# Rail Transit Technology and Design Guidelines

Gannett - DeLeuw



Metro Rail Planning Study

August 1990

# RAIL TRANSIT TECHNOLOGY AND DESIGN GUIDELINES

The Municipality of Metropolitan Seattle (Metro) is considering as part of the region's long-range transit program, the introduction of a high capacity transit component to the Metro transit network by the year 2000. The Metro Rail Planning Program is comprised of a series of studies to evaluate the feasibility of rail transit within corridors that have previously been identified for some form of high capacity transit. Not only will these studies determine the viability of a high capacity transit system, but will also recommend an initial system as well as system phasing and extensions. In the context of the Metro Long Range Plan for transit, these studies will begin the process of improving long-term mobility for regional residents. The Design Guidelines Study is one of the studies currently under way as part of the Metro Rail Planning Program. This study includes evaluation of existing rail transit technology, operating assumptions and plans, and civil design of both guideway and stations. This document presents a compendium of four technical memoranda completed as part of this Design Guidelines Study. The reports included in this document are:

- Technology Assessment
- Civil Design Guidelines
- Station Design
- Operating Assumptions.

The overall purpose of the Design Guidelines Study is to identify and recommend appropriate rapid transit technologies that should be used as a basis for exploring the feasibility of implementing rail transit in any of the high capacity transit corridors being considered by Seattle Metro. Identification of the appropriate rail transit technology provides a foundation for the development of detailed information on transit station requirements, civil engineering design specifications, and procedures for developing operations plans.

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# Technology Assessment

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# I. INTRODUCTION AND PURPOSE

## A. Introduction

The Municipality of Metropolitan Seattle (Metro) is considering as part of the region's long-range transit program, the introduction of a high capacity transit component to the Metro transit network by the year 2000. The Metro Rail Planning Program is comprised of a series of studies to evaluate the feasibility of rail transit within corridors that have previously been identified for some form of high capacity transit. Not only will these studies determine the viability of a high capacity transit system, but will also recommend an initial segment as well as system phasing and extensions. In the context of the Metro Long Range Plan for transit, these studies will begin the process of improving long-term mobility for regional residents. The Design Guidelines Study is one of the studies currently under way as part of the Metro Rail Planning Program. Task 1 of the Design Guidelines Study is entitled Assess Appropriate Rail Vehicle Technology. This technical memorandum presents the analysis, conclusions and recommendations related to Task 1 of the Design Guidelines Study.

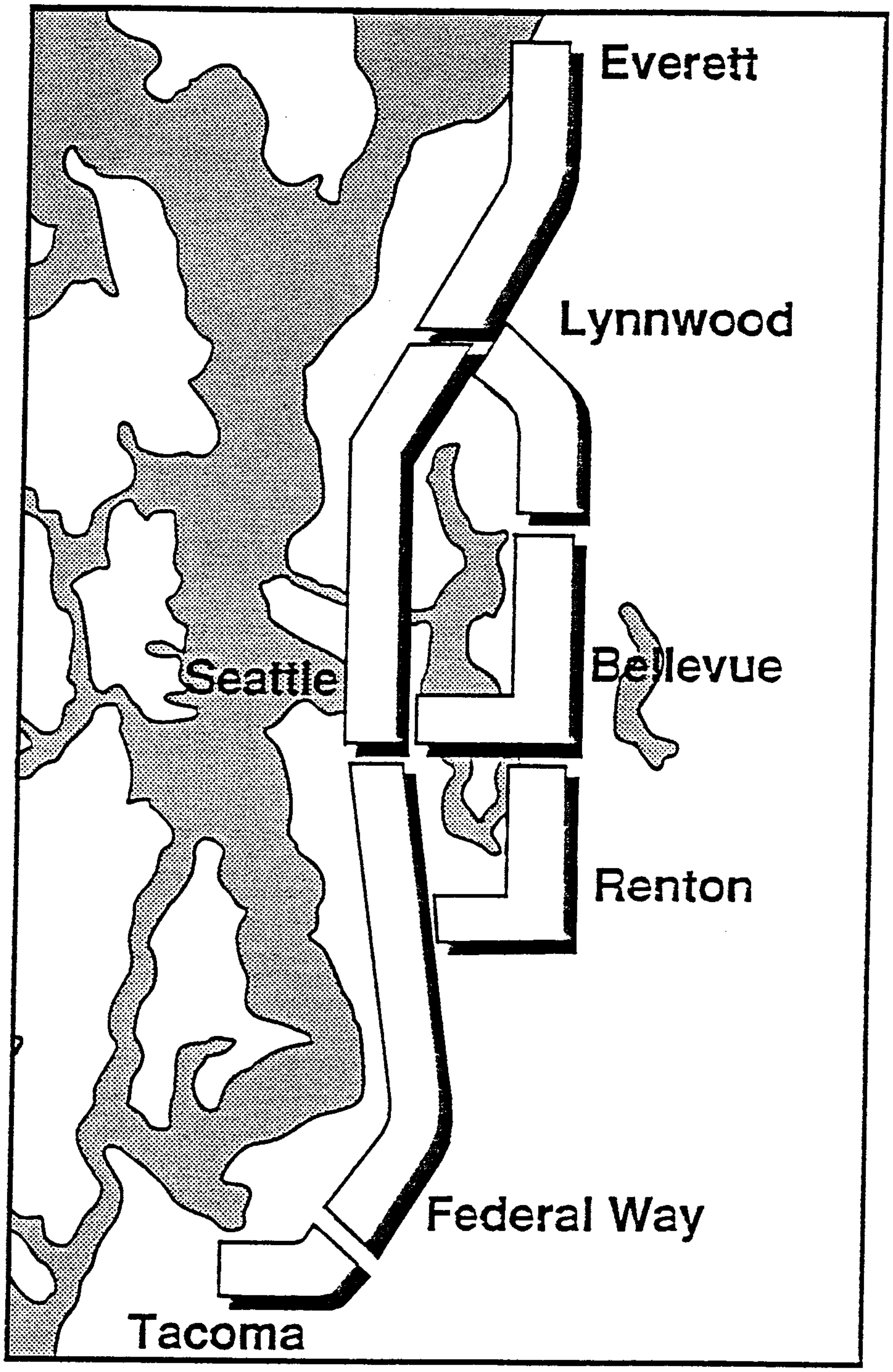
## B. Purpose

The overall purpose of the Design Guidelines Study is to identify and recommend appropriate rapid transit technologies that should be used as a basis for exploring the feasibility of implementing rail transit in any of the high capacity transit corridors being considered by Seattle Metro (see Figure 1). Once the appropriate rail transit technologies are identified, a second purpose of the Design Guidelines Study is to provide detailed information on transit station requirements, engineering design specifications, and procedures for estimating both capital and operating costs. The contents of this memorandum contains documentation on the analysis, results, conclusions and recommendations of work undertaken to address the following tasks and subtasks of the Metro Rail Planning Study:

Study B - Design Guidelines Study

Task 1 - Assess Appropriate Rail Vehicle Technology

1.1 - Describe Technology Options
1.2 - Assess Suitability of Technology to the Region
1.3 - Identify Constraints in Use of Technology
1.5 - Recommend a Range of Suitable Technology Options




Metro Rail Planning Study

Transit Technology Assessment

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HIGH CAPACITY TRANSIT CORRIDORS

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Figure #1

## C. Methodology

The overall purpose of this technology assessment is to identify and recommend appropriate rapid transit technologies that should be used as a basis for exploring the feasibility of implementing rail transit in any of the high capacity transit corridors being considered by Metro. The methodology which is used in this report is summarized below.

Selection of the appropriate rail transit technology for Metro high capacity transit corridors was accomplished by completing five steps. First, all available transit technologies were inventoried and then sorted into six basic transit classes. The transit classes were based on type of service provided, maximum operating speed and passenger capacity of a minimum operating unit. The six basic transit technologies were: Small - Low Speed (PRT); Small - Low Speed; Small - High Speed; Intermediate - Low Speed; Intermediate - High Speed; and Large - High Speed.

Second, analysis was undertaken to determine the performance requirements that need to be met by the class of transit technology best suited for the high capacity transit corridors. These performance requirements were: minimum average speed and cruise speed; vehicle capacity; and vehicle linking.

Third, the above performance requirements were compared with performance capabilities of the various transit classes.

Fourth, specific physical corridor requirements for rail transit were identified for the following locations or potential conditions: the Downtown Seattle Transit Tunnel; the University District/Downtown Bellevue Tunnels; Interstate 90 Floating Bridge; Ship Canal Crossing; At-Grade Crossings; and Aerial Structures.

The physical characteristics of the selected technologies were compared with the Metro corridor requirements to determine which technologies were compatible with requirements and should therefore be considered for implementation in the high capacity transit corridors. Results of this comparison generated the conclusion that LRT is the most appropriate technology for Metro rail transit implementation.

## D. Background Studies

The North Corridor Alternatives Analysis (NCAA), Multi-Corridor Project (MCP), North Corridor Extension Project (NEXT), and Tacoma-Seattle Transit Connections Project (Tac-Sea) were carefully reviewed at the beginning of this task in order to understand what had been considered previously and utilize as much information as possible from those studies in the current effort. It was not necessary to review material for standard bus and advanced bus since they are being studied in the Bus/High Occupancy Vehicle Study which is being undertaken simultaneously with this Rail Planning Study. Reviewed sections of the following reports can be found in the Design Guidelines Study - Full Set of Appendices document.

### 1. North Corridor Alternatives Analysis (NCAA), A Cooperative Study of PSCOG and Metro, May 1984.

The purpose of this study was to evaluate alternative transit investments needed by the year 2000 for the North Corridor from the Seattle CBD to South Snohomish County. A steering committee of PSCOG and Metro members guided the study. Recommendations from this report were:

- Light rail transit and advanced technology bus are preferred alternatives for the North Corridor; and
- The I-5 alignment is preferred over all other alignments studied in the North Corridor.

In May 1984, the PSCOG Executive Board adopted the following position regarding the North Corridor:

- Select advanced technology bus and light rail transit in the downtown Seattle tunnel as the two leading contenders for implementation in the North Corridor.
- Complete the North Corridor work as the first step to a draft environmental impact statement, concurrently with the Multi-Corridor Study.

The Executive Board's action led to the Multi-Corridor Project which included additional analysis of the North Corridor as well as analysis of the East and South Corridors.

Some assumptions and criteria which were included in this study were:

- Trains would consist of a maximum of three cars for alternatives operating on the surface in the Seattle CBD and four cars for alternatives operating in exclusive rights-of-way.

- During peak periods the loading standard would be 130 passengers, of which 64 would be seated and 66 would be standing.

- All station stops in the Seattle CBD on the surface would be low platform; all other stations for the surface LRT alternatives would have high platform loading (car floor height). All stations for the LRT tunnel alternatives would have high platform loading.

- Station dwell times would be no less than 15 seconds from stop to start, with longer dwell times programmed as necessary to meet patronage demands.

- The maximum feasible departure frequency of trains would be 40 trains/hour or 1 train every 90 seconds for alternatives operating in exclusive rights-of-way, and 30 trains/hour or 1 train every 120 seconds for alternatives operating on the surface in semi-exclusive or mixed traffic situations in the CBD.

Documents which were used to review design and operation guidelines were: North Corridor Alternatives Analysis--Development of Alternatives, March 1983; North Corridor Alternatives Analysis--Operations Plan, March 1984; and North Corridor Alternatives Analysis--Costs, Engineering and Financial Considerations, March 1984.

2. **Multi-Corridor Project (MCP), A Cooperative Study Of PSCOG And Metro. Completed July 1986.**

This study examined long range transit and high occupancy vehicle alternatives for increasing capacity in the region's three highest priority corridors: downtown Seattle to South Snohomish County, east to Bellevue and south to Federal Way. The Multi-Corridor Project Steering Committee submitted recommendations to:

- Implement a light rail system by 2020 to meet the region's public transportation needs.

- Use a phased implementation approach that includes evaluation of the effectiveness of such projects as the Downtown Seattle Transit Tunnel and I-90.

- Maximize the cost-effectiveness and benefits of the phased approach through specific actions listed in the recommendations.

Specifically, MCP assumptions and criteria included:

- Maximum train length would be four cars.

- The minimum train headway would be 90 seconds and the maximum is 30 minutes.

- Vehicle capacity was assumed to be 130 passengers (64 seated, 66 standees) as per NCAA. Off-peak train sizing was to be based on all seated load. No standees for longer than 20 minutes during peak hours.

- Turnback allowance would be 3.5 minutes and 0.2 miles.

- Station dwell times were assumed to be 15 seconds as a minimum, but longer dwell times were used to satisfy high passenger volumes at each station when necessary.

- Speed limits would be 55 miles per hour in all exclusive segments except as reduced by civil speed restrictions; 45, 40, or 35 miles per hour maximum speed in those segments where trains are operating in a semi-exclusive mode in the median of streets; and 25 miles per hour maximum speed at grade crossings.

Both the PSCOG Executive Board and the Metro Council endorsed the steering committee's recommendations.

On March 26, 1987, the PSCOG Assembly adopted the recommendations, along with those of the Tacoma-Seattle Transit Connections Project and the North Corridor Extension Project, as an amendment to the Regional Transportation Plan.

For the purpose of this report, the following MCP documents were used: Bus-LRT Trunk/Feeder Alternative, 1986; Bus-LRT Trunk/Feeder Alternative Full Set of Appendices, 1986; MCP Draft Final Report Conceptual Design, February 1986; and Phase III Evaluation of Corridor Alignment Alternatives, March 1986.

3. **North Corridor Extension Project (NEXT), Snohomish County Transportation Authority. Completed January 1986.**

The purpose of this project was to evaluate long-range, high-capacity transit investments from the northern terminus of the North Corridor portion of the Multi-Corridor Project to Everett. Snohomish County officials initiated the study in light of projections for population and employment growth in the county. The study was conducted simultaneously with the Multi-Corridor Project. Recommendations were:

- Rail transit via the I-5 alignment from the King-Snohomish County line to the Everett CBD was the preferred alternative.

- Major stations should be located at Alderwood Mall and downtown Everett.
- Levy a .3 of one percent sales tax and consider other funding sources to assure financial feasibility.
- Maintain flexibility for future extensions.
- Develop an action plan for the preferred alternative.

On May 24, 1987, the PSCOG Assembly adopted the project recommendations, along with those of the Multi-Corridor Project and the Tacoma-Seattle Transit Connections Project, as an amendment to the Regional Transportation Plan.

Three reports were used to collect design and operations guidelines. These reports were: The North Corridor Extension Project: The Feasibility of HCT in Snohomish County, January 1986; LRT Conceptual Engineering, October 1985; and Phase III--Development of Conceptual Alternatives, February 1985.

Design and operations guidelines used in NEXT were the same as the NCAA and the MCP. Vehicles were six-axle articulated LRV's with design capacity assumed at 130 passengers (64 seated, 66 standee). Off-peak train sizing was based on all-seated load. Maximum train length would be four cars.

Traction power, signaling, communications, and fare collection systems were the same as those used for analyses in the NCAA and MCP projects. For yards and shops it was assumed that the main facilities would be at Ryerson Base, with light maintenance capability and storage tracks developed at Alderwood Mall, and a minimum-service facility at Everett.

Typical guideway configurations for aerial structures, at-grade and subway construction were developed at a conceptual level for the NCAA project. Each of the guideway concepts was based upon established design criteria and proven construction methods.

4. **Tacoma-Seattle Transit Connections Project, Pierce Subregional Council, PSCOG. Completed January 1987.**

The purpose of this study was to examine the feasibility of a rail transit connection between Pierce and King Counties by 2020 and to also examine financial implications and identify near-term actions to support the inter-county transit service plan. Recommendations included:

- Rail transit was the preferred long range technology.
- Implementation of rail transit should be viewed as one component of an overall regional transportation strategy.
- Specific actions (stated in the recommendations) should be taken to maximize cost-effectiveness and benefits.

On May 24, 1987, the PSCOG Assembly adopted the project recommendations, along with those of the Multi-Corridor Project and the North Corridor Extension Project, as an amendment to the Regional Transportation Plan.

The Tacoma light rail transit alternative would be an extension of the light rail transit system proposed by the MCP and NEXT projects. An LRT system in Pierce County would connect into a regional system running from Everett to Tacoma. The LRT line would follow the general I-5 corridor from Federal Way to the downtown Tacoma core and then south to South Tacoma.

For each of the identified alignments it was assumed that there would be two new park-and-ride lots developed within Pierce County. There would be six stations, including one at the Tacoma Dome and three in downtown Tacoma. There would also be one rail maintenance and storage yard within the County.

Documents used for review of design and operations guidelines were: <u>Tacoma-Seattle Transit Connections Study, Phase III Evaluations and Recommendations</u>, February 1987 and <u>Tacoma-Seattle Transit Connections Study, Conceptual Engineering</u>, February 1987.

## E. Conclusions from Previous Studies

The conclusions and recommendations, which were very consistent for all four of the studies discussed in the previous section, are summarized below.

1. **<u>Technology</u>** The NCAA concluded that light rail transit and advanced technology bus were the preferred alternatives. The MCP, NEXT and Tac-Sea studies all recommended light rail as the appropriate transit technology.

2. **<u>Alignment</u>** All four studies recommended the I-5 alignment to the north and to the south. The MCP also recommended the east alignment to Bellevue and to the north along the east side of Lake Washington.

3. <u>Train Consist</u> The NCAA recommended 3-car trains for surface operation and 4-car trains for tunnel and exclusive right-of-way. The other three studies reaffirmed this recommendation.

4. <u>Capacity</u> All four studies recommended a transit vehicle capacity of 130 passengers which included 64 seated and 66 standing. There were to be no standees in the off-peak.

5. <u>Station Platforms</u> The NCAA recommended low platforms for CBD surface operations and high level platforms for the downtown tunnel and all other stations. This recommendation was not changed in the other three studies.

6. <u>Station Dwell Time</u> All studies recommended a minimum of 15 seconds dwell time at each station with a longer dwell time if passenger loading volumes require.

7. <u>Headway Between Trains</u> The NCAA recommended 40 trains per hour which represents a minimum headway of 90 seconds between trains for alternatives operating in exclusive rights-of-way. The recommendation was 30 trains per hour with a headway of 120 seconds between trains for alternatives operating on the surface in semi-exclusive or mixed traffic. The MCP further recommended that the maximum headway was not to exceed 30 minutes. These recommendations were not altered in the other studies.

8. <u>Operating Speed</u> The MCP specified a speed of 55 miles per hour in all exclusive segments except as reduced by civil speed restrictions. It recommended 45, 40 or 35 miles per hour maximum speed in those sections where trains are operating in a semi-exclusive mode in the median of streets and 25 miles per hour maximum speed at grade crossings.

## F. Development Since Previous Studies

Clearly the most important development since the previous studies were completed is the near completion of the downtown Seattle tunnel. The decision was made to include tracks for light rail transit in the tunnel and that has been accomplished. Perhaps the most important factor related to the downtown Seattle tunnel is the fact that the stations were constructed with low level passenger loading platforms. The impact of this decision is discussed in later sections of this memorandum.

Another key development since the previous studies is completion of the I-90 floating bridge. Studies to date indicate that the bridge is capable of accommodating two lanes (one in each direction) of light rail transit. There is still a question as to whether or not the bridge can also accommodate an additional lane that could be used as a reversible bus/HOV lane. Studies are currently under way to address this and other issues in more detail related to the I-90.

The current acceleration of economic activity in the Seattle area has resulted in rapid growth in population and employment. This growth has, in turn, resulted in increased travel demand throughout the region. Freeways and roadways are becoming more congested with more frequent delays than were experienced in the past. Development continues to occur in suburban areas which tends to increase the number of commuters traveling back into the center city on a daily basis. As a part of the Metro rail study, analysis is being undertaken to revise travel forecasts and estimates of potential rail transit ridership. As will be explained in later sections of this memorandum, it does not appear that projected travel demand has increased to a level that would change the rail transit capacity requirements to a level that cannot or should not be accommodated by a light rail system.

There have not been any major breakthroughs in transit technology since the previous studies were completed. Research and development continues, but new more appropriate technologies are not yet in operation or available for implementation. There have been developments in low capacity technology such as PRT, but they are not currently available and would not have adequate speed or capacity to function as a high capacity transit system in one of the Metro corridors. Magnetic levitations being developed for rail transit systems, but as yet is not available for revenue service. As will be explained later in this memorandum, this technology is also not compatible with the downtown Seattle tunnel.

Several fully automated transit systems are now in operation, most of which have gone into service since the earlier studies were completed. The automated transit system now operating in Vancouver, Canada is one of the best examples available of a successful AGT operation. With automated systems in operation, studies have been done or are under way to evaluate both the advantages and disadvantages or automatic train operation. Results and conclusions to date show both advantages and disadvantages with no compelling argument on one side or the other. Ridership seems to be related more to characteristics and demographics of the corridors being served than to the automation itself. As will be explained later in this memorandum, automated transit would be difficult, if not impossible, to operate jointly with advanced technology buses in the downtown Seattle tunnel. This means that rail transit vehicles must be capable of manual operation in the tunnel. It is possible to operate transit technology that would run under manual control in the tunnel and under automatic control elsewhere, but the cost of automation may be difficult to justify.

## G. System Integration Requirements

The Metro rail study is exploring the feasibility of high capacity rail transit in three different corridors; to the north, east and south. As alternative transit technologies are investigated, care will have to be taken with regards to overall system integration of service and operations between the three corridors. Since all three corridors are an extension of the downtown Seattle tunnel, the transit system selected for any corridor will need to be compatible with operation in the downtown Seattle tunnel. Additionally, if different technologies are used in different corridors, passengers will have to transfer at a station from one technology to the other. This increases the transfer requirement for trips between corridors and transfers tend to discourage transit ridership. From an operating point of view, it is much more cost effective to operate one technology in several corridors rather than a mix of technologies. More than one technology requires different operating and maintenance facilities and limits the ability to share spare vehicles and parts between the corridors. Although many cities in the world have more than one technology in operation, implementation of new systems such as Metro need to carefully consider the advantages and disadvantages of operating different rail transit technologies in different corridors.

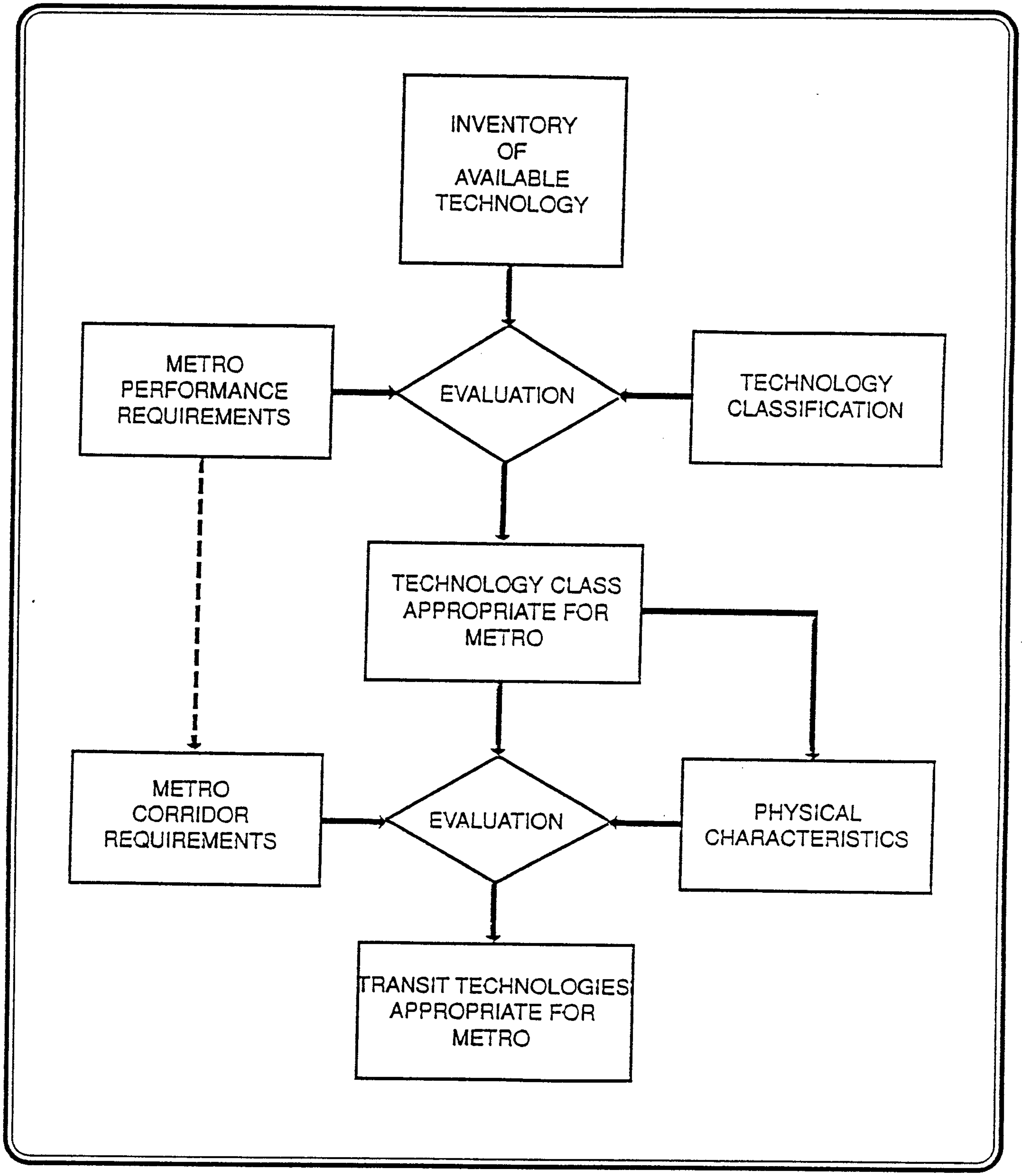
# II. TRANSIT TECHNOLOGY SELECTION PROCESS

There are a number of steps involved in the process of selecting an appropriate transit technology for any given application. These steps are illustrated in Figure 2. The first step is to inventory all of the existing or potentially available technologies from around the world. The second step is to establish a classification system based on basic characteristics of transit technology. Each of the inventoried technologies is then assigned to one of the technology classifications for the purpose of grouping the technologies into a relatively small number of transit technology classes. Each technology class is then subjected to review against performance requirements for operation by Metro in the Puget Sound Region. The evaluation process results in the selection of a technology class that is most appropriate for implementation in the Metro system. There will typically be transit systems from several different manufacturers that can eventually be selected from the technology class determined to be most appropriate. By properly identifying the appropriate technology class, it is possible to avoid the "trap" of investigating specific transit technologies before it is clearly understood what characteristics should be included in the transit system needed.

Once the technology class appropriate for Metro has been selected, the next step is to undertake a more detailed analysis of the specific physical characteristics of the individual technologies included within that class. In a parallel effort, planning and engineering studies are carried out in each of the potential high capacity transit corridors to establish the specific Metro corridor requirements for operation in identified transit corridors. The physical characteristics of each technology in the appropriate technology class are then compared with the Metro corridor requirements to determine the specific transit technologies that are most appropriate for operation in the Metro system.

Once the technology selection process has been completed and the desired technology has been determined, the stage is set to approach technology suppliers and request proposals for supplying the desired system. Technology suppliers will then be provided with clearly defined performance and technical requirements. Proposals from interested suppliers can then be evaluated leading to selection of the specific transit hardware to be acquired, implemented and operated.

This Design Guidelines Study is limited to addressing only the process from developing an inventory of available technologies to a selection of transit technologies appropriate for operation by Metro. This is part of the system planning phase of the standard transit implementation process. Final procurement would be accomplished during the final design and construction phases with operation commencing upon completion of construction and testing.

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TECHNOLOGY SELECTION PROCESS
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Figure #2

# III. TECHNOLOGY DEFINITIONS AND DESCRIPTIONS

## A. Physical Elements of a Transit System

Six major physical elements of transit technology must be considered relative to the system needs of the corridor in order to select the appropriate transit technology (See Figure 3).

### 1. Transit Vehicle

The transit vehicle provides seats for some passengers and floor space for additional passengers to stand. Several design features such as number of seats, floor area for standing passengers and placement of entry/exit doors affect the functional capacity of each vehicle. Depending on capacity requirements, vehicle articulation and training (linking) may be used to increase capacity and to reduce capital and operating costs.

### 2. Suspension

Rubber tires

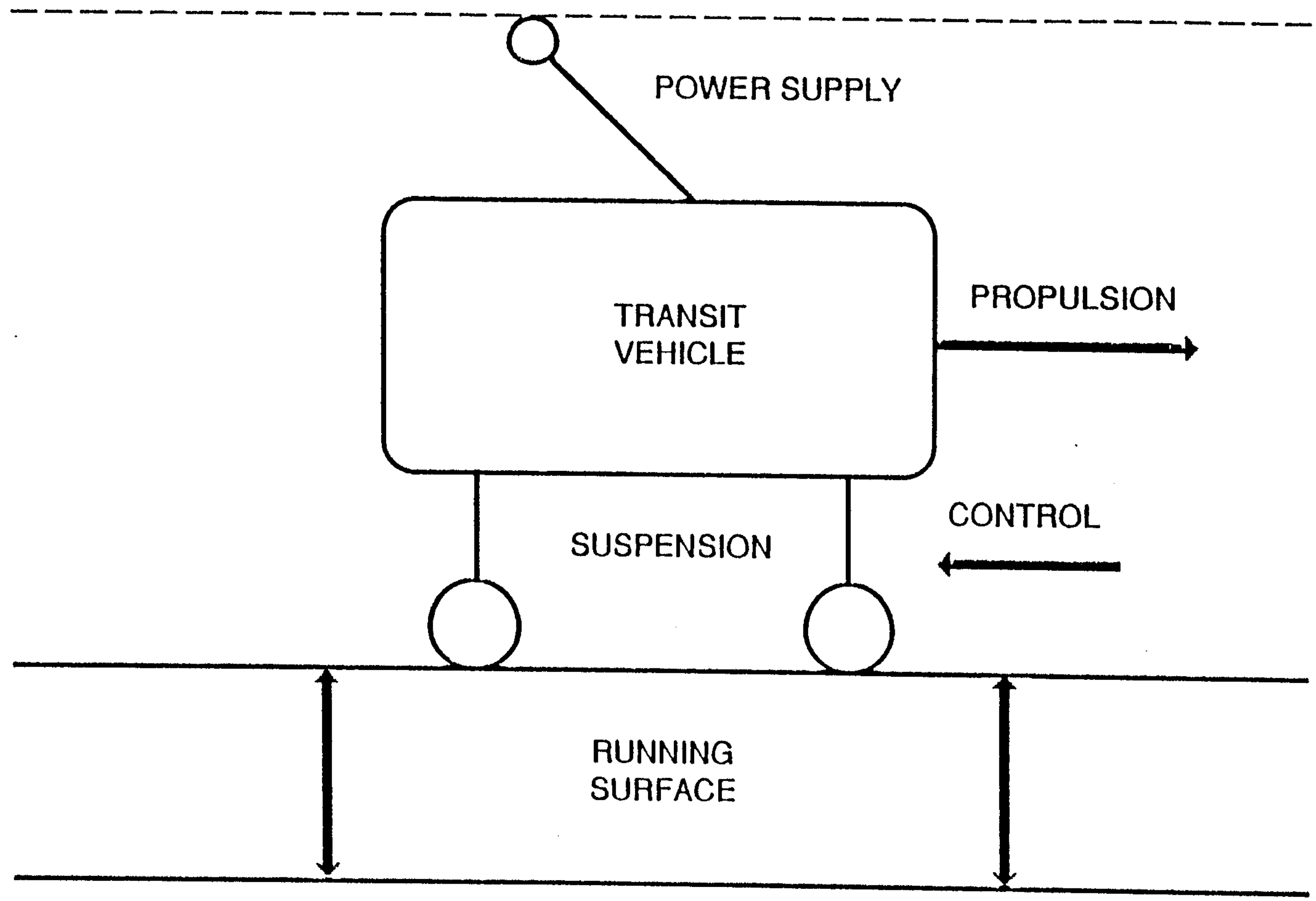
- predominantly bus transit
- used for some rapid transit, monorail and peoplemover systems
- can be operated in mixed traffic and/or on guideway with guided bus

Steel wheel/Rail

- can be mixed traffic or separate
- can be at-grade, on structure, in tunnel
- allows training of vehicles

Magnetic levitation/Air-cushioned

- requires separate guideway
- technical/operational reliability unproven in revenue service

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PHYSICAL CHARACTERISTICS ELEMENTS

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### 3. Control/Communication

There are basically two types of control/communication systems: manual systems employing a driver and automatic systems without a driver. Each type has distinct advantages and disadvantages. In most systems, the preferred level of automation lies somewhere between a totally manual and a totally automated system. Virtually every automated system, for example, is capable of manual operation in the event of technical problems or emergency situations. On the other hand, some form of automatic train control is usually implemented for systems operated under manual control to prevent trains from colliding.

### 4. Running Surface

Transit systems can operate in mixed traffic or in a separate configuration. A system that can mix with traffic at grade is most flexible; it can share existing rights-of-way, it can pick up and deliver passengers close to their destinations, and it can travel on grade-separated structures or in tunnels when necessary to reduce potential traffic interference or to minimize travel time by avoiding obstructions. Systems that operate in mixed traffic must be operated manually for optimum safety. In some instances, provision is made for the vehicle or operator to actuate the signal system and give preference to transit operation.

A transit system that requires a separate guideway can be operated at the grade level of traffic, on an elevated structure, or below grade in tunnels and underpasses. Separate guideways do represent high costs of installation and maintenance, however, and cost-effectiveness of a separate guideway configuration for the transit system must be carefully evaluated.

### 5. Propulsion

Contemporary transit systems use three major types of propulsion systems:

- diesel - can be deployed in mixed traffic (buses) or on a separate running surface (diesel locomotive). Tunnel operation may require adequate ventilation.

- rotary electric - can be deployed in mixed traffic or in separate situations.

- linear electric - requires a guideway separate from traffic and pedestrians.

- dual power - can be deployed in mixed traffic or in a separate situation. Uses diesel power in mixed traffic and rotary electric in a separate situation, particularly during tunnel operation.

Energy cost and engine efficiency are key factors to be considered in the selection of a propulsion system. The most cost effective solution depends on cost of fuel or energy combined with the operating and maintenance cost of the propulsion system itself.

### 6. Power supply pick-up

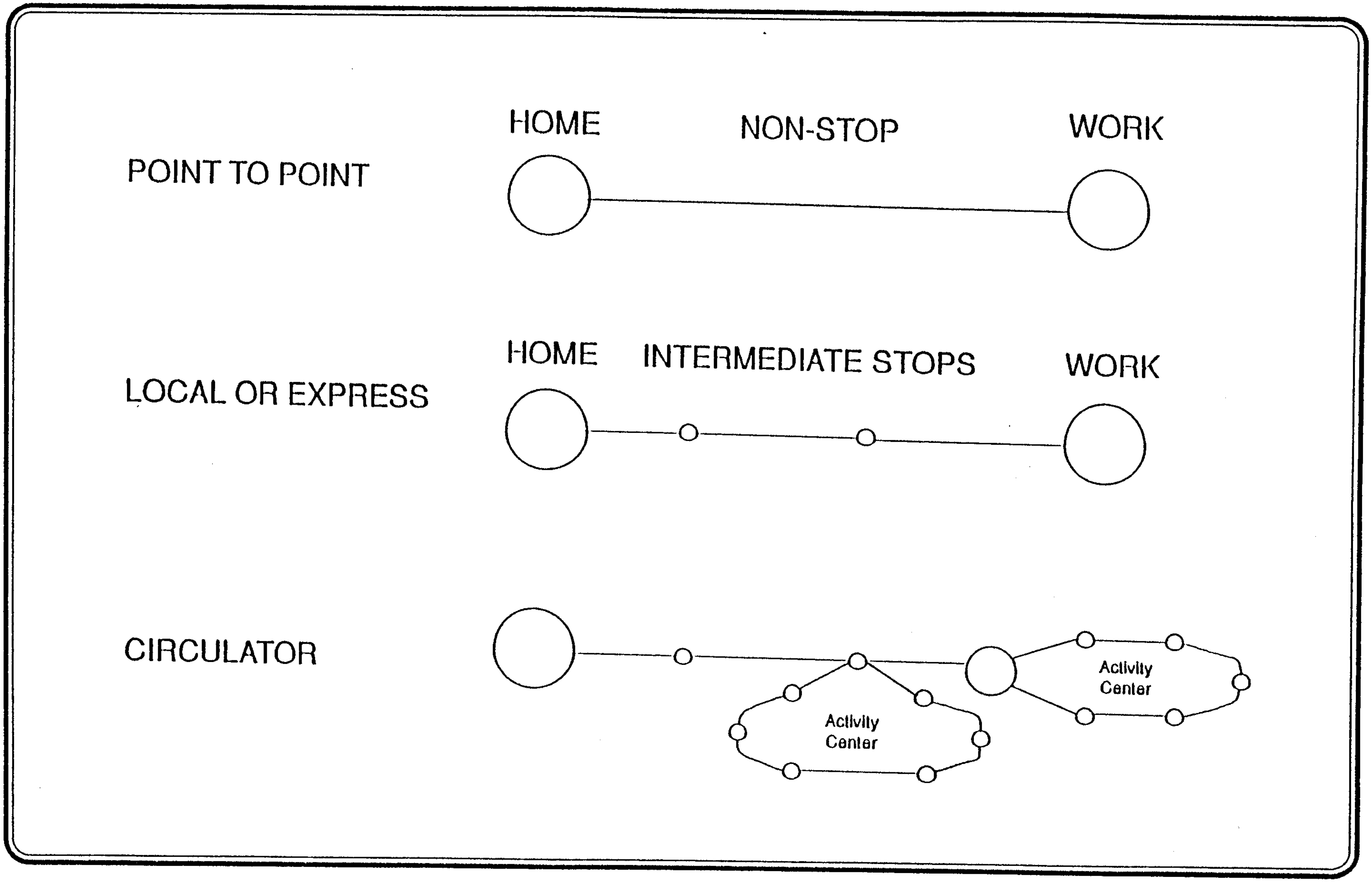
Power supply pick-up can be:

- on-board - mixed traffic or separate guideway
- overhead - mixed traffic or separate guideway
- third rail - separate guideway
- guideway - included as part of the guideway

No specific technology or grade configuration represents a perfect solution to a transit problem. Rather, a reconciliation of objectives must be found to give the most appropriate solution. A desirable option for one corridor may not prove feasible in another corridor. On the other hand, system integration and consistency of technology between corridors can be important. The more corridors using the same technology increases the efficiency of operation and minimizes capital cost. It may not be desirable, however, to impose the unique requirements of one corridor on all other corridors. There are numerous examples (such as San Francisco) where a number of different transit technologies are operated in different corridors. A system integration analysis needs to be carried out in each city to determine how best to mix the various transit modes that may be operated.

## B. Technology Classifications

As explained earlier, the primary objective of Phase 1 in the technology selection process is to select the appropriate class of transit technology for implementation of the high capacity transit system. In order to accomplish this objective, a classification system was developed which provides a basis for grouping all the different types of technologies available into classes based on different characteristics and capabilities. The classification system developed for this study was based on the following three characteristics:

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SERVICE CATEGORIES
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