Civil Design Guidelines

TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

List of Figures

CIVIL DESIGN GUIDELINES

I. INTRODUCTION

The Municipality of Metropolitan Seattle (Metro) is considering as part of the regional transportation plan, the introduction of a high capacity transit component to the Metro Transit Network by the year 2000. In November 1988, King County voters approved a rail advisory ballot which endorsed further consideration to proceed on development of a regional rail system. Responding to this ballot and other factors, the Metro Rail Planning Study 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 initial operating segments 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 the region's residents. This Design Guidelines Study is one of the studies currently under way as part of the Metro Rail Planning Study.

A. Purpose of the Design Guidelines Study

The purpose of the Design Guidelines Study is to identify design and operations guidelines for high capacity transit. This study identifies factors critical to guideway geometry; discusses applications of geometric factors on guideway alignment and system operation; recommends a generic guideway geometry guideline for the range of transit technologies and equipment being considered; and identifies the next steps to be undertaken regarding corridor guideway alignments. Specific tasks within this study include assessment of appropriate rail vehicle technologies; design and operations guidelines; costing procedures and assumptions; and a model ordinance for rail conversion. The final product of the Design Guidelines Study will be a design and operations handbook which outlines specific technical information necessary for the construction of the selected high capacity transit system.

B. Purpose of this Technical Memorandum

The purpose of this technical memorandum is to develop and document the design and operational characteristics of selected transit technology types for all elements of the transit system, including vehicles, guideway and stations. Section II of this memo presents an overview of design and operation standards developed and used in previous regional transportation studies in the Seattle metropolitan area. A separate appendix entitled Design Guidelines Study, Full Set of Appendices, contains the actual data from these studies. Section III of this report presents the planning assumptions and typical design guidelines. The remaining sections of this report present prototypical design and operations guidelines.

II. BACKGROUND STUDIES

The purpose of this task is to document design and operations assumptions and standards that were used in the North Corridor Alternatives Analysis, the Multi-Corridor Project, the North Corridor Extension Project and the Tacoma-Seattle Transit Connections Project. A description of the technology and constraints upon which these assumptions were based is discussed. In depth information regarding these assumptions and standards are presented in a separate document entitled Design Guidelines Study, Full Set of Appendices.

A. 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.

B. 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 is four cars.

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

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

- Turnback allowance is 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 will 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.

A number of the MCP documents discuss design and operations guidelines. 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.

C. **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 is 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.

D. 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 is 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 will be two new park-and-ride lots developed within Pierce County. There will be six stations, including one at the Tacoma Dome and three in downtown Tacoma. There will also be one rail maintenance and storage yard within the County.

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

III. PLANNING ASSUMPTIONS AND TYPICAL DESIGN GUIDELINES

A. Recommendations For Technology

Task 1 of this study evaluated the technologies of today and recommended that Light Rail Transit (LRT) be used in the Seattle area. Summarized below are the conclusions and recommendations regarding the rail technology investigated in this study.

Light Rail

This technology is likely to be the easiest technology to implement. Facilities such as the Downtown Seattle Transit Tunnel and the I-90 floating bridge have already been constructed to accommodate this technology. Higher average speeds can be achieved by reducing the number of at-grade crossings and/or extent of operation in mixed traffic. Stations can vary from simple and inexpensive to very substantial structures. This technology has proven itself in service in over a dozen systems throughout North America.

Automated Guideway (AGT) Peoplemover

This technology has major constraints that would make it difficult to implement in the Downtown Seattle Transit Tunnel, the University District/ Bellevue tunnels, and the Ship Canal. Existing technology still requires the use of a third rail as a power source for AGT. In addition, high level platforms are also required. These are not compatible with join operations in any corridor tunnels. Given these constraints, this technology is not recommended for further consideration in the high capacity transit corridors.

Monorail

This technology has major constraints that would make it difficult to implement in the Downtown Seattle Transit Tunnel, across the I-90 floating bridge, and in certain options to cross the Ship Canal. Monorails are typically more cost effective if it is required that a large percentage of the guideway be elevated. Currently available monorail technology does not have adequate speed capability and train composition is difficult to adjust for different levels of ridership demand. This technology is not recommended for further consideration in the high capacity transit corridors.

Based on the information presented in the text of this document, it is recommended that the LRT be considered for implementation in the high capacity transit corridors. Figure 1 presents a summary of vehicle characteristics to used when designing both guideway and station facilities.

GENERAL CHARACTERISTICS
OF
METRO RAIL VEHICLE

Vehicle Length	-	90 feet
Vehicle Width	-	8 ft. 8-3/4 inches
Passenger Capacity	- -	76 seated, 90-107 standees crush load 211-237 passengers
Maximum Speed	-	60 - 70 MPH
Power Supply	-	750v dc. - overhead
Train Consist	-	4 cars (max.)
Door Configuration	- -	4 sets of doors each side high and low platform access
Suspension	-	Steel wheel on steel rail
Gradient Capability	-	6% service grade. With ice conditions in Seattle, vehicles should be fitted with sanders.
Accessibility	-	lift equipment for low platform wheelchair access.

B. Assumptions

The design and operating guidelines presented herein are based upon the following assumptions:

- Technology assumptions are consistent with assumptions presented in previous Metro related studies.
- The ultimately selected vehicle technology will be capable of running in joint service with manually operated buses in the Downtown Seattle Bus Tunnel (DSBT) and other corridor tunnels.
- Station platforms in the DSBT will remain low as long as joint operations are maintained.

C. Typical Design Guidelines

The following statement is typical of the type of design guidelines issued by transit authorities. This statement deals with specific areas which could be considered essential for the development of a comprehensive approach to the design and development of transit facilities.

1. An integrated approach will be used for signing for all transit modes.
2. All passenger facilities will be attractively landscaped. Landscaping should be cost-effective considering initial capital cost and ongoing maintenance costs. Where feasible xeriscape (low water, indigenous plants) concepts should be followed. Landscaping should not compromise patron safety, security, or circulation.
3. All passenger facilities should be reasonably accessible to the mobility disadvantaged.
4. All passenger facilities will be designed to ensure the safety and security of patrons and workers. Passenger areas should be under the direct surveillance of operations/security personnel. The type of surveillance (station attendants, CCTV, or roving patrols) will be determined after a selection of technologies and fare collection procedures.
5. Advertising will be permitted within passenger facilities as a means to produce revenue for Metro. The design and placement of advertising will be restricted through design guidelines and criteria so as not to conflict with or interfere with system signing and information.

6. Works of art in passenger facilities will be accommodated in an integrated approach with station design development and the locational and environmental requirements of the art works themselves.

7. The design of passenger facilities will maximize the use of standardized functional and architectural components in order to enhance patron understanding of the system and to maximize operational efficiency. A unique and unified approach to passenger facility design should be used in order to establish a simple and strong image for the selected technologies while responding to the need for individual expression and contextual response. It is the intent of Metro to provide a baseline standard for passenger facility design which can be enhanced within the limits of adopted standards and guidelines.

8. Patron comfort is an important concern in the design of passenger facilities. All passenger facilities should provide weather protection and ventilation consistent with patron comfort, the adopted technology, expected patronage, and the location of the facility, where air tempering is considered, passive technology should be employed when feasible.

9. Public conveniences in passenger facilities will be provided if there are no resultant compromises to patron circulation, security, and maintainability. Conveniences that should be considered in design include seating, telephones, and drinking fountains.

IV. GUIDELINES--VEHICLES AND GUIDEWAY

The purpose of this section of the Design and Operations Guidelines is to provide vehicle and guideway information sufficient to allow planning consultants to develop conceptual designs, estimates of capital, operating and maintenance cost, and to determine the impacts of construction and operations upon the adjacent community. This section will also allow others to understand the general technical aspects of the proposed system. Planning "envelopes" for determining alignment and station location feasibility and the basis for developing an operating strategy are included. These guidelines are presented at the level of detail suitable for later UMTA Alternatives Analysis.

When designing a high capacity fixed guideway system an important element from a planning perspective is the determination of projected impact upon the surrounding community and the reservation of right of way. Design guidelines for a fixed guideway system present information for the development of the guideway and stations. This design is primarily based on the type of vehicle and technology chosen for the system. For this study, a three dimensional envelope which will provide sufficient space for an LRT system to be constructed will be required in order to be able to assess the community impacts and preserve adequate right of way for the system.

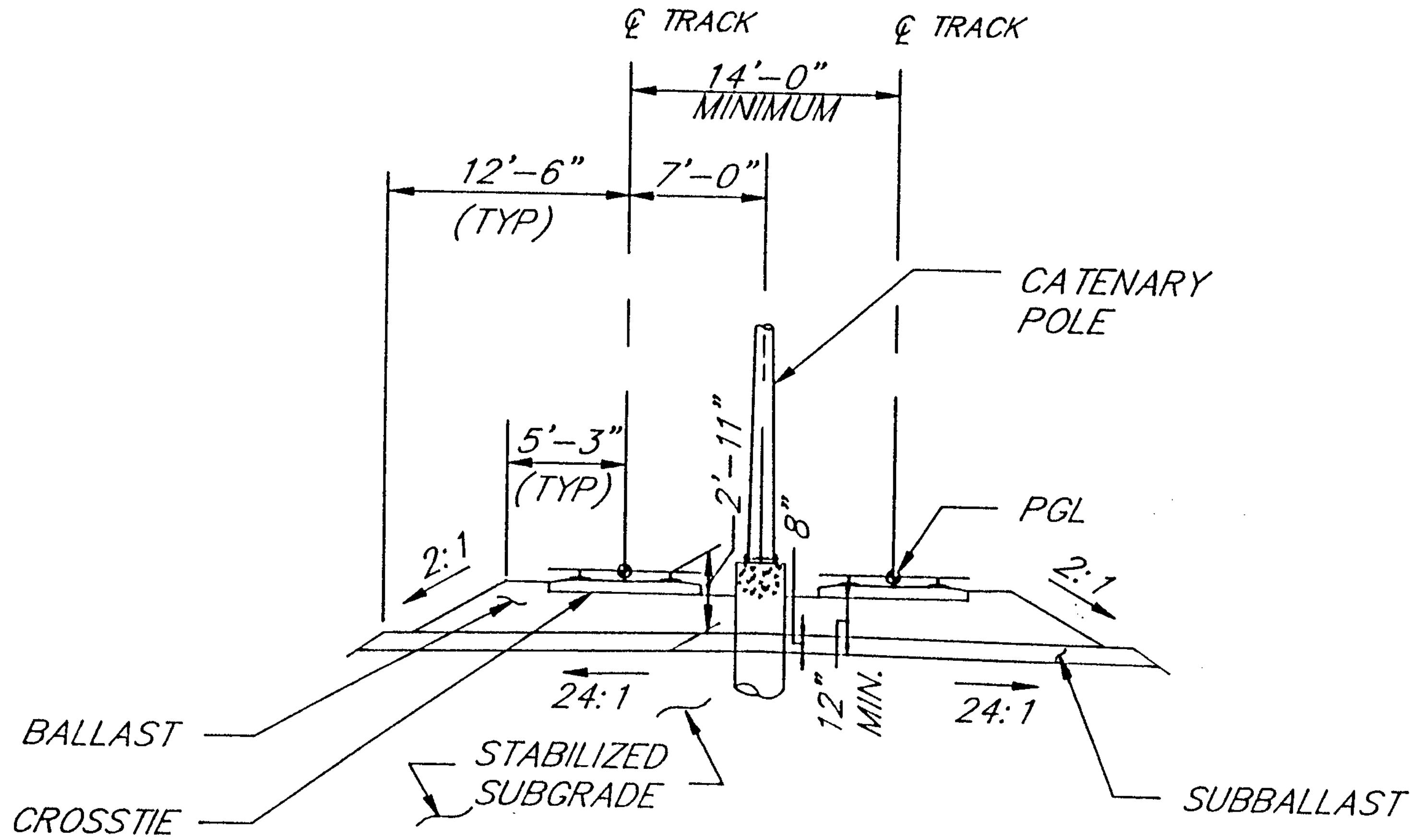
For guideways, the horizontal and vertical dimensions of the envelope are dictated by the vehicle. In this case, the proposed technologies of LRT and AGT have very similar dynamic envelopes. Due to its power source, the AGT envelope is smaller than the LRT. For this reason, we propose to develop an envelope based upon an LRT system -- an envelope which can be used by either technology.

The station envelope is developed similarly to the guideway envelope.

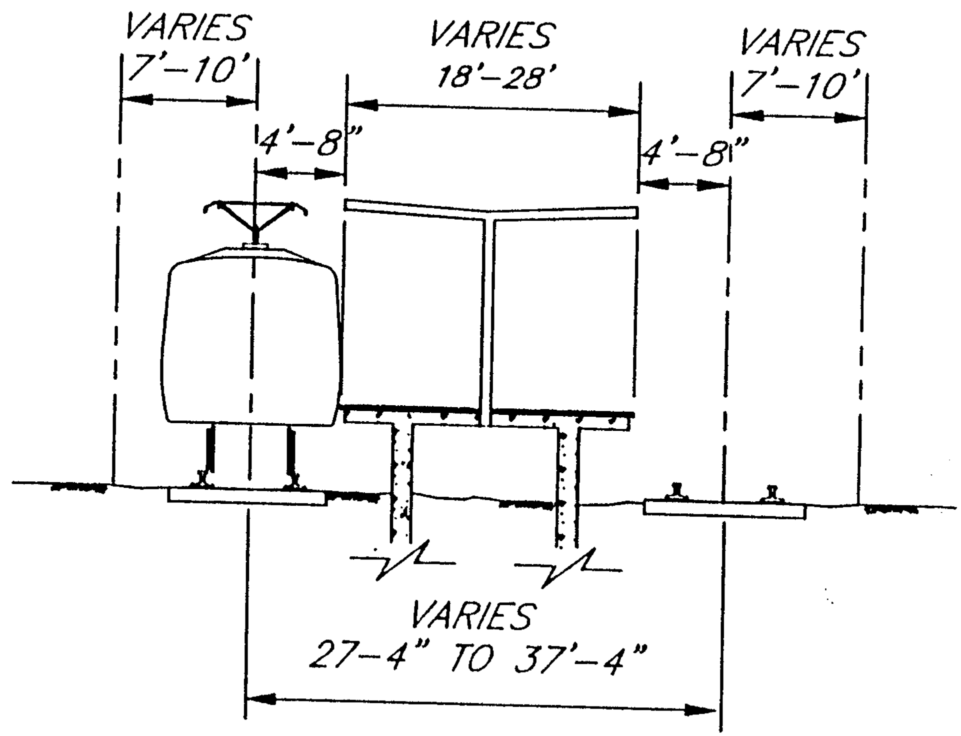
When a technology and vehicle is selected during alternatives analysis, the design of the guideway and station within the envelope will be developed at a more detailed level. For now, the most important aspects of this exercise is to determine the right of way necessary for this system, the physical impact which this system will have upon the community along specific right of ways, conceptual station locations and vehicle run times, and the determination of projected capital operating and maintenance costs which will allow accurate comparisons to be made between various alternatives.

A. Cross Sections

Typical cross-sections generally suitable for LRT are presented in Figures 2 through 7. Cross-sections for both types of technologies are similar in nature at this stage of design development. The main purpose of the typical sections is to present horizontal and vertical dimensions and clearances required to implement the LRT system.



TYPICAL AT GRADE SECTION



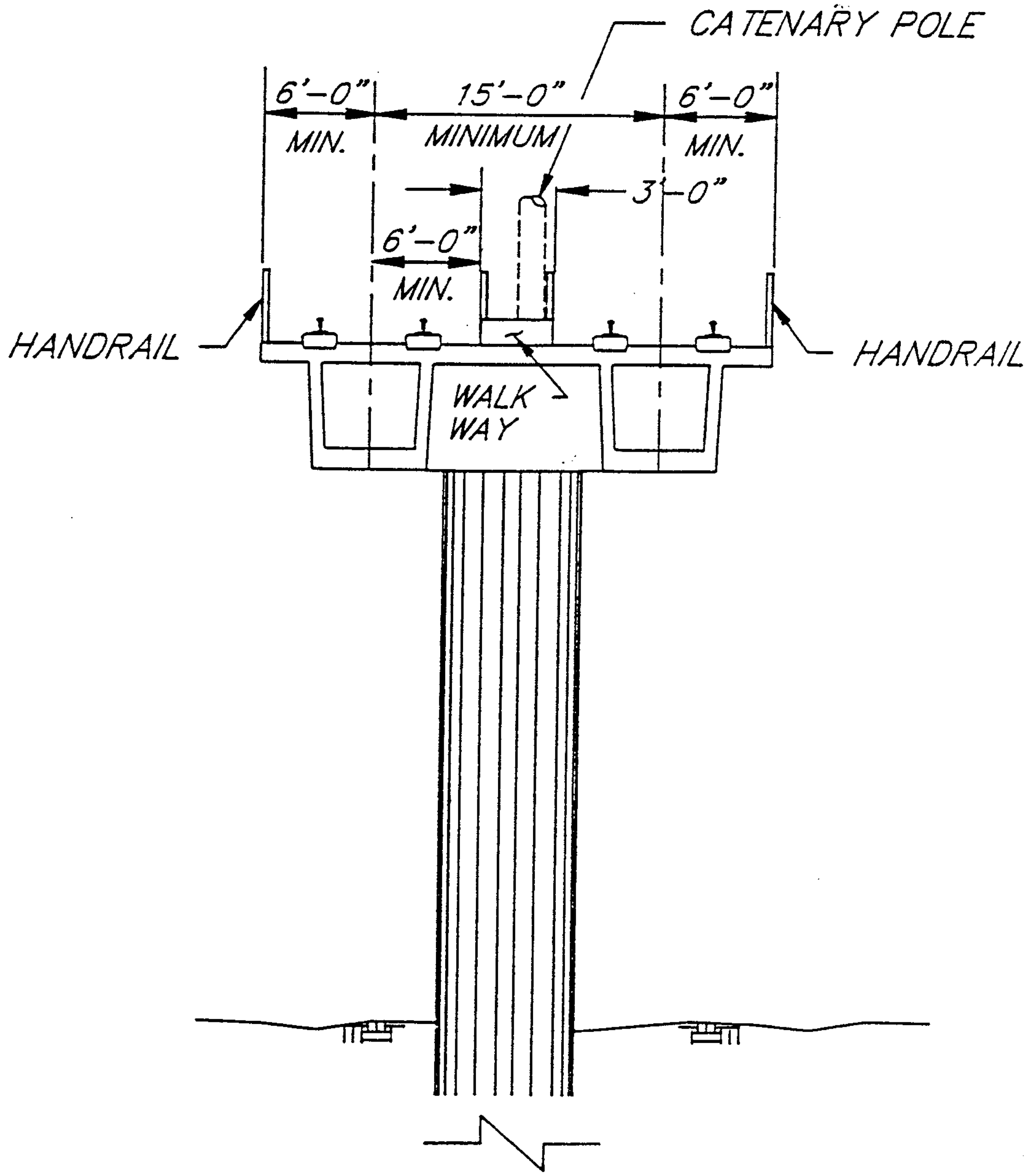
TYPICAL AT – GRADE STATION

Metro Rail Planning Study

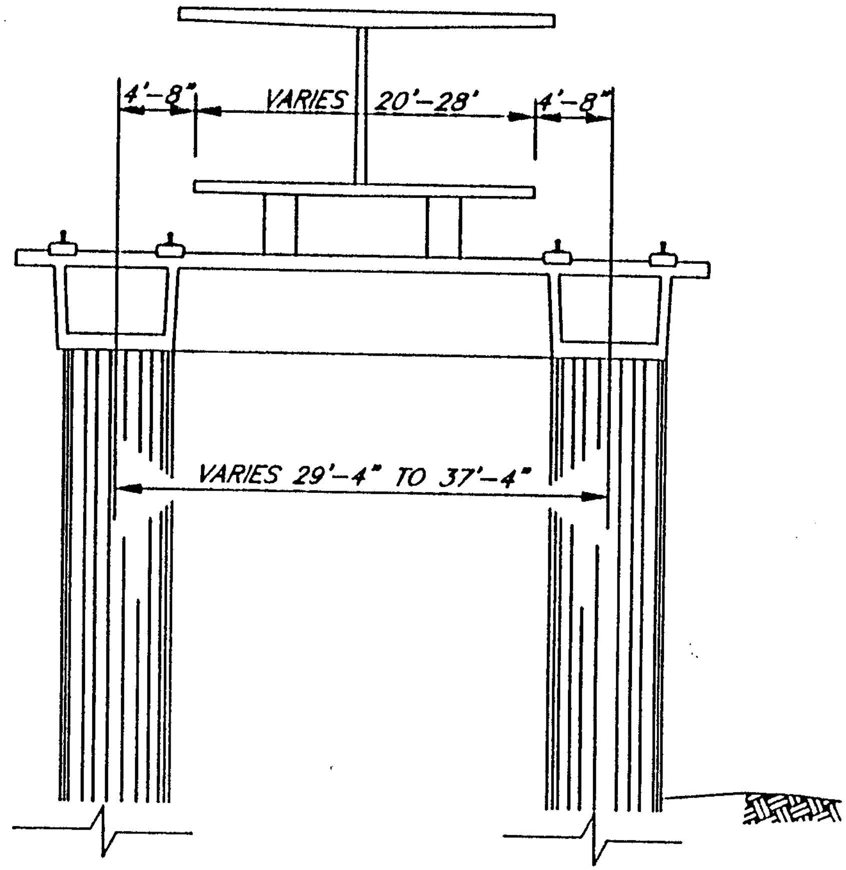
Civil Design
Guidelines

GANNETT - DELEUW

TYPICAL AT-GRADE
STATION
August 1990



TYPICAL AERIAL STRUCTURE
SINGLE COLUMN



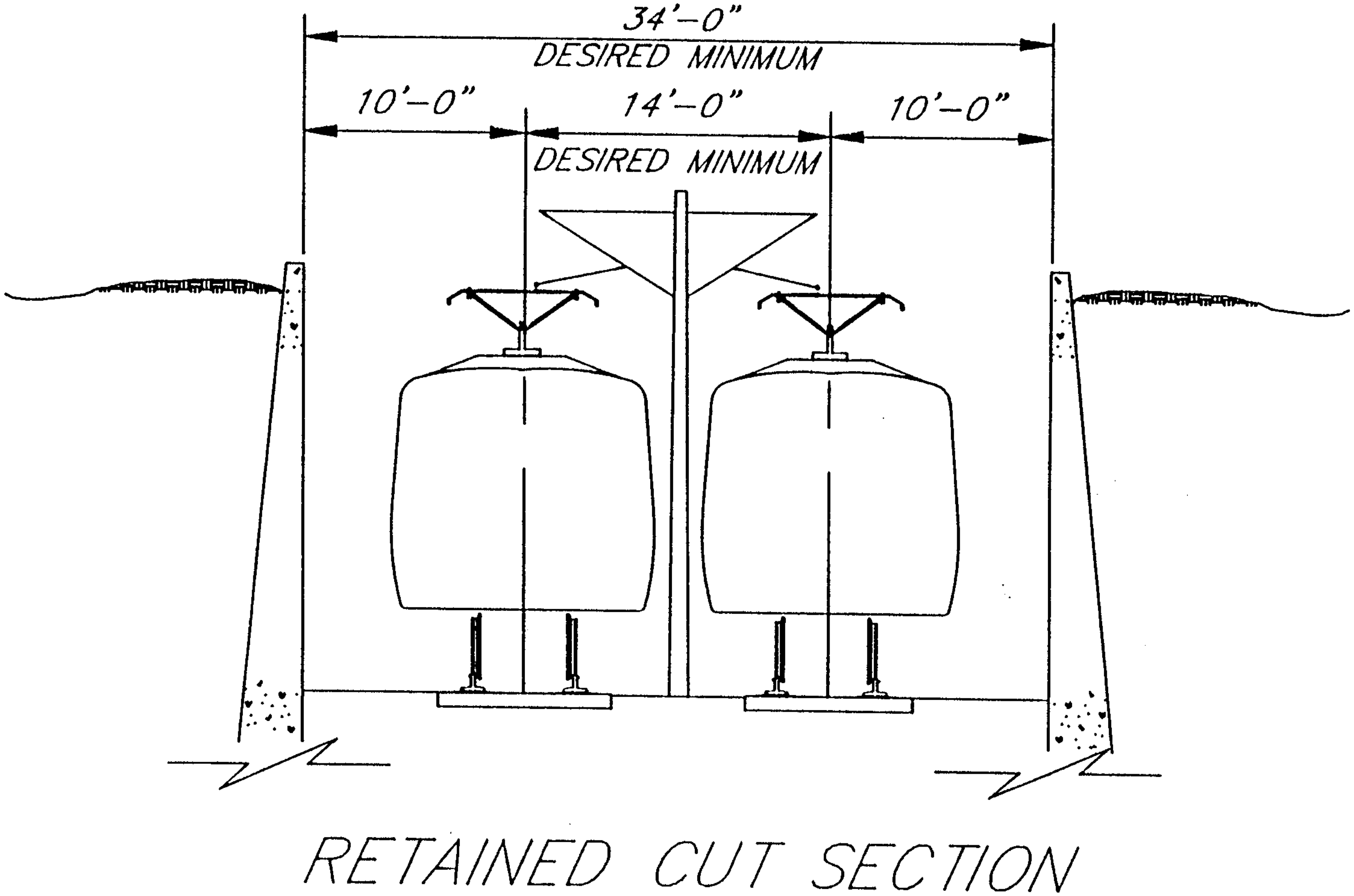
TYPICAL CENTER PLATFORM AERIAL STATION

Metro Rail Planning Study

Civil Design
Guidelines

GANNETT - DELEUW

TYPICAL CENTER PLATFORM
AERIAL STATION
August 1990

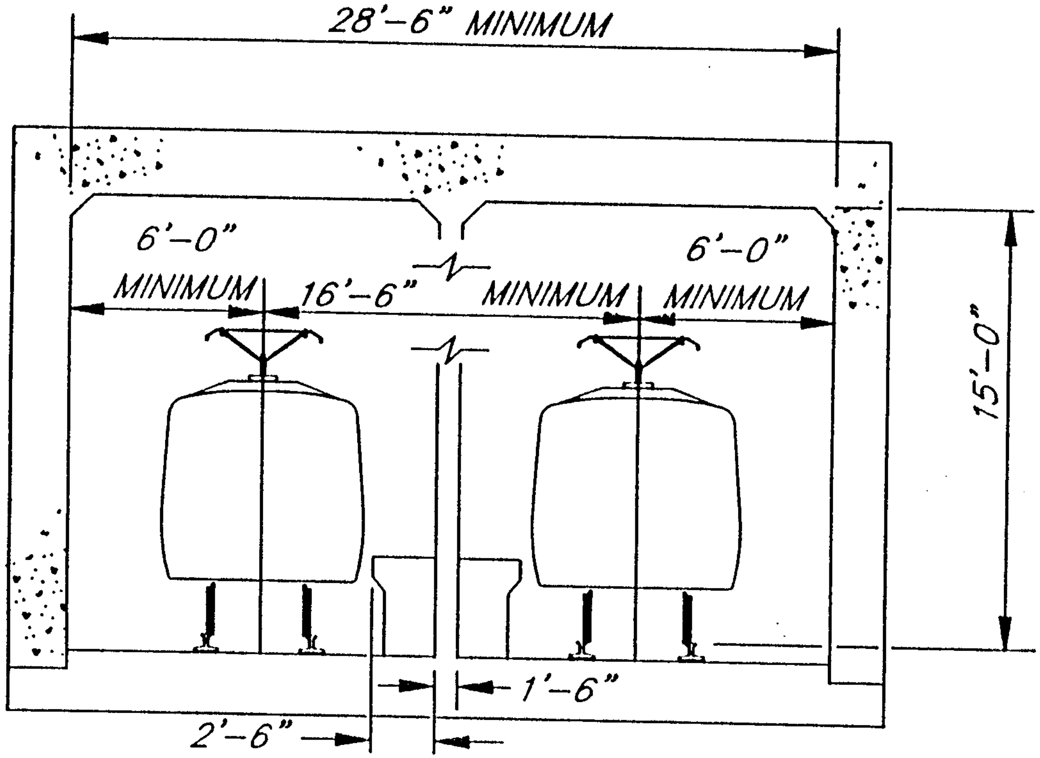


Metro Rail Planning Study

Civil Design
Guidelines

GANNETT - DELEUW

TYPICAL RETAINED CUT
SECTION
August 1990



TYPICAL DOUBLE BOX

Metro Rail Planning Study

Civil Design
Guidelines

GANNETT - DELEUW

TYPICAL DOUBLE BOX
SECTION
August 1990

B. Design Parameters for Metro Rail Planning

The following presents design guidelines and standards for a light rail system. The guidelines will provide geometrics and spatial requirements suitable for LRT.

1. Vehicle

a. general

The vehicle shall be of the articulated type, double ended,four door on each side with access to both high level and low level platforms. The vehicle shall have three trucks, each having two axles. The center truck shall be unpowered.

b. operating characteristics

Vehicles shall be capable of operating as single units or as multiple units consisting of two, three or four vehicles. The vehicles shall be designed for manual operation with an Automatic Train Stop (ATS) system to enforce wayside signals. Vehicles shall also be capable of operation without ATS protection if determined necessary due to an emergency situation or an ATS system failure.

c. basic dimensions

The preliminary basic design dimensions are:

- Length of car over coupler faces 90'-0" maximum
- Overall width of car over rub rails — 8'-8 3/4" maximum
- Width of car at thresholds — 8'-8 3/4" maximum
- Width of passenger side doors — 4'-0" clear,minimum when fully opened
- Height of floor above top of rail — 39"
- Height of car from top of roof mounted equipment to top of rail (static) — 12'-0" maximum
- Interior height - from floor to ceiling (at car centerline) — 6'-'6" minimum
- Minimum running clearance: trucks(except track brakes) — 2-1/2"
- Minimum running clearance: under car equipment, level track — 8"

d. passenger capacities

Seating: 76 - Two seats at each end of the car may be folded up to provide space for one passenger in a wheelchair at each end.

Standing: Service load - 107
Heavy load - 161

e. vehicle weight

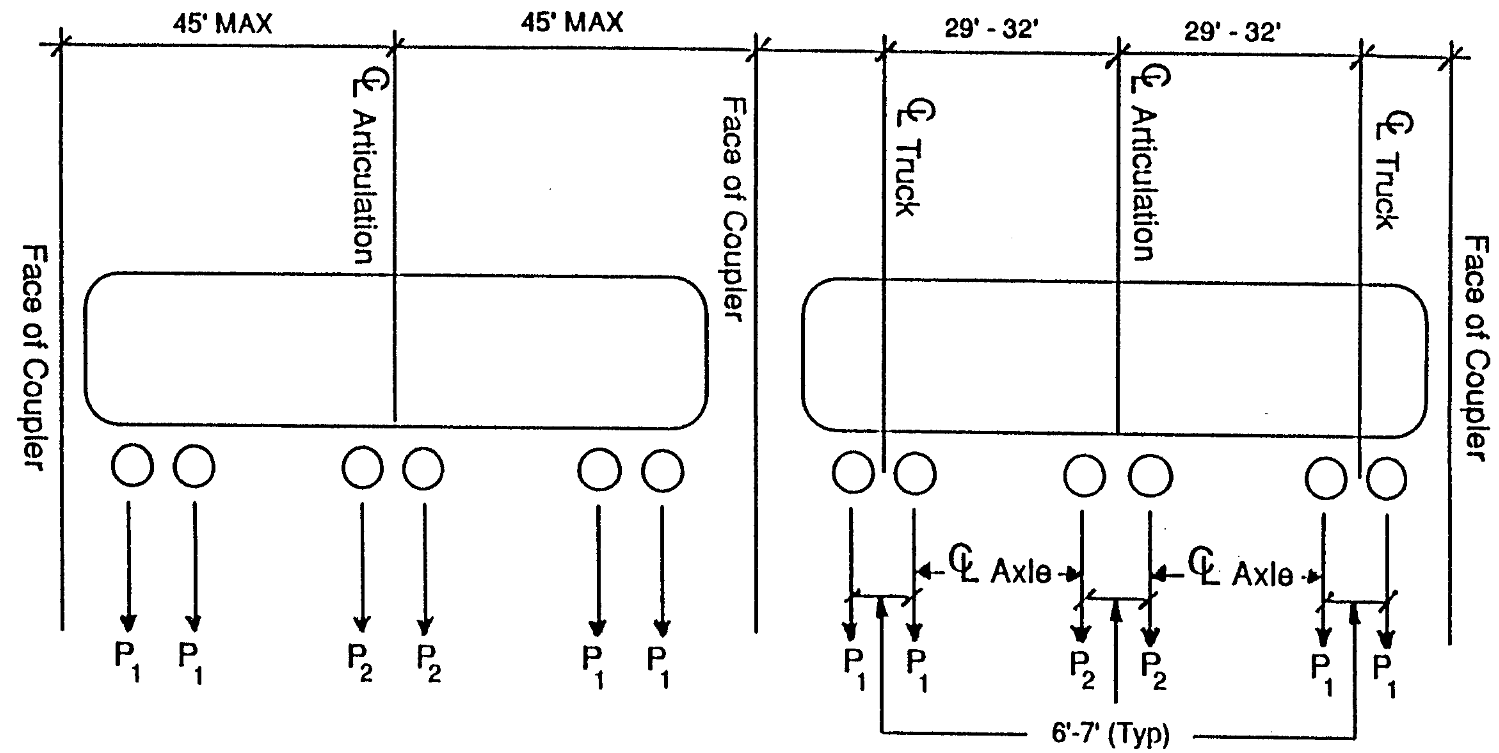
For design performance purposes, the weight of each vehicle shall be as follows:

AW0:	Maximum Empty Car Operating Weight	94,000 lbs.
AW1:	Seated Load Car Weight, based on 76 seated passengers and one operator at 154 lb/person	106,000 lbs.
AW2:	Service Load Car Weight, based on 76 seated passengers, one operation and 90-107 standing passengers at 154 lb/person (four persons per square meter)	123,000 lbs.
AW3:	Heavy Load Car Weight, based on 76 seated passengers, one operator and 135-161 standing passengers at 154 lb/person (six persons per square meter)	131,000 lbs.

For structural design purposes, the guideway structural design load shall not exceed 135,000 lbs.

f. vehicle loading distribution and dynamic outline

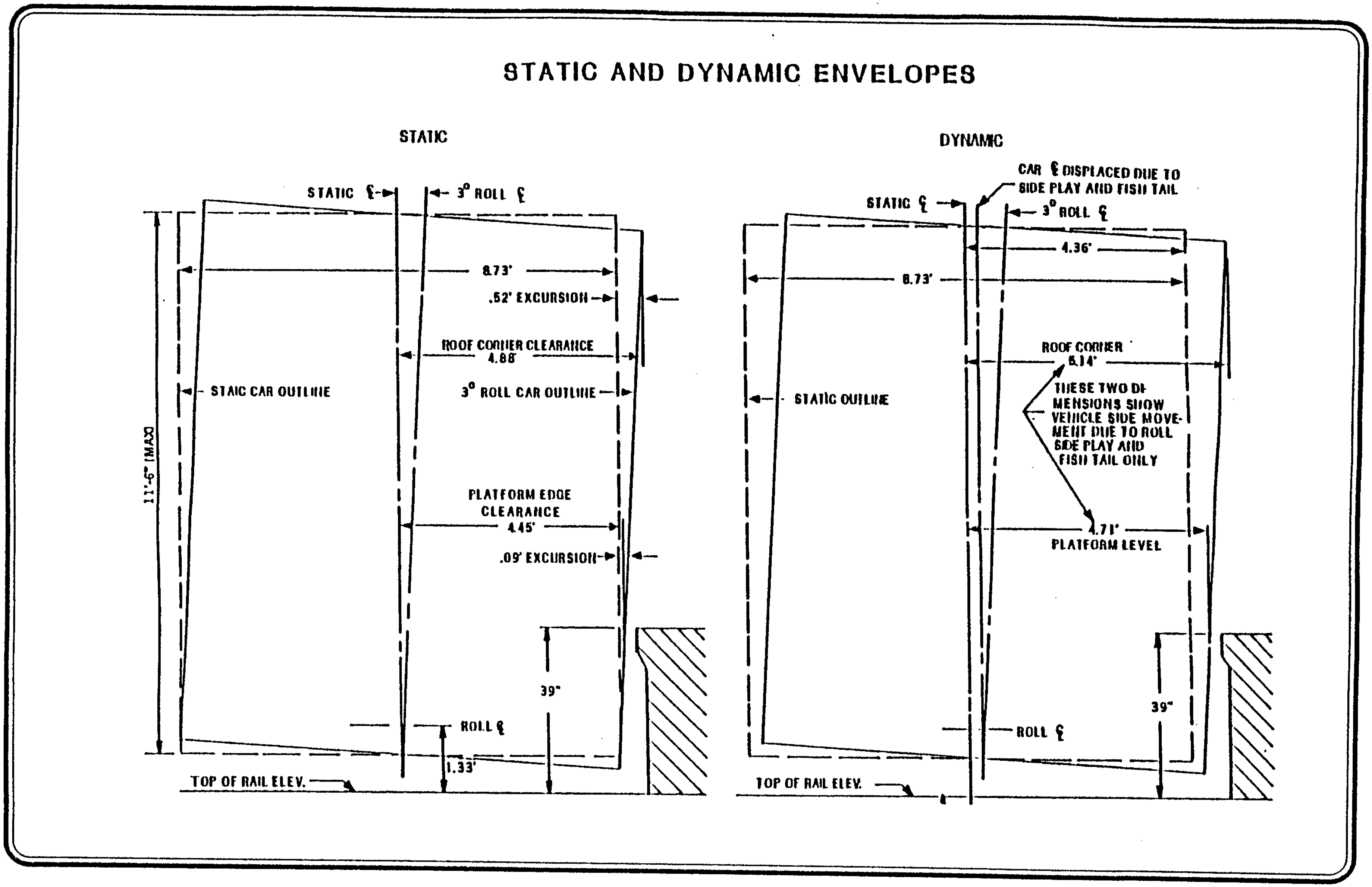
Figures 8 and 9 present the vehicle loading distribution and vehicle dynamic outline respectively.



ESTIMATED LOADING DISTRIBUTION (LBS)

	Distr. to Center Truck	P_1	P_2	TOTAL
Unloaded	20%	18,200	10,600	94,000
	30%	16,675	13,650	94,000
Loaded	20%	26,400	14,700	135,000
	30%	23,850	19,800	135,000

ESTIMATED LOADING
DISTRIBUTION



Metro Rail Planning Study

Civil Design
Guidelines

GANNETT - DELEUW

STATIC AND DYNAMIC ENVELOPES

August 1990

Figure #9

2. Track Alignment

a. general

The alignment parameters were developed with consideration for safety, passenger comfort, and current accepted railroad and transit engineering practice. Track safety requirements meet or exceed those prescribed by the federal Railroad Administration's "Track Safety Standards on Track Geometry", for Class 5 tracks. The parameters for the design of alignments have been established in accordance with the recommendations of the current issue of *Manual for Railroad Engineering* published by the American Railway Engineering Association (AREA). Rider comfort requirements are based on the AREA Joint Committee Report "Passenger Ride Comfort on Curved Track," published in Bulletin 516, June-July 1954.

The horizontal alignment of main-line tracks shall consist of tangents joined to circular curves by spiral transition curves. Spirals shall also be used in all lead tracks and other heavily used tracks in the yard. Curvature and superelevation shall be related to design speed and the acceleration and deceleration characteristics of the design vehicle. Whenever practical, the geometrics shall accommodate the maximum service operating speed of 55 miles per hour, depending on the location of curves, spacing of stations, construction limitations, and the performance characteristics of the design vehicle. The desired minimum main-line design speed shall be 40 miles per hour, and the absolute minimum 30 miles per hour. When operating in a roadway having frequent grade crossings, a design speed of 10 miles per hour above posted highway speed should be attained.

These criteria are based on a track gauge of 4 feet 8-1/2 inches as measured from 5/8 inch below the top of rail.

b. minimum tangent length

The desired minimum tangent length in feet shall be three times the design speed in miles per hour. Seventy-five feet shall be used as the minimum for main-line track. Yard track shall have a desirable minimum tangent length of 25 feet with minimum of 10 feet.

c. track spacing

Normal track centers using center support catenary poles shall be 14'-0". Minimum track centers using center support catenary poles in restricted areas can be 13'-0" assuming the use of narrow (8'-9"±) transit vehicles. If wider cars are used, the minimum track spacing should be reevaluated. Both normal and minimum track centers will require widening on curves to compensate for vehicle middle ordinate and end overhang. Track center dimensions for parallel tracks near stations with center platforms will be dependent upon the width of the platform.

d. track superelevation

Superelevation shall be constant through circular curves, except those lying in an acceleration or a deceleration zone, and shall be achieved by maintaining the top of the inside rail at the top-of-rail profile and raising the outside rail by an amount equal to the track superelevation.

Track superelevation is based on the following formula:

$$E_t = E_a + E_u = \frac{3.96V^2}{R_c}$$

where:

Et = Total superelevation = $E_a + E_u$
E_a = Actual track superelevation in inches
Eu = Unbalanced superelevation in inches
V = Design speed in miles per hour
R_c = Radius of curvature in feet

The desired maximum actual superelevation (E_a) shall be 4 inches. However, where the design speed of a section of alignment can be increased by the addition of actual superelevation above 4 inches, an absolute maximum of 6 inches may be used. The desired maximum unbalanced superelevation (E_u) shall be 3 inches. However in sections of restricted alignment, an absolute maximum unbalanced superelevation (E_u) of 4-1/2 inches can be used to attain the desired design speed. Superelevation shall be specified in 1/4-inch increments. Superelevation of less than 1/2" shall not be specified; zero superelevation shall be used when the calculated or desired value is less than 1/2 inch. When zero superelevation is used however, the amount of resulting unbalanced superelevation shall not exceed 1-1/2 inches.

Where space allows, the actual superelevation (E_a) provided should equal the total superelevation (E_t) required.

e. circular curves

Circular curves shall be defined by the arc definition of curvature and specified by their radius (R_c) in feet.

The desired or absolute minimum radius for any other selected design speed shall be determined by the formula:

$$R_c = \frac{3.96V^2}{(E_a + E_u)}$$

using E_a = 6 inches and E_u = 3 inches for the desired minimum radius or E_a = 6 inches and E_u = 4-1/2 inches for the absolute minimum radius.

The desired minimum length of curvature of circular curve (L_c) in feet along main-line tracks shall be three times the design speed (V) in miles per hour, or 100 feet, whichever is greater.
In general, the largest radius curve practical, satisfying the above conditions, should be used in each situation to minimize maintenance and maximize speed.

For yard and main-line multitrack layouts, where two or more tracks follow the same general alignment, the tracks shall be placed on concentric curves.

f. transition spiral curves

The transition spiral is defined as a curve whose radius varies inversely as the distance along the curve from the point of spiral. All transition spirals computed for the control track shall be Talbot (clothoid) spirals, in which the following relationship pertains where:

$RL = R_c L_s$

R = Radius of curvature of the spiral at any given point between the TS and SC

L = Distance along the spiral from the point of spiral, TS, to the given point

R_c = Radius of curvature of the circular curve R_c equals R at SC

L_s = Length of spiral from TS to SC

All horizontal circular curves in main-line tracks require transition spirals where joining tangent track or where compounded to a curve of a different radius. The track superelevation shall be attained linearly throughout the length of the transition spiral curve. Where topographic conditions permit, the desirable design lengths (L_s) of transition spiral curves shall be the greater obtained from the following formulas:

$L_s = 1.4\ VE_a$

$L_s = 60\ E_a$

where:

L_s = Length of transition spiral curve in feet

V = Design speed in miles per hour

E_a = Actual track superelevation in inches

Where physical restrictions exist, the minimum spiral length shall be the greatest length obtained from the following formulas:

$L_s = 1.17\ VE_a$

$L_s = 1.0\ VE_u$

$L_s = 50\ Ea$

L_s = 75 feet minimum

where:

E_u = Unbalanced superelevation in inches

For multi-track layout where two or more tracks follow the same general alignment and the distance between track centers in the circular curve is the same as in the adjoining tangents, the tracks shall be parallel to the control spiral. If the distance between track centers in the circular curve is different that in the adjoining tangents, each spiral shall be a "true" spiral, and its geometry shall be defined individually.

g. reverse curves

If the minimum tangent length specified in section 1.2 cannot be accommodated between reverse curves, the transition spiral curves of the two curves may be extended to meet at the point of reverse curvature.

h. compound curves

Compound circular curves may be used provided they are connected by an adequate transit spiral curve or superelevation transition length. Lengths of transition spiral curves or superelevation transitions shall be determined from the formulas with E_a (the difference between superelevations of the two circular curves) substituted for E_a, and E_u (the difference between the unbalanced superelevation of the two curves) substituted for E_u.

i. vertical alignment general

The profile grade is defined as the top of the low rail. Changes in profile gradients shall be joined by vertical curves at crests and sags. No compensation of grades is required for horizontal curvature. In areas of curved alignment where the profile is given for one track only, the elevations of the second track shall be adjusted uniformly to accommodate the differences in lengths throughout the curves.

j. maximum and minimum gradient, main-line

The desired maximum profile gradient on main-line track shall be ±4.0 percent. The absolute maximum profile gradient for main-line track shall be ±6 percent.

To facilitate drainage, a minimum gradient of ± 0.3 percent shall be maintained in underground and aerial line structures. A minimum gradient of zero for at-grade line construction is acceptable if drainage can be accommodated.

k. maximum and minimum gradient, yard and secondary tracks

In yard and secondary tracks, the minimum gradient shall be 0.0 percent and maximum gradient shall be ±1.0 percent, except as follows:

- For turnback, center pocket, and other storage tracks, the desirable gradient shall be zero percent and the maximum gradient shall be ±0.3 percent. The gradient for storage tracks may be 0.5 percent provided the grade is sloped away from the lead track and/or has a sag in the profile. Permanent stub-end storage tracks shall be sloped away from the turnout at 0.3 percent. Through storage tracks shall be 0.0 grade or where feasible, have a sag in their profiles.

- Throat area tracks preferably shall be on a slope. The desirable gradient shall be 0.3 percent sloped away from the main-line tracks.
- Tracks located within shop buildings shall be level.

l. vertical curves

The desirable length of vertical curve (LVC) in main-line track shall be determined by the following formulas:

$$LVC = \frac{AV^2}{25} \quad \text{(crest)}$$

$$LVC = \frac{AV^2}{45} \quad \text{(sag)}$$

where:

LVC = Length of vertical curve in feet

V = Design speed in miles per hour

A = The algebraic difference in the grades (in percent) approaching and leaving the curve.

The absolute minimum length of vertical curve in main-line track shall be the greatest of the lengths determined by the following formulas:

$$LVC = \frac{AV^2}{30} \quad \text{(crest)}$$

$$LVC = \frac{AV^2}{60} \quad \text{(sag)}$$

$$LVC = 3V$$

$$LVC = 100$$

$$LVC = 70A$$

m. stations and special trackwork

Stations and special trackwork (turnouts and crossovers) shall be located on horizontal and vertical tangents. Horizontal tangents shall extend 75 feet beyond the future limits of the station platforms.

The minimum gradient through stations is ±0.3 percent. The maximum gradient shall be ±1.0 percent through those stations at which the tracks are not to be used for storage. If the station tracks are to be used for storage, the maximum gradient shall be ± 0.5 percent; the absolute maximum gradient through special trackwork shall be ±2.0 percent.

3. **Clearances**

a. variations of the clearance outline due to curvature and superelevation

When a vehicle enters a horizontally curved track (including turnouts), the clearance envelope must be adjusted for vehicle end overhang, middle ordinate and superelevation. The additional clearances required on curves due to middle ordinate and end overhand are approximately equal to each other; and equal 365/R with R=Radius of curvature in feet, and the result in feet. For purposes of conceptual design, additional clearances required to compensate for superelevation will be ignored.

b. horizontal clearances

The horizontal distance from the edge of a high or low platform to the car body shall be 3 inches from the static car outline or static car outline extended.

The following side clearances from center line of tangent track are based on an assumed 8'-9"± wide vehicle. If wider cars are used and where the track is curved, the clearance must be increased accordingly.

	PREFERRED	MINIMUM
• Clearance to a fence or retaining wall with side walkways	10"-0"	7'-8"
• Clearance to tunnel wall without walkway	6'-0"	5'-10"
• Clearance to edge of tunnel walkway	---	5'-0"
• Distance between transit track and adjacent railroad track assuming fence between transit track and railroad track * must be coordinated with railroad	---	22'-0*
• Right-of-way width in median of highway between stations	---	34'-0"
• Outer face of curb of adjacent traffic lane in a nonexclusive median	---	5'-5"
• Distance to centerline of a crossing gate support mast	15'-0"	9'-0"
• Distance to face of curb of adjacent parallel street at crossing gate	19'-6"	13'-6"
• Distance to face of curb of adjacent parallel street where there are no crossing gates or other signs and equipment.	10'-6"	10'-0"

c. **vertical clearances**

Transit structures over public highways shall be in accordance with the Standard Specifications for Highway Bridges adopted by the American Association of State Highway and Transportation Officials or as modified by the Washington Department of Transportation or local jurisdiction, whichever is applicable. Vertical clearance,guideway structure over local public roads and streets, shall be as required by the Authority having jurisdiction over the roads.

Vertical clearance, guideway structure under a fixed structure, shall be 17'-0" when practical, 16'-0" minimum measured from top of rail to the nearest point of obstruction.

Vertical clearance, top of rail to contact wire at unobstructed points and grade crossing shall be 18'-0".

4. **Walkways**

A continuous evacuation walkway space 2'-6" wide x 6'-8" high, free of all obstructions, shall be provided adjacent to each track, from any point on the track to a station, grade crossing or other exit point. Walkways need not to be paved in sections of tie and ballast construction. The maximum cross slope of the evacuation walkway shall be 8:1.

For ballasted, at-grade sections the evacuation walkways shall on the outside of the LRT tracks. For ballasted, at-grade sections approaching center platform stations, the evacuation walkways should cross to the center of the LRT tracks, where the track spacing spreads to greater than 15 ft. Stairways should be provided for access to the platforms.

5. **Special Trackwork**

a. **configurations**

- Flex junctions between routes shall use No. 20 or No. 15 turnouts depending upon civil restrictions and speed requirements. Similarly, non-flex junctions shall use No. 15 or No. 10 turnouts.

- Main-line track crossovers, turnouts to the yard, pocket tracks, and end-of-line storage tracks shall use No. 10 turnouts.

- Pocket tracks for aerial and subway installations shall use No. 10 equilateral turnouts. At-grade locations shall consist of No. 10 lateral turnouts.

- Yard tracks shall use No. 6 turnouts; if space permits, however, No. 8 turnouts may be considered.

Combinations of these units to be used on the system include the following arrangements:

- *Turnback Tracks.* A three-track arrangement in which a center pocket track is situated between main-line tracks. To conserve space on aerial and subway construction, equilateral turnouts will be used to provide the connection from the center pocket to the main-line tracks. At-grade sections will utilize all lateral turnouts.

- *Emergency Storage Tracks.* This arrangement includes a single crossover between two main-line tracks at wide track spacing followed by a modified crossover that has been lengthened to serve as a center pocket track and a crossover.

- *Universal.* This arrangement employs two single back-to-back crossovers connecting main-line tracks.

- *Double Crossover.* This arrangement, consisting of four lateral turnouts connected together by a diamond crossing composed of two end frogs and two center frogs, shall be used in all direct-fixation locations.

b. location criteria

Crossovers and turnouts shall be located on tangent track and on constant profile grades with a desired maximum grade of ±1 percent and a maximum grade of ±2 percent.

Turnback tracks, storage tracks, universals and double crossovers should generally be located adjacent to stations to facilitate operations and maintenance. Lacking a specific operations plan, special trackwork should be located at every other station for estimating and conceptual design purposes.

c. operating speed through turnouts

TURNOUT NO.	MAXIMUM SPEED LIMIT (MPH)
6-Lateral	12
8-Lateral	16
10-Lateral	20
15-Lateral	30
20-Lateral	41
10-Equilateral	28

d. special trackwork lengths

#10	Double Crossover @ 14' track ctrs.	203
#10	Double Crossover @ 29' track ctrs.	310'
#10	Universal @ 14'track ctrs.	470'
#10	Universal @ 29' track ctrs.	670'

For each foot increase or decrease in track centers, add or subtract 10' of overall length.

6. Stations

Platform length is a function of maximum train length. Trains on the Metro system will be limited to 360' owing to the constraints of the downtown tunnel. A 380' platform length will allow for the use of 4-90' articulated vehicles or other similar combinations and provide additional stopping tolerance.

Platform width is a function of the circulation elements serving the platform. A center platform station in the median of a highway or other restricted access will be served from above by an 8' wide elevator for the handicapped and a 6' stair or escalator. Side clearance form the most restrictive element is in the vicinity of 8' although lesser clearances have been used on other systems. This series of clearances results in a 24' wide center platform. Where no vertical circulation elements are required, an 18' wide center platform should be sufficient.

Side platforms can have their vertical circulation elements located outside the platform. The width of this platform is then a function of space required to hold patrons waiting for trains. A 12' nominal width is recommended.

7. Parking Lot Sizing

The size of parking lots required to handle a given number of cars will vary considerably depending upon the shape of the land available. However a "rule-of-thumb" that works reasonably well for conceptual analyses is to allow 80 cars/acre plus one acre for bus, kiss-n-ride and general circulation.

8. Glossary

Crossover/Double - Two single crossovers which intersect between the connecting tracks.

Crossover, Single - Two turnouts, with rail between the frogs arranged to form a continuous passage for track mounted vehicles between two nearby and parallel tracks.

Junction, Flex - The bifurcation of a pair of main line tracks into two sets of main line tracks with the tracks separated vertically so that they do not cross each other. (Similar to a full highway interchange).

Junction, Non-Flex - The bifurcation of a pair of main line tracks into two pairs of main line tracks with the tracks not separated vertically thereby requiring opposing traffic to cross at-grade.

Track, Pocket - A track auxiliary to the main track for meeting, passing, turnback or storing trains. Usually accessible from both main tracks on a double-track transit line. May be single ended or double ended.

Turnout - A track structure with movable rails to divert rolling stock from one track to another.

Turnout, Equilateral - A turnout in which the diversion, due to the angle of the turnout, is equally divided between the track from which the turnout is made.

Turnout, Lateral - A turnout in which the diversion, due to the angle of the turnout, is entirely on one side of the track from which the turnout is made.