V monorail concept, the new Hitachi monorail, and ICTS could achieve a design life of 30 years in an urban environment, based on the WED Mark III and Mark IV monorails, the Hitachi Haneda monorail and Kitakyushu prototype vehicle, and the ICTS prototype vehicle, respectively.

Design life is considered not to be a key issue for decision makers.

3.2 SYSTEM OPERATION ISSUES

Seven evaluation criteria were identified under this heading. They include: 1) System Capacity, 2) Operation in Ice Conditions, 3) Branching/Networking Capabilities, 4) Train Makeup, 5) Failure Management, 6) Reliability, and 7) Safety.

3.2.1 System Capacity

It is important to select a mode which will transport the range of anticipated passenger volumes; thus, a capacity analysis was performed for each of the modes using the prototypical, highway and rail corridors. The contract-specified capacity levels examined were 5,000; 10,000; 20,000; and 30,000 passengers per hour (pph) on the peak link in the peak travel direction.

- Rapid rail and pre-metro can meet the 30,000 pph capacity level.

- Monorail and light rail can meet the 20,000 pph capacity level. Light rail would require some grade separated intersections and a downtown transit mall.

- ICTS can exceed the 10,000 pph capacity level. It could reach the 20,000 pph capacity level if its advanced train control system is demonstrated in revenue service to attain turnback operations at 85-second headways.

Capacity is considered to be a key issue for decision makers. This issue includes meeting initial capacity requirements and the ability to expand to future estimated levels.

3.2.2 Operation in Ice Conditions

A climatological factor which must be acknowledged is occasional winter ice storms in Dallas. This evaluation criterion addresses each mode's ability to operate in such conditions.

- Loss of traction due to ice/snow accumulation affects the propulsion and braking of fixed guideway transit. Rapid rail, pre-metro, light rail, and ICTS will be minimially affected due to their steel wheel / steel rail design.

- Monorail operation in ice conditions is uncertain. WED has no experience in such conditions; although Tokyo has a climate similar to Dallas, Hitachi officials related no significant operating experience in icy conditions. Consequently, it could be necessary to heat sections of a Dallas monorail beamway near stations and on grades and curves. This will affect capital and operating costs of the system, but should solve this potential problem.

- All modes could require selective heating of power distribution rails and switches, but this is not a differentiating factor among the modes.

Operating in ice conditions is an aspect that decision makers should be cognizant of, but is not considered to be a key issue in selecting among the modes.

3.2.3 Branching/Networking Capabilities

Flexibility of system operation is achieved through the ability of one or more transit lines to branch to form a network throughout the service area. This feature is also desirable to assure that a fixed guideway transit system can be expanded in the future to serve increased demand or new areas.

- Rapid rail, pre-metro, light rail, and ICTS modes all use conventional railroad switches for branching and networking maneuvers. Such switches allow merge, diverge, and crossover movements. Therefore, these modes are considered very flexible, and can branch and form networks without difficulty.

- Monorail switching requires that an entire beam segment be moved out of the beamway alignment and replaced with another segment, thus monorail switching is inherently more difficult because of its greater mass. It can take up to ten times as long to cycle a monorail switch as a railroad switch.

- The nature and physical configuration of monorail switching can impose special constraints on its urban deployment relative to rail systems: the greater area required by monorail switches may be a physical constraint, and the greater cycle time may impose operational headway constraints at higher passenger capacity levels. Monorail systems are technically capable of branching, but they are not well-suited for extensive network applications. Monorails can certainly be used in urban applications, but the design of an urban monorail system should incorporate configurations that minimize the disadvantages inherent in monorail switching.

Branching and networking capability is considered to be a key issue for decision makers.

3.2.4 Train Makeup

The Hitachi monorail systems currently incorporate couplers at each end of a unit and routinely change the units making up a train. The existing Mark IV trains do not have such couplers, but the proposed WED Mark V monorail is planned to have them. Thus both monorail systems have (or could have) consist flexibility generally equivalent to that exhibited by current rail systems and ICTS. Train makeup is not a key issue for decision makers.

3.2.5 Failure Management

Transit systems must be capable of continued operations when malfunctions occur. This evaluation criterion focuses on inherent differences in the capabilities of each mode to work around failures.

- o Because all modes have or will have coupling features on the vehicles, recovery of stalled trains can be accomplished by pushing or pulling with another train.

- o Failure management for monorail systems is potentially more difficult because its elevated beamway configuration does not normally include a walkway alongside, thus limiting access to stalled trains. A monorail switch is more difficult to to move manually than railroad-type switch, thus a monorail switch failure would cause greater operational impacts than a rail switch failure.

Failure management is considered to be a key issue for decision makers.

3.2.6 Reliability

System reliability is an essential aspect of transit performance, since failures drastically reduce the level of service provided by the system.

- o Light rail, pre-metro, and rapid rail systems have demonstrated acceptable levels of reliability through extensive operations.

- o Both the Hitachi and WED Mark IV monorail vehicles currently in service have exhibited excellent reliability records in their respective applications. The reliability of these systems is commensurate with the recorded reliability of U.S. rapid rail systems, and far better than the average of U.S. light rail systems.

- Reliability for the proposed WED Mark V, the new design Hitachi vehicles, and the ICTS system have not been established.

Reliability is considered to be a key issue for decision makers.

3.2.7 Safety

Passenger safety is an important aspect of transit service. This criterion addresses unique safety issues of each of the modes.

- Mixed traffic, light rail operations are more susceptible to accidents involving automobiles and pedestrians. Available data indicate total accident rates of two times, and collision accident rates of ten times, higher than those experienced in rapid rail or pre-metro systems with exclusive rights-of-way. There have been very few reported monorail accidents.

- Provisions for emergency evacuation of passengers from transit vehicles is of concern. With the exception of the Seattle monorail system, virtually every fixed guideway transit system in urban revenue service in the United States has emergency walkways for access to cars by operating personnel and for emergency evacuation of passengers. Including such walkways reduces the aesthetic and cost advantages of the monorail beamway. Emergency slides on monorail vehicles have been proposed by WED and can be useful for emergency evacuation in some situations. Even with such slides, emergency walkways would be essential in areas where the beamway is higher than 25 feet, over water, or over other adverse environments where slides cannot be used. The maintenance requirements and the potential liability consequences of not providing walkways along other sections of monorail beamway must be seriously weighed against the asthetic and cost benefits derived from omitting them.

Safety is considered to be a key issue for decision makers.

3.3 URBAN INTEGRATION ISSUES

This section summarizes those issues affecting the ability of the modes to be effectively integrated into an urban environment. The evaluation criteria in this category include: 1) Visual Intrusion of Elevated Structures, 2) Operations in Mixed Traffic, 3) Physical Barriers, 4) External Noise, 5) Geometric Constraints, and 6) Implementation Time.

3.3.1 Visual Intrusion of Elevated Structures

Any fixed-guideway transit system using elevated structures will visually intrude on neighborhoods it serves. Some modes require more massive elevated structures than others. The extent of this intrusion by different modes is dependent on the specific area and can be largely subjective.

- At a distance, the visual mass of monorail beamway and elevated rail structures is similar. The vertical dimension of the beamway is about the same as for the guideway of other modes. However, the less-frequent column spacing of the monorail and ICTS guideways tends to reduce their visual impact, and make them less intrusive.

- Near or under the system, the thinness and separation of the monorail beamways provide a more "open" structure, allowing more light to reach the ground, and giving a "lighter", more pleasing appearance. As many people in built-up areas will view the transit systems from below, the monorail beamway can constitute less of a visual intrusion than conventional transit structures. Adding a walkway to the monorail beamways could reduce its visual advantages.

- The elevated power wires and supporting structures required by the pre-metro mode will add to the visual intrusion of pre metro elevated structures.

Visual intrusion of elevated structures is considered to be a key issue for decision makers.

3.3.2 Operation in Mixed Traffic

This evaluation criteria affects only light rail and pre-metro as the other modes of this study cannot operate in mixed traffic with automobiles nor have grade crossings at streets.

- Operation of light rail vehicles along city streets creates a potential interference with automobile traffic, and vice versa.

- There are locations along the typical corridors in Dallas where automobile traffic and train headways at higher capacity levels will produce unacceptable mobility interferences. The number of locations and the extent of traffic congestion and transit system delay depends on traffic volumes and train frequency. There will be relatively few such locations below the 10,000 pph capacity level and not many more at the 20,000 level. These potential problems can be solved by a judicious use of at-grade gates, grade separations, and downtown transit malls.

Mixed traffic operation is a design issue of which decision makers should be cognizant; it is not considered to be a key issue.

3.3.3 Community Physical Barriers

Transit systems can create physical barriers in communities. The method of deployment determines the level of barrier that results. In increasing order of severity, the most divisive implementation methods are:

1.0 Subways (essentially no barrier)

2.0 Elevated structures, which allow automobile and pedestrian traffic to move freely below.

3.0 Light rail transit with at-grade crossings.

4.0 At-grade, fenced right-of-way for any transit mode (complete barrier).

The potential for creating community physical barriers is an aspect of the modes and their design that could be a key issue for decision makers.

3.3.4 Exterior Noise

The potential for unplesant noise impacts on nearby observers and residents is an important characteristic of the modes.

- Without accounting for train length variation and noise attenuation effects, at-grade and elevated rapid rail is the noisiest mode investigated, and WED Mark IV monorail is the quietest. Rapid rail is considered to be in the "annoying" to "very annoying" range.

- Adjusting each mode for varying train lengths to satisfy capacity requirements and accounting for noise attenuation measures, light rail and ICTS are the quietest and Hitachi monorail is the noisiest of the elevated modes. At-grade, WED Mark IV monorail is the quietest and rapid rail is the noisiest. It is anticipated that attenuation measures for the rail modes would be needed in several locations throughout a corridor. Their use would reduce the noise to levels significantly below the "annoying" human response range at 50 feet.

With appropriate noise attenuation measures, exterior noise is considered not to be a key issue for decision makers.

3.3.5 Geometric Constraints

ICTS, light rail, and pre-metro are capable of negotiating significantly sharper horizontal turns than rapid rail or monorail: less than 100 ft. compared with 250 ft. These different capabilities can affect the amount of land required to deploy different modes and thus the method and cost of building the system in an urban environment. This could be significant in the selection of a mode for Dallas, depending upon the alignment(s) that are selected.

Geometric constraints is an aspect of the modes about which decision makers should be cognizant; it is not considerd to be a key issue.

3.3.6 Implementation Time

The relative implementation times for the modes were investigated, with the following findings:

- From an analysis of some recent transit implementations, the projects that have demonstrated the shortest completion times are light rail projects involving at-grade construction/rehabilitation of existing railroad rights-of-way. When elevated construction is required, precast guideway designs also allow fast construction times.

- Any mode utilizing subway construction will take the longest time to construct.

- The actual determination of implementation time of any mode requires a specific analysis of the proposed project, corridor, and alignment.

Implementation time could be a key issue for decision makers in choosing between modes with at-grade and elevated or subway guideway alignments.

4.0 CORRIDOR ANALYSIS

The findings of the detailed corridor analysis can be grouped into two categories: 1) unique physical characteristics or constraints resulting from the application of the modes in the rail and highway corridors, and 2) capital, operation and maintenance, and total annual costs of each mode.

In the corridor analysis, the monorail mode was defined as a composite of Hitachi and WED technologies. The WED Mark V concept urban vehicle is not sufficiently defined to permit operations and cost analyses, thus the Hitachi vehicle was used. The WED guideway design is more appropriate than that of Hitachi for the Dallas area; thus the monorail guideway in the corridor analysis was like the current WED Mark IV design, but modified to support the larger and heavier urban vehicles.

4.1 PHYSICAL AND OPERATIONAL CHARACTERISTICS

In the corridor analysis, specific requirements were established for each mode. These requirements included passenger stations guideway and right-of-way. Vehicle fleet, labor requirements, and other impacts varied by mode, by alignment, and by guideway exclusivity. Mode differences were not always significant, given the similarity of the basic requirements. These issues are discussed at length in Sections 8.0, 9.0, and 10.0 in the Final Report. An overview is given below.

4.1.1 Stations

Important aspects of stations in the corridor analyses are as follows:

- o The light rail mode allows the simplest station designs due to its at-grade configuration.

- Station lengths depend on mode and capacity levels. They varied from 150 ft. (rapid rail at the 5,000 level) to 500 ft. (pre-metro at the 20,000 and 30,000 levels).

- Stations in the highway alignment were more complex than in the railroad alignment, because of right-of-way constraints and limited passenger accessibility afforded by certain highway locations.

4.1.2 Guideway and Right-of-Way

Rail Corridor. In the rail corridor, guideway alignments and profiles were determined by available right-of-way and mode guideway exclusivity requirements.

- Light rail would operate at-grade the entire length of the rail corridor except for a few grade separations at major arterials and railroads. Pre-metro would also operate at-grade for most of this corridor; it would be elevated in the CBD.

- Monorail, ICTS, and rapid rail would be grade-separated (generally elevated) in the northwestern and CBD section of the rail corridor, but in some of the southeastern section they would operate at-grade in a protected right-of-way.

- In the rail corridor, relatively little land outside of the existing railroad rights-of-way would have to be acquired. A fixed guideway transit system would necessitate relocating some existing railroad tracks.

Highway Corridor. In the highway corridor, guideway alignment and profile were dictated largely by the existing highway configuration.

- Along the freeways investigated, the outer separation between the main travel lanes and the frontage road along the east side would generally be the best location for transit guideway.

- Light rail at-grade cannot be placed in the specified highway alignment.

- Although columns could physically be placed in the medians of most of the freeways, State Department of Highways and Public Transportation clearance requirements, station design difficulties and costs, and station accessibility would preclude the use of the median area for fixed guideway transit.

- The highway corridor would require significant amounts of additional right-of-way, both for stations and for guideway. It would also require relocation of some existing buildings, frontage roads and ramps, and railroad tracks. Along the South Central Expressway, existing highway alignment and land uses south to the Hawn Freeway do not allow for transit guideway in the outer separation; new right-of-way east of the frontage road would be needed.

- A 3.2-mile downtown subway was also investigated for the highway corridor to compare subway and elevated system costs.

4.1.3 Vehicle Fleet

The number of vehicles required for each mode is a function of mode capacities and performance, and of guideway exclusivity. Because of the similar length and number of stations in the two corridors examined, fleet requirements for both the corridors were similar.

- Rapid rail required the fewest vehicles because it has the highest capacity vehicle. Fleet size ranged from 46 vehicles at the 5,000 pph capacity level to 278 at the 30,000 level.

- Pre-metro had the second lowest vehicle requirements, about 30% to 40% more than the rapid rail fleet.

- The monorail and light rail modes required about the same number of vehicles: about 70% more than the number of rapid rail vehicles.

- ICTS required the highest number of vehicles: about 2.6 times as many as rapid rail.

4.1.4 Labor Requirements

Operating and maintenance labor requirements are primarily a function of passenger-carrying requirements and vehicle capacity. The number of stations, length and type of guideway, and local operating and management policies also affect labor requirements.

- At the 5,000 capacity level, light rail and monorail were estimated to have the lowest personnel requirements (393 and 408, respectively), pre-metro and rapid rail about 420, and ICTS about 450.

- At the 10,000 and 20,000 capacity levels, rapid rail was estimated to have the lowest number of personnel, primarily because it has the fewest vehicles and operating trains. At these levels, the number of monorail and pre-metro employees were similar, and were greater than rapid rail. Light rail and ICTS had the most employees at these levels.

- Rapid rail had about 1,100 employees at the 30,000 level; pre-metro, the only other mode to serve this level, had about 1,250.

- ICTS required the most total labor, primarily because of the capacity limitation of its trains and the local requirement for drivers on each vehicle, which would negate a major potential advantage of ICTS: automated operation.

4.1.5 Travel Time

Differences in travel times between the modes were significant in the corridor analyses:

- Modes operating in an exclusive corridor (monorail, ICTS, and rapid rail) had similar travel times.

- Light rail in a non-exclusive corridor would be 10% to 50% slower due to its totally at-grade configuration. This would vary with the degree of protection (gates) and grade separation at cross streets, the degree of mixed traffic downtown, and the priority trains have over street traffic.

- Pre-metro would be 8% to 26% slower than the exclusive guideway modes, depending on the amount of at-grade guideway and the degree of protection and priority in those sections.

4.2 COST SUMMARY

Capital, operating and maintenance, and total annual costs were estimated for each mode, along each corridor, and for each passenger capacity level that each mode could serve. Cost results are summarized in this section; detailed cost information is presented in Sections 9.0, 10.0, and 11.0 of the Final Report.

4.2.1 Capital Costs

Capital costs for each mode were estimated for: 1) guideway, 2) stations, 3) power distribution systems, 4) command, control, and signal systems, 5) maintenance and storage facilities, 6) vehicles, and 7) right-of-way. Engineering and contingency costs were added to these categories.

Figure 4-1 shows an example of the relative amounts of these capital cost categories at the 10,000 pph capacity level for all modes and both corridors.

The following general conclusions can be drawn from the capital cost analysis:

- o The extent of elevated guideway was a major determinant of total capital costs. Capital cost estimates for the highway corridor were significantly higher than the rail corridor primarily because the former would require almost totally elevated guideway.

- o Vehicle capacity was the other major factor in capital costs. Modes with higher vehicle capacities had fewer vehicles, and, generally, lower capital costs than modes with smaller vehicles. This difference increased with capacity requirement.

- o Right-of-way costs were about the same for all modes and for both corridors. Although the use of highway right-of-way in the highway corridor was assumed to be free, land costs for stations outside of the highway right-of-way often made this capital cost category slightly higher than that of the rail corridor.

Figure 4-2 summarizes capital costs for each mode, corridor, and capacity level.

- o Light rail in the rail corridor was the least expensive mode to implement, primarily because of its much lower at-grade guideway costs.

- o Pre-metro in the rail corridor had the second lowest capital costs at the 5,000 to 20,000 capacity levels, again due to the greater degree of at-grade guideway than the other modes. At the

FIGURE 4-1
TOTAL CAPITAL COSTS
AT THE 10,000 PPH CAPACITY LEVEL

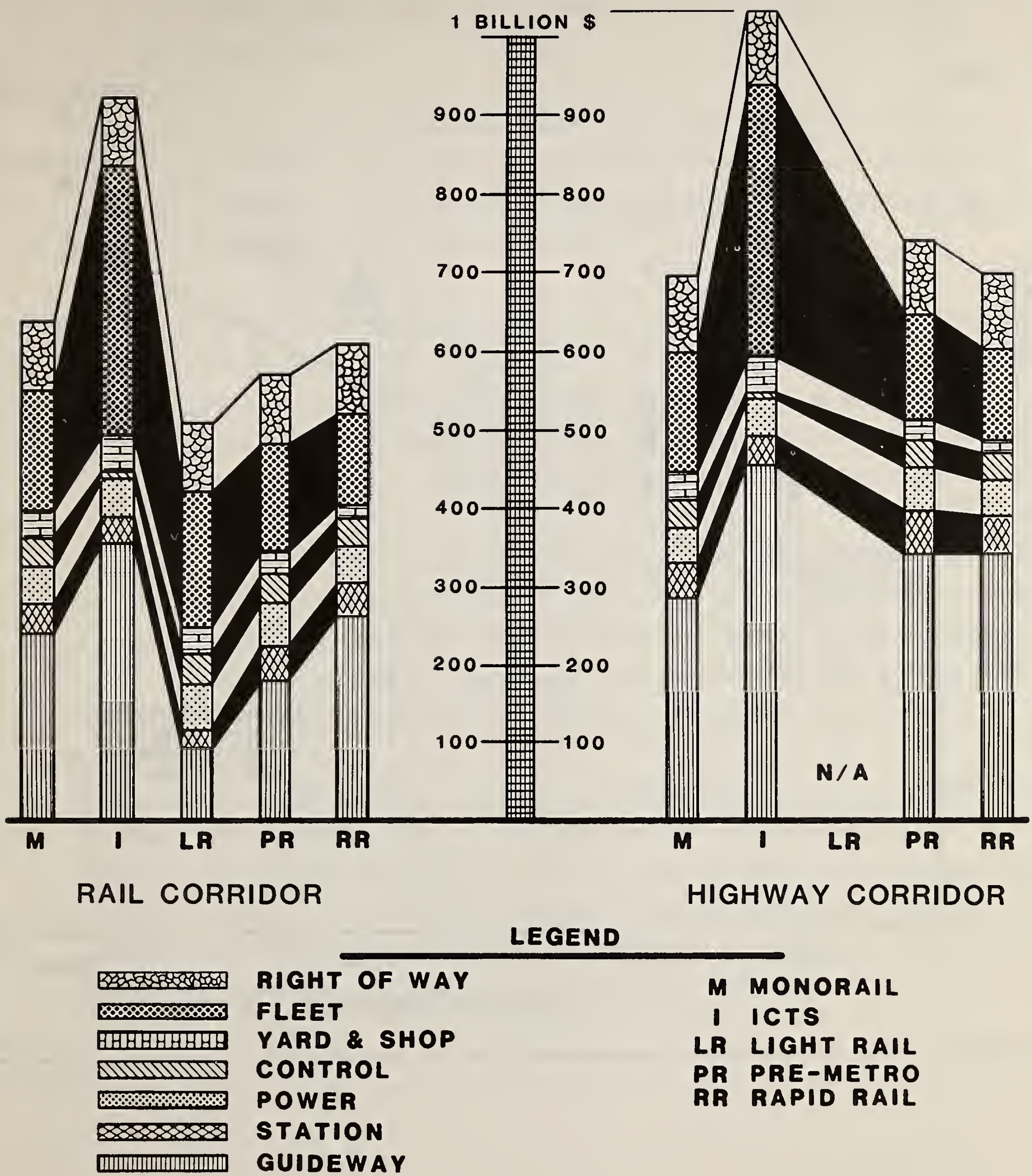
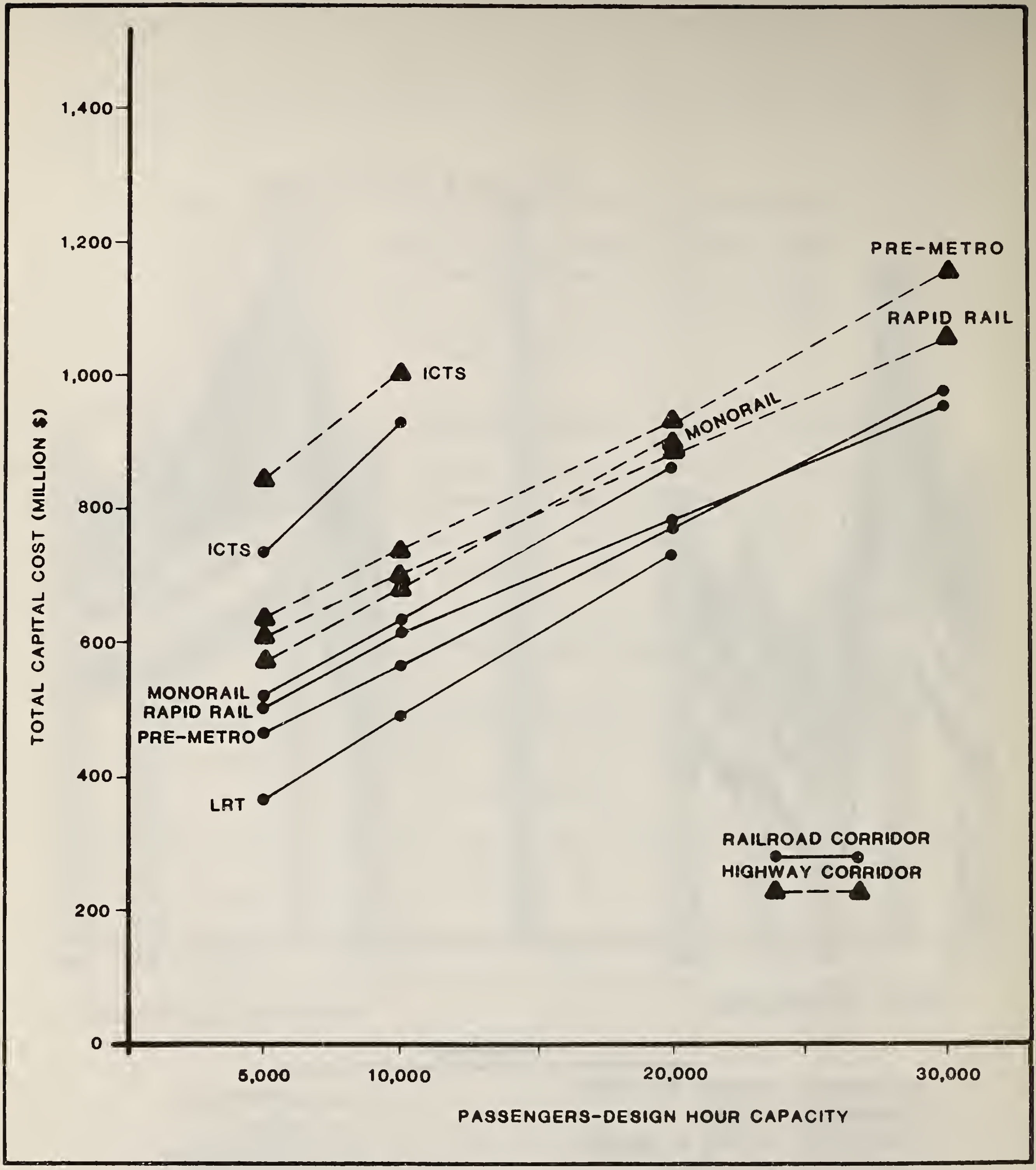


FIGURE 4-2
TOTAL CAPITAL COSTS



30,000 passenger per hour capacity level, lower fleet costs resulted in rapid rail in the rail corridor being the lowest capital cost mode.

- Monorail had the fourth (of five) highest capital costs in the rail corridor: its elevated guideway savings did not offset its higher fleet costs or the lower at-grade guideway costs of the other modes.

- Light rail, pre-metro, rapid rail, and monorail in the rail corridor all had lower capital costs than any mode in the highway corridor, primarily because of the amount of elevated guideway required in the highway corridor.

- In the highway corridor, monorail had the lowest capital cost at the 5,000 and 10,000 pph capacity levels, and was second to rapid rail at the 20,000 pph capacity level. Monorail and rapid rail were both less expensive than pre-metro, which generally had higher guideway, station (due to train length), and fleet costs.

- ICTS, regardless of corridor, had significantly higher capital costs than the other modes. This was primarily due to the higher number of vehicles (each of which has sophisticated automated control equipment on-board) and guideway costs (due to the reaction rail and higher degree of tolerances required).

A separate cost analysis of a 3.2-mile downtown subway, replacing elevated guideway, was undertaken for the highway corridor. The total capital cost increases of the subway option, including engineering and contingencies, ranged from $147 million to $184 million. This downtown subway resulted in increases in total costs of 21% and 31% for monorail, 14% to 18% for ICTS, 16% to 26% for pre-metro, and 16% to 27% for rapid rail.

4.2.2 Operation and Maintenance Costs

Given the corridors, the modes considered, and the bases for O&M cost estimates, several general conclusions can be made about O&M costs in these typical Dallas corridors.

- For such similar system configurations, the type of corridor had little effect on the O&M costs of each mode. At each capacity level, the estimated annual O&M costs for each mode varied by less than three percent between highway and rail corridors.

- At the lower capacity levels, annual O&M costs differed relatively little among the modes: there was an estimated 7% separating the least expensive and the sixth most expensive mode/corridor combinations. At the 20,000 capacity level and higher, the difference between the best and second best modes became more apparent: rapid rail was 11% to 12% less costly than the other modes. The primary reason for this difference was due to relative vehicle capacities.

- At low capacity levels, light rail in the rail corridor had the lowest O&M costs. As capacity requirements increased, the guideway exclusivity of most other modes allowed relatively fewer trains, thus lower O&M costs.

- Monorail O&M costs were about the same as those of pre-metro at the three capacity levels monorail served, making it generally the second or third best mode when considering only O&M costs independent of corridor. Monorail had the lowest O&M cost in the highway corridor at the lowest capacity level. As capacity requirements increased, the gap between monorail and the lowest O&M cost mode increased, but it remained within 15%.

- Because it has the largest unit capacity, rapid rail became the lowest O&M cost mode at the 10,000 level and remained so at the higher capacity levels. Only the rapid rail and pre-metro modes met the 30,000 capacity requirement. Rapid rail was significantly less expensive to operate and maintain at this capacity level.

- ICTS consistently had the highest O&M costs in both corridors at the capacity levels it could serve. This was due in part to: 1) the requirement of having train drivers/attendants on a system designed to be automated, and 2) having relatively low capacity vehicles in corridors with medium to high capacity requirements.

These conclusions are based on estimates of only operating and maintenance costs. Full annual costs, that include an annualization of capital costs, are a better indicator of both costs and cost-effectiveness, and provide a more appropriate basis for modal comparisons.

4.2.3 Total Annual Costs

Total annual costs were estimated using annualized capital costs and the annual O&M costs. An example of the components of total annual costs is shown in Figure 4-3. Total annual costs for all modes, corridors, and capacity levels are summarized in Figure 4-4. Table 4-1 provides a relative ranking of the annualized costs of the modes in both corridors.

The results presented in Section 11.1 of the Final Report led to several general conclusions for the typical rail and highway corridors in Dallas about the annual costs of each mode considered in this study.

- Annualized capital costs were a major factor in determining overall modal costs and cost-effectiveness. In this study, they were found to constitute between 33% and 54% of total annual costs.

FIGURE 4-3
TOTAL ANNUAL COSTS
AT THE 10,000 PPH CAPACITY LEVEL

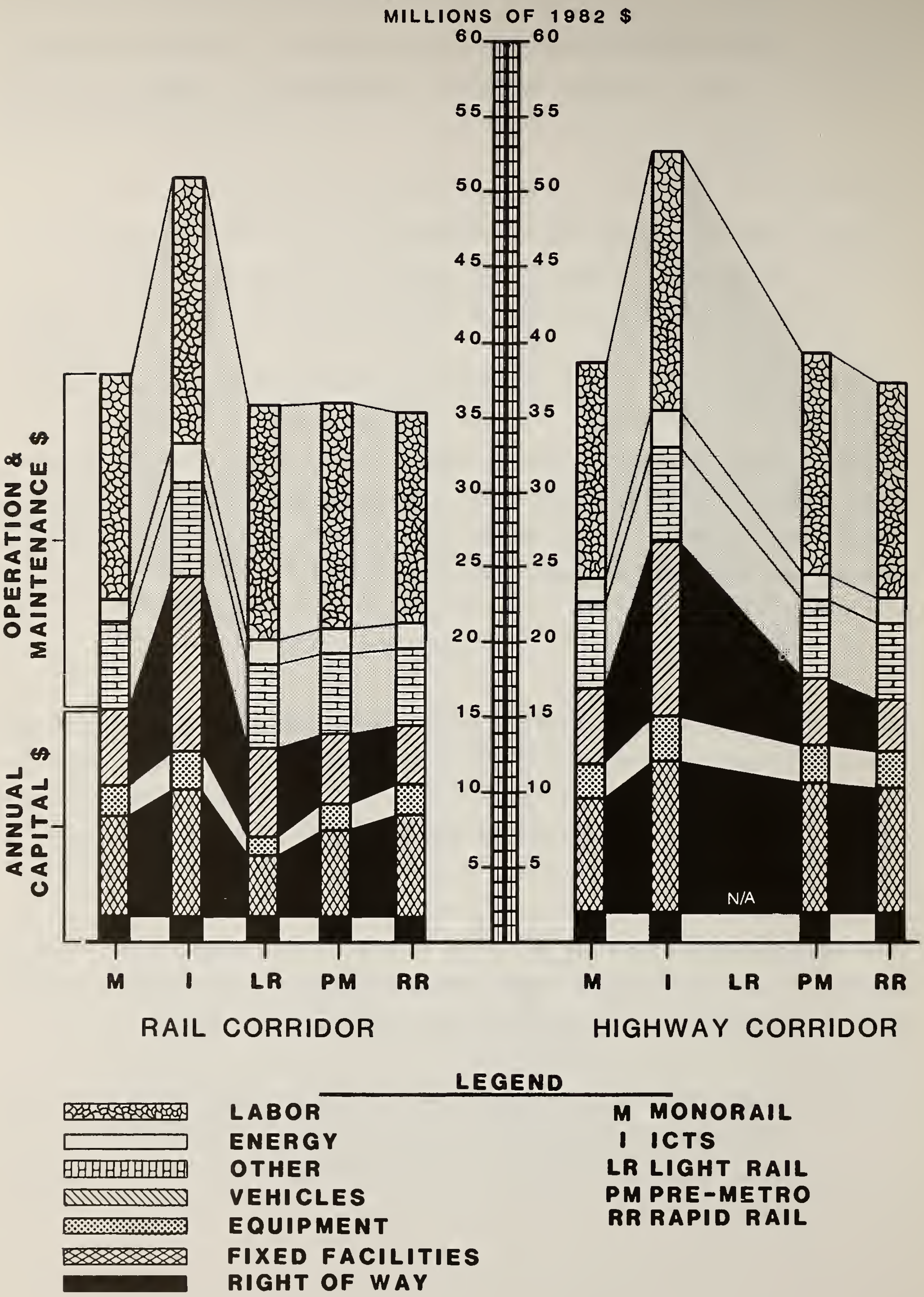
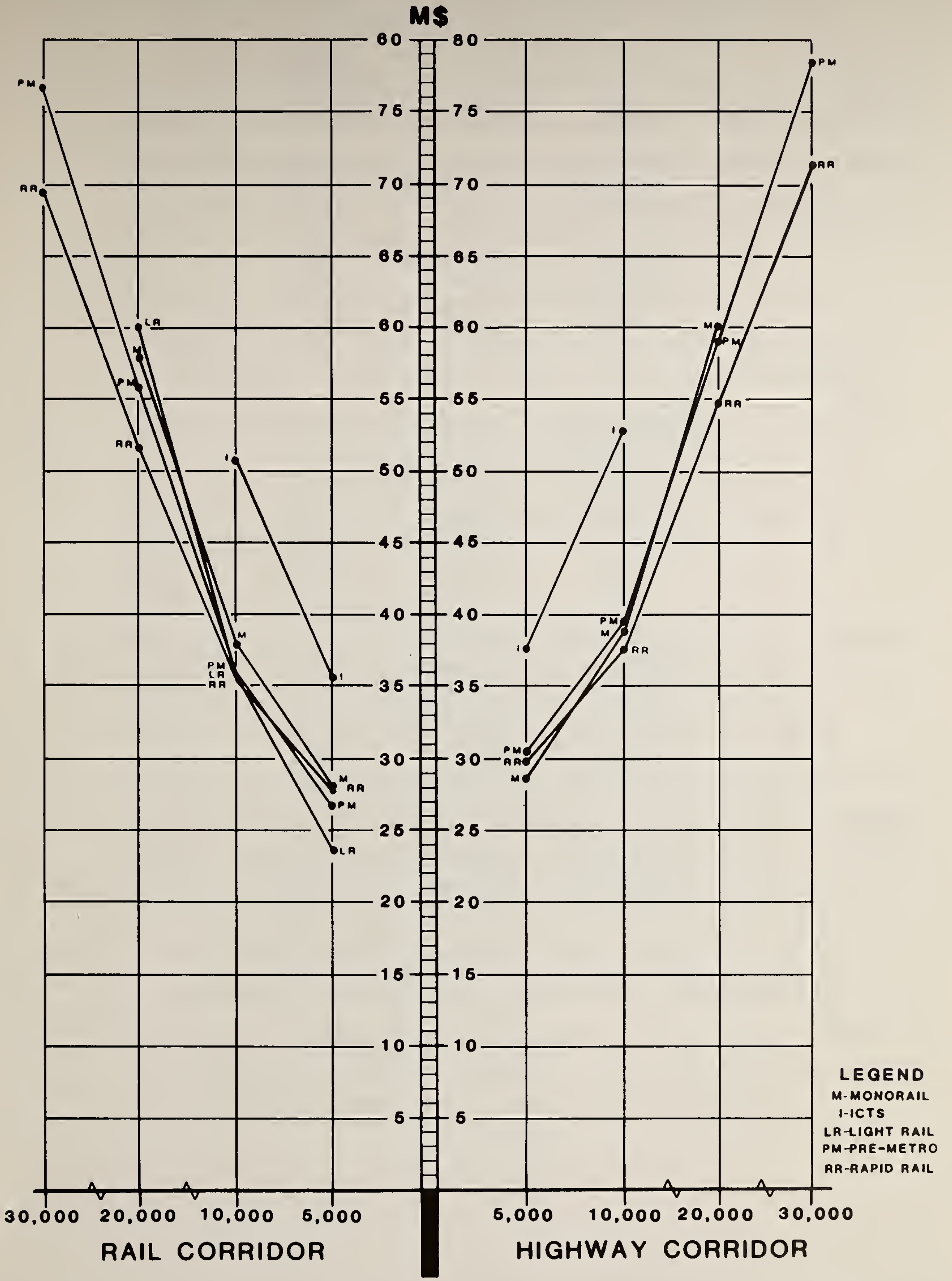


FIGURE 4-4

TOTAL ANNUAL COSTS BY MODE AND CAPACITY LEVEL



M$ – Total Annual Costs, Millions Of 1982 $

TABLE 4-1
SUMMARY OF TOTAL ANNUAL COSTS BY CAPACITY LEVEL

Capacity Level	Rank	Mode	Corridor	Total Annual Cost (millions)	Index
5,000	1	Light Rail	Rail	23.8	100
	2	Pre-Metro	Rail	26.6	112
	3	Rapid Rail	Rail	27.6	116
	4	Monorail	Rail	27.7	116
	5	Monorail	Highway	28.8	121
	6	Rapid Rail	Highway	29.6	124
	7	Pre-Metro	Highway	30.1	126
	8	ICTS	Rail	35.4	149
	9	ICTS	Highway	37.5	158
10,000	1	Rapid Rail	Rail	35.4	100
	2	Light Rail	Rail	35.6	101
	3	Pre-Metro	Rail	35.9	101
	4	Rapid Rail	Highway	37.4	106
	5	Monorail	Rail	37.9	107
	6	Monorail	Highway	38.8	110
	7	Pre-Metro	Highway	39.4	112
	8	ICTS	Rail	50.5	143
	9	ICTS	Highway	52.9	149
20,000	1	Rapid Rail	Rail	51.6	100
	2	Rapid Rail	Highway	54.8	106
	3	Pre-Metro	Rail	55.8	108
	4	Monorail	Rail	57.8	112
	5	Pre-Metro	Highway	58.9	114
	6	Monorail	Highway	59.9	116
	7	Light Rail	Rail	60.0	116
30,000	1	Rapid Rail	Rail	69.1	100
	2	Rapid Rail	Highway	71.2	103
	3	Pre-Metro	Rail	76.6	111
	4	Pre-Metro	Highway	78.4	113

- Light rail in the rail corridor was the most cost-effective mode for the lowest capacity levels and was tied for first at the 10,000 capacity level. The primary reason for this was the significantly lower cost of the at-grade fixed facilities. At higher capacity levels, its cost strength at the lower levels - nonexclusive guideway - became its weakness. Significantly more vehicles and several grade separations were needed to meet capacity requirements, increasing both capital and O&M costs.

- Rapid rail was the most cost-effective mode at the 10,000 through 30,000 capacity levels, and its margin of effectiveness increased with the capacity level. The primary reason for the high standing of rapid rail was the capacity of its vehicle. With the largest vehicle, it required the fewest total number of vehicles (giving both capital and O&M cost advantages) and the fewest number of operating trains and vehicle miles (meaning lower O&M costs).

- Monorail was the most cost-effective mode in the highway corridor at the 5,000 level. When considering all mode-corridor combinations, monorail was, at best, the fourth most cost-effective mode at the three capacity levels it served. Its lowest total annual costs, regardless of corridor, were between 7% and 16% higher than the most cost-effective mode. Although the larger, elevated monorail guideway required for the urban vehicles was less expensive than elevated guideways for the other modes, this advantage was offset because most other monorail capital costs were approximately equal to (e.g. stations, power, and control systems) or even greater than (e.g. at-grade guideway and, in some cases, fleet) those of competing fixed-guideway modes, while O&M costs in an urban transit setting were comparable to those of the other modes.

- The light rail vehicle was cost-effective over a range of applications, as shown by the pre-metro data. At the 5,000 capacity level, pre-metro in the rail corridor was second most cost-effective: 12% higher than light rail in that corridor. Pre-metro in the rail corridor essentially tied for first at the 10,000 level and third at the 20,000 level (by 8%), and at the 30,000 level (by 11%). Pre-metro was one of the two modes that could serve all four capacity ranges. Pre-metro could be applied in the highway corridor, but it was among the least cost-effective there, usually ranking sixth or seventh out of the nine mode-corridor combinations considered.

- ICTS was the least cost effective of any mode in any corridor at the two capacity levels that it could serve. This was, in part, because in this study, ICTS was not permitted to take advantage of its automation: by local policy decision each train had a driver/attendant. Also, its vehicles had the lowest capacity of any in this study, yet were estimated to be as expensive as any of the others, even those that can carry nearly three times the number of passengers. With many more vehicles required at each capacity level, ICTS had much higher capital and O&M costs.

The total annual cost results suggested a conclusion about corridors, as well. In most cases, the annual O&M costs were about the same for either corridor application of each mode; yet, the corresponding total annual costs for rail applications were always less. Fixed facilities and right-of-way costs were higher in the highway corridor, as much more elevated guideway was needed, the construction was found to be more difficult, and adjacent land was more expensive.

4.2.4 Fare Analyses

A fare analyses was undertaken to determine what fare would be required for each mode, at each capacity level to recover 50% and 100% of annual costs and to recover 50% and 100% of total annual costs.

The analyses showed that:

- O&M cost recover fares were nearly the same for both corridors. At the 5,000 capacity level, fares to recover 100% of annual O&M costs varied between $1.19 (light rail) and $1.41 (ICTS), regardless of corridor. At the 10,000 capacity level, these fares declined to between $.84 (rapid rail) and $1.05 (ICTS). At higher capacity levels, these declined further to between 50¢ and 80¢.

- Fares to recover total annual costs were between 1.5 and 2 times higher than fares to recover O&M costs. Such fares were higher for modes in the highway corridor than the same mode in the rail corridor.

5.0 DECISION MAKING PROCESS

To assist in structuring a decision making process for selecting among fixed guideway transit modes, an example decision framework was prepared to identify the various trade-offs to be considered. This framework focused on the concerns of four distinct groups of people: 1) the users of the new system; 2) non-users who would be affected by its deployment; 3) agency personnel who would direct its design, construction and operation; and 4) the governing board that would establish policy and oversee operations, performance, and expansion.

The decision framework was prepared in two steps. First, the key issue findings of the study were reviewed to determine which would have relevance to each of the four groups of people identified above.

Second, each key issue was analyzed to illustrate how the decision might change depending on a decision maker's particular focus. Finally, a form for implementing the suggested decision making process was offered.

Considerations for deploying one technology or multiple (different) technologies in a service area were also presented as part of this decision making process.

APPENDIX

SUPPLIERS' COMMENTS

INTRODUCTION TO SUPPLIER COMMENTS

This *Dallas Fixed Guideway Rapid Transit Mode Analysis* was undertaken to compare two modes currently not in wide application, monorail and ICTS, with modes that have extensive application in the United States and worldwide: light rail, pre-metro, and rapid rail. Because data for monorail and ICTS are limited, it was essential to enlist the support and cooperation of the three affected suppliers: Hitachi, Ltd. and WED Transportation Systems, Inc. (WED) for monorail, and the Urban Transportation Development Corporation (UTDC) for ICTS. Accordingly, this study effort proceeded in close coordination with these firms, including site visits, meetings, and oral and written exchanges of information; and the Consultant team is grateful for their cooperation and assistance.

Some of these suppliers requested that they be permitted to review the final draft documents and provide comments, in the interest of ensuring that information about their products was correct and complete. This was done, and supplier comments were considered in developing the final text of the report. There remain, however, some differences of professional opinion, interpretation, and perceptions of fact. At the request of two suppliers, and in keeping with the cooperation established with the suppliers, the Consultant team, with the approval of the client, agreed to incorporate comments from the three suppliers as appendices to the Final Report and this Executive Summary. WED and UTDC submitted comments; Hitachi did not.

The reader is encouraged to recognize the following when reading these supplier comments and to refer to the complete text of the report when evaluating them:

1. These comments are provided by organizations marketing a product that is new in urban transit applications.

2. The Consultant team has not edited these comments in any way; they are included exactly as they were received. Some comments are out of context, and some are incomplete in that they mention only the beneficial aspects related to their products.

3. Some comments respond to earlier draft versions, to which changes have subsequently been made. Thus these comments may no longer be pertinent.

4. These comments do not indicate the total scope of the study; neither do they reflect the balanced assessment of all the modes contained in the Report.

5. The Consultant team does not take any responsibility for the accuracy or validity of any of these comments by the suppliers.

6. The Consultant team is also not responsible for nor necessarily in agreement with, the suppliers' inferences from this study and extrapolations to the ongoing Dallas and DART transit planning process.

DISNEY-TURNER TEAM

EXECUTIVE SUMMARY

The needs of the Dallas Area can only be served through area-wide transportation planning as embodied in the DART concept. Obviously, mass transportation is an essential element in solving the long-term growth needs of the Dallas Area and comparative data as contained in the report can be vital to final system planning by a permanent DART authority.

We compliment the Consultant Team on their very comprehensive study of rail technologies, including monorail, and after the initial study was presented, appreciate the consideration and inclusion of the majority of the 200 comments submitted by WED. While there exists some remaining professional differences of opinion in significant areas, the "study's bottom line" is that all technologies considered will be capable of successfully accommodating the transportation needs of the Dallas Area in a safe and reliable manner.

It has been difficult to summarize comments on this comprehensive study in the relatively short allotted space of ten pages contained in the detailed report and a two-page Executive Summary. Therefore, phrases have been extracted from the study and incorporated in comments even at the risk of being criticized for "taking things out of context." However, in all references, information is only used when the full text supports the reference.

We feel the fundamental conclusions are:

1) Each technology is cost effective in specific applications.

2) As detailed systems planning begins to take place, remaining "technological differences" will tend to narrow, with all being feasible and with no clear best technology.

3) All technologies (excluding ICTS), in each application, have a cost range no greater than 16%, with each being the most cost effective in certain corridors. Certainly, with order of magnitude costs estimates, a too-close-to-call scenario exists.

4) As transit planning evolves in the Dallas Area, we feel that final solutions will tend to be in the "more elevated configuration" and in the capacity ranges where monorail is cost effective when compared to other technologies.

5) Final planning needs to be performed and all technologies should be allowed to compete and decisions made based upon competitive costs, rather than relying on preliminary engineering estimates which, by their very nature, do not incorporate detailed technological nor applications engineering.

Finally, since this Executive Summary does not allow space for detailed discussions on any particular item, we encourage readers to closely review the detailed comments regarding the monorail made by us elsewhere in the full report.

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March 23, 1983

Mr. Dennis M. Elliott
Lea, Elliott, McGean/DeLeuw, Cather
1000 West Randal Mill Road
Arlington, Texas 76012

Dear Mr. Elliott:

I appreciate the opportunity to review a copy of the Draft Final Report on the Dallas Fixed Guideway Rapid Transit Mode Analysis submitted with your March 21, 1983 letter.

I also understand that many of the comments by our Mr. E. F. Ries, Senior Vice President Marketing and Product Applications were incorporated in your text, and that his letter dated March 4, 1983 will be incorporated in your final report.

Nevertheless, I find one remaining, fundamental point that has to be made at the very introduction of your report which otherwise is a highly professional undertaking. When significantly different transit modes are compared, as you well know, each mode needs to be optimized within its own capabilities and constraints for the given application. This clearly could not be done in this report for ICTS because of some arbitrary perceptions and ground rules imposed upon the study. In view of this, I respectfully request that you include the following text in Section 1.0 Introduction of your final report:

"ICTS is unique among the candidate systems considered in this report, it is the only representative of a new class of transit alternatives known as Automated Guideway Transit (AGT).

ICTS (as other systems in the AGT class) was developed and is under contract for construction in Detroit and Vancouver, BC, as a fully automated transit system with un-manned (driverless) operation of trains or vehicles in urban applications.

Because of perceived requirements in Dallas, driverless operation of trains is not allowed in this comparative analysis. Similarly, the operational assumptions limit the permitted headways to two minutes, inspite of the claimed ICTS capability to operate at 60 seconds headway. Thus ICTS passenger carrying capacity is reduced throughout this analysis.

These two limitations force the ICTS system to appear less effective and more costly in this unintended, conventional, manually operated application than in its intended, automated operational mode in other cities."

Please feel free to make minor editorial changes, provided you retain the essence of this clarification. Your inclusion of this letter in your report will be also appreciated.

I thank you for providing the opportunity to comment on your work.

Sincerely yours,

G. J. Pastor
President
UTDC (USA) Inc.

GJP/delb

cc: Mrs. Adlene Harrison, Chairman
Mr. Maurice Carter

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*U.S. GOVERNMENT PRINTING OFFICE : 1984 0-421-428/306

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