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Planning, Architecture, Engineering

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DANIEL, MANN, JOHNSON, & MENDENHALL

ARCHITECTS & ENGINEERS

3325 WILSHIRE BOULEVARD · LOS ANGELES 5, CALIFORNIA · DUNKIRK 1-3663

PHILLIP J. DANIEL, A.I.A.
ARTHUR E. MANN, A.I.A.
S. KENNETH JOHNSON, A.I.A.
IRVAN F. MENDENHALL, C.E.
STANLEY A. MOE, A.I.A.

ASSOCIATES
ALFRED W. DAY, A.I.A.,
JACK C. HANDLEY
MARVIN J. KUDROFF, C.E.
T. K. KUTAY, A.I.A.
SHUJI MAGOTA, C.E.
ANTON H. MATUSEK
VINCENT A. MEGNA, M.E.
DAVID R. MILLER, C.E.
W. ARTHUR ROOT, E.E.
ROBERT J. SULLY
ROBERT C. WESTERFELD, M.E.

February 2, 1960

Mr. C. M. Gilliss
Executive Director
Los Angeles Metropolitan
Transit Authority
1060 South Broadway
Los Angeles 15, California

RE: Rapid Transit Program
Progress Report - Technical
Supporting Material

Dear Mr. Gilliss:

Transmitted herewith are ten (10) copies each of a report in two volumes which comprises the technical supporting material to accompany our Progress Report.

This report contains a more detailed resume of the work we have been able to accomplish during this Initial Phase of the Rapid Transit Program and, in addition, we have included in the second volume the reports we have received from our consultants on specialized aspects of the program.

Respectfully submitted,

David R. Miller

DANIEL, MANN, JOHNSON, & MENDENHALL
Architects & Engineers

David R. Miller
Project Manager

LOS ANGELES METROPOLITAN TRANSIT AUTHORITY

PROGRESS REPORT

RELATING TO

INITIAL CONSIDERATION OF SYSTEMS AND ROUTES

FOR A

MASS RAPID TRANSIT PROGRAM

February 2, 1960

DANIEL, MANN, JOHNSON, & MENDENHALL
ARCHITECTS & ENGINEERS

PROGRESS REPORT

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LOS ANGELES METROPOLITAN TRANSIT AUTHORITY

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C. M. Gilliss

General Manager

C. T. Bass

Secretary

Virginia L. Rees

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A. J. Eyraud

Hayden F. Jones

Russell A. Quisenberry

Arthur J. Will

THE PROJECT TEAM

DANIEL, MANN, JOHNSON & MENDENHALL	Architects & Engineers and Program Consultant
MASON & HANGER-SILAS MASON CO., INC.	Associate Engineers and Consultants for Underground Construction
GIBBS & HILL INC.	Consultant - Electrical Equipment
VICTOR GRUEN & ASSOCIATES	Consultant - Community Planning
COLONEL S. H. BINGHAM	Consultant - Transit System Operations
HAROLD OTIS	Consultant - Transit Equipment
LLOYD ALDRICH	Consultant - Civil Engineering
HENRY A. BABCOCK	Consultant - Rights-Of-Way
LE ROY CRANDALL & ASSOCIATES	Consultant - Foundations and Geology

INTRODUCTION

INTRODUCTION

SECTION I

INTRODUCTION, SUMMARY AND CONCLUSIONS

As directed by the Contract, the scope of work during this initial phase of the Rapid Transit Program has emphasized the screening of transit system proposals presented by manufacturers and inventors of transit systems and equipment and the initial consideration of conditions existing within the four transit corridors that would affect the selection of the type of system. The purpose of this screening of systems and initial consideration of routes, was the development of a limited number of transit systems having sufficient merit to warrant a detailed comparative analysis. This detailed analysis, in the next phase of the program, would provide the basis for the selection of the system most adaptable to the Los Angeles Transit requirements.

An important part of this initial phase also has been the accumulation of basic data and the planning work necessary for the establishment of a master plan of ultimate transit development in order to insure the orderly consideration of the transit system and that initial efforts will be compatible with the requirements of the future. In addition, work has begun on the collection of data and certain of the engineering efforts which should carry forward in the next phase, and which will provide the basis for many of the decisions which must be made in the next phase.

The team which has been assigned to this effort has been made up of individuals from the various DMJM technical staff groups together with our Associate Engineer, Mason & Hanger-Silas Mason Company, Inc. and the other consultants in the following specialities:

Gibbs & Hill	Equipment - Electrical Engineering
Victor Gruen Associates	Community Planning
Colonel S. H. Bingham	Transit System Operations
Harold Otis	Transit Equipment
Lloyd Aldrich	Routes
Henry Babcock	Land and Rights-Of-Way Evaluation
LeRoy Crandall & Associates	Foundation Engineering and Geology

These specialists have met frequently with the project staff for discussions on various aspects of the work. Several of the consultants have been asked to report on special problems and these reports have been included in the appendix of the technical supporting material.

The program has been divided into three general tasks with a project task group assigned to each. These task groups have operated under the direction and coordination of the Partner-In-Charge and of the Project Manager. For convenience, the reporting herein will generally be done using the same divisional framework as these tasks which are:

Transit Planning and Criteria

Transit Systems

Transit Facilities

The following paragraphs will discuss the progress and findings of each of the groups with recommendations for further work required during succeeding phases provided further on.

TRANSIT PLANNING AND CRITERIA

The first task assigned to this group was that of criteria research and the development of transit system criteria. This is necessary to set the pattern for the consideration and evaluation of the various transit systems. Recommendations for criteria to be satisfied by transit systems to be considered for application to Los Angeles take the form of desirable minimums, and are set forth in later paragraphs.

DEVELOPMENT OF REQUIREMENTS FOR ULTIMATE TRANSIT SERVICE

Much progress has been made in the planning work necessary for the development of requirements for ultimate transit service. This work is being carried out in connection with representatives of Coverdale & Colpitts and using the data previously developed by them.

Frequent conferences have been held with officials from City and Regional Planning agencies in order to ascertain their progress toward the development of the Master Plan for the metropolitan area and to obtain their projections of future growth.

The corridor layouts and traffic projections previously submitted to the Authority by Coverdale & Colpitts have been considered along with information from various planning agencies on future land use patterns. The possible effects of transit service on land use patterns have been explored. This is leading to the development of the definition of the place of rapid transit within the over-all transportation plan and the requirements that transit must serve within the community.

Our findings, to date, have led to the outlining of three broad concepts of transit service that may be considered as ways of providing different levels of service. These transit system concepts are:

1. Full coverage systems which would provide means of serving the majority of origins and destinations within the community with rapid transit service as advocated by George Rowan and others.

2. Flexible systems utilizing bus equipment to provide for feeder distribution and trunk service with a single vehicle.

3. Trunk line rapid transit systems served by feeder and distribution systems using buses or other equipment.

The Authority directed our initial effort toward the trunk line concept which was the result of the corridor recommendations of Coverdale and Colpitts. The relationship of these transit concepts to the ultimate transit requirements will be studied further with information from Coverdale and Colpitts to determine the levels of service needed now and in the future. Once the concept is established, then a master plan for ultimate transit service can be recommended.

PLANNING CENTRAL CITY TRANSIT SERVICE

Our studies, to date, have indicated the type of service to the Central City area to be most important, particularly during any initial phase of a program, so that future expansion can be accomplished without interference to service or adding unnecessary cost.

Studies are now being carried out to gauge the effect on real estate values and other development by various routes and configurations of service and by elevated or subsurface construction. Requirements for downtown distribution and pickup are also under study as are means of providing local and express transit service both to and through the Central City. Close contact has been maintained with the Central City Study Committee and other groups having interest in Central City Planning.

A field reconnaissance has been made of the Central City to determine potential route alternates, and a study has been made of possible utility intereference. In reviewing the factors involved in construction in the Central City, special emphasis has been placed on the determination of methods giving the least interference with normal activities. Alternate route layouts are currently being studied and preliminary cost information has been developed in order to ascertain the affect of the various layouts on the overall program. Some of the alternate solutions are:

- Inner loop system
- Outer loop system
- Single line centrally located
- Single line offset

Inherent in the study of these alternates are the factors of whether the line can be placed overhead or underground and whether service to the Central City can be provided by a series of stations, or if a secondary distribution system is required.

CORRIDOR CONSIDERATIONS

Insofar as the detailed consideration of alignments is concerned, the scope of our study has been primarily oriented toward the four corridors shown by the origin and destination study as being the most likely to support mass rapid transit. These are: Reseda via Cahuenga and Wilshire; Wilshire; Long Beach; and San Bernardino.

Particular attention has been directed toward the conditions existing therein which would affect the selection of a type of system. During the course of the initial engineering for route and alignment selection for these corridors, we have accomplished detailed field reconnaissance of each in order to obtain the necessary information on controlling features. Conferences have been held with many agencies concerned with existing facilities within these corridors. Information on utilities at critical points has been obtained, alignment data and existing and future plans have been secured from the California Division of Highways and various railroad companies. We have reviewed the existing street pattern and utility rights-of-way. A preliminary foundation and geology study has been made. Out of all of this, we have, for each of the four corridors, determined a number of alignment alternates that can now be studied in detail and compared.

Ultimately, these studies of route alignment and equipment will culminate in the selection of the combination of segments of the most adaptable type of rights-of-way and a conclusive alignment recommendation for each corridor.

A significant part of the considerations of alignments within corridors is the land use and community acceptance studies being developed with our consultants, Victor Gruen Associates.

These land use studies have indicated those areas presently undergoing transition or having activities which could not be disrupted. Land use work maps have been prepared and are currently being used in our evaluation processes.

TRANSIT SYSTEMS

The determination of the best type of mass rapid transit system for the Los Angeles Metropolitan Area must take into account the fact that this city, perhaps more so than any other, is free of governing precedents that would dictate the choice of equipment and system that should be applied here. Two fundamental aspects that must be considered in the choice of any transit system for application to a specific area are: (1) the basic merits of the system itself, and (2) the routes to which the transit system must be applied. Fortunately for Los Angeles, a complete freedom of choice is possible concerning the former, and diverse alternatives are available from which to recommend suitable solutions to the latter.

We have explored, in general, all of the possibilities of modern developments in rapid transit to determine which systems have sufficient merit to be considered for the basis of the transit system here. A brief summary of this effort follows.

The review and evaluation of these transit systems have been done on a completely impartial basis keeping an open mind to determine the advantages and benefits of any new ideas in transit systems. It is recognized that whatever is proposed ultimately must form the basis of an operable transit system which would have to be constructed within-the relatively near future, but we must consider all transit ideas even though they may not have been completely developed.

In this evaluation of modern transit systems, we have been aided by our consultants, particularly Gibbs & Hill, Mr. Harold Otis and Colonel Sidney Bingham. We have received transit system presentations by any proponent who wanted to make a formal presentation to the Authority of his system. In addition to this, we have had informal discussions with manufacturers, persons and firms who had general ideas as to transit equipment, but did not wish to make a specific recommendation for a system to the Authority. In addition, we have received several ideas that, while not being actively proposed by any single proponent, appeared worthy of consideration, and these were, therefore, included also in the evaluation.

We find that of many of the systems still are only in the concept stage with their real potentialities yet to be developed and explored, and some present intricate engineering and design problems which must yet be solved. Some of the systems are far advanced with development virtually completed and with operating test installations that can be inspected and evaluated.

In order to develop sufficient information to facilitate evaluation of these various systems, a series of 75 questions were prepared and given to each system's proponent. These questions dealt with such subjects as operating and performance characteristics of the vehicle, dimensions of vehicles, type of suspension, propulsion systems, braking, cost estimates, patents, structural requirements, etc. Many of the proponents whose systems are still only in the concept stage, were unable to answer these questions, while some submitted very complete design and cost information along with the answers to all of the questions.

The evaluation process and the selection of a limited number of systems meriting further study involves the application of judgment and comparison with certain requirement standards. One of the factors that must be taken into account in this selection is the status of the system in regard to its capability of being developed into an actual operating system in the reasonably near future.

This development work is a time consuming process for a new system. For the more unconventional systems, this process takes years before sufficient knowledge can be accumulated to provide a sound basis for the application of the system to a multi-million dollar transit program. The system must generally meet the transit system criteria set forth previously and must show some reasonable basis for consideration and application to the Los Angeles Program.

Engineers' Recommendations - Systems

Of the nine general categories of transit systems considered by this screening study, we have found three categories that we feel merit further consideration and detailed comparison.

These are set forth as follows:

A. Conventional two rail system (Modern design)

B. Suspended System - Symmetric Split Rail

C. Supported System - Overriding (Saddlebag)

Each of these systems have several proponents with systems in various stages of development. In each category, there is at least one proponent or system that has been developed to the point of having an adequate high speed test installation that can be properly studied and evaluated.

During the latter part of this initial phase of the program, a system was presented that appears to be a significant new concept for possible application in rapid transit. It is a so-called "ground effect" vehicle which uses air suspension and a type of magnetic propulsion. While the engineering of a specific prototype vehicle has not been completed and no test section is available, it does appear worthwhile to devote some further study to the potentialities of this vehicle. We feel that even in this next phase when we will be making the detailed comparison and evaluation, it would be in order to receive presentations of any new systems so as to insure that nothing is overlooked and that the system finally chosen will be the best of all of the possible alternates.

Of the systems that have not been recommended for further study, some further comment is in order. Our evaluation covered only the possible application to the peculiar requirements of the Los Angeles Transit

Program and we see, in many of the systems, ideas and concepts which do have much merit and which made the selection difficult.

Some of the systems show promise for the future, but are presently not developed to a point where they could be used with confidence as the basis for an operating transit system.

The three systems that are recommended for further comparison have been reviewed with our Consultants, Gibbs & Hill, and with Colonel S. H. Bingham, and we have their general concurrence in this recommendation.

Conventional Rail System

Certainly the wide spread use and acceptance of the conventional two-rail system and its simple switching and adaptability to either overhead, ground level, or underground operation, would indicate that it should be one of the systems included in the detailed comparative analysis. Such a system, as adaptable to Los Angeles, would use lightweight, high speed equipment and be of modern design. Further consideration would be given to the possibilities of the use of pneumatic tires and special roadbeds.

Because of its adaptability, and long history of transit service, the conventional rail system must be regarded as a standard that must be bettered by any other system. The question then is asked as to why consider other systems? The answer lies in several factors, among which are those of safety in operation, levels of community acceptance, and noise.

Several of the newer types of monorail systems give some promise of improvement along these lines. Therefore, in order to insure that the best and most modern system is chosen as the basis for the rapid transit program, these other systems, which show promise should be studied in detail and compared with the conventional rail system to see which one is the most feasible and adaptable here to the Los Angeles problem.

Suspended System - Symmetric Split Rail

This type of suspended system had one active proponent - the French group headed by the Societe Lyonnaise des Eaux et de L'Eclairage. In addition, the staff studied the split rail proposal made by Northrup to Seattle and the split rail designs made some time ago by our Consultants, Gibbs & Hill.

Actually, the split rail design is not a true monorail at all. It is in effect a narrow gauge railroad with the cars suspended beneath the rails. The system is included in the category of systems operating or under test by virtue of the 1.2 mile test installation of the French group now being completed south of Paris. Neither the Northrup or the Gibbs & Hill designs have been fully developed or test facilities constructed.

The French group, which includes some of the giants of French industry and with some subsidy from the French Government have been doing engineering and development work on a split rail system for some time. This work has culminated in the construction of a 1.2 mile test installation in France which will permit testing of vehicles at speeds of over 60 miles per hour.

This split rail type of suspended system overcomes many of the disadvantages of the classical type of asymmetrically suspended system. It does have some disadvantages in comparison to supported systems in the higher structure required and the loss of economy with train operations at ground level. A switch has been developed, but is somewhat cumbersome, and may be slow in operation. However, the split rail form is the best of the suspended systems, and the French designs do include an ingenious suspension system that offers real promise of adequate sway control. Certainly this system should be carefully evaluated and compared with the other two systems.

Supported Monorail Overriding - Saddlebag

This supported system has had three active proponents: Alweg, Lockheed, and Hendrik de Kanter. In addition, the staff studied the supported system as proposed by Alan Hawes for Seattle.

The Alweg system is a supported system using the overriding or saddlebag principle. The system is sponsored by Dr. Axel Wenner-Gren, a wealthy Swedish industrialist. Most of the engineering and testing of the equipment has been done in Germany. It also is not exactly true monorail, since it must use guide or stabilizing wheels. The system has been under operational test since 1952 when a 2/5 scale model was installed on a 6000-ft. oval test track. In 1957, a full-scale test track, slightly over one mile was constructed. The original small-scale model is reported to have achieved speeds of up to 80 miles per hour with quiet, smooth operation.

The full-scale test track is not a loop and speeds are limited to about 60 miles per hour. In addition to these test installations, a 3600 foot Alweg facility has been installed at Disneyland to serve as an amusement ride running at lower speeds. This monorail facility is reported to be one of the most used attractions in Disneyland. A variation of the overriding monorail system which does not use pneumatic tires has been designed by Lockheed, but there is not a test installation.

The basic principle of the overriding system also appears to be an improvement over the classical asymmetric design, and systems of the overriding type have been more thoroughly tested at high speeds than other modern monorail systems. There are several disadvantages also. The running beams require extreme care in casting and fitting, in order to produce a smooth ride. Also, the switching is slow and cumbersome, although switch designs have been developed which have some advantages over those designed for the suspended split-rail system.

The overriding type is considered to be the best of the supported monorail systems, and therefore, it should be also carefully evaluated and compared with the other two systems.

Transit System Equipment

In addition to the evaluation of the various transit systems, the project staff have accomplished much in the way of initial engineering work on other aspects of the transit system equipment.

DMJM electrical and systems engineers, along with our Consultant, Gibbs & Hill, have developed preliminary criteria and recommendations for further engineering of automatic train control and operations systems and signal and communications systems. These systems give promise of operational economy and safety of a modern, high speed system.

Tentatively, we have concluded that the power supply system which shows the most promise is the direct current electric traction system which has been used for transit service for years. Nuclear and other unconventional sources of power together with alternating current electric power were found to offer less advantage than the conventional power system. We have devised some variations of the D.C. system which may offer savings in the cost of substations.

We are continuing to study the car components of the transit equipment to see if still further improvements in design can be made and we are convinced that major weight reductions are possible which would affect substantial savings in structure. Another aspect deserving further immediate engineering effort is the design of the trucks of the systems, and the advantages and disadvantages of the use of pneumatic tires. We have found that there are many technical problems involved in the high speed operation of heavily loaded pneumatic tires and discussions are under way with rubber manufacturers to see if these can be solved. The problems of dynamic and other forms of braking are being studied to see if some of the problems noted in existing operations can be solved.

TRANSIT FACILITIES

The determination of the transit system to be used for the Los Angeles area has required investigations beyond the mechanical aspects of the equipment. Necessary supporting structures for transit systems have been reviewed and layouts made to delineate station requirements for the various systems. The possibilities of operation in freeway or railroad right-of-way have been considered together with the problems involved in underground construction of subways. The studies of cost of facilities are, of course, of fundamental importance.

Specific requirements for way structures under different right-of-way conditions have been developed which have resulted in clearance diagrams and preliminary structural layouts of the recommended systems. Criteria for structural design has been outlined and assumptions have been made based on current practice, to establish comparison data suitable for any of the configurations of rapid transit recommended for further study. Preliminary concepts of access and space requirements of stations have been made together with a review of factors of passenger convenience and economics of construction. Progress on the development of maintenance and storage requirements of transit systems has been made and initial efforts begun toward the location of necessary yards and shops.

One of the principal items which has been accomplished is the preliminary foundation and geology study by our Consultant, LeRoy Crandall & Associates, and the review of underground construction conditions by our Associate Engineer, Mason & Hanger-Silas Mason Company, Inc.

One of the purposes for these studies was the determination of the possibility of application of low cost tunneling methods to subway construction in areas where this must be considered. Application of such developments as the "Mitry Mole" and various mining devices to Los Angeles conditions was studied. These advanced tunneling techniques are only advantageous in soft rock conditions which, unfortunately do not exist in the Los Angeles area under initial system plannings. The geology study showed that sands and gravels would be encountered in these areas and, therefore, more conventional tunneling methods would have to be used. However, indications are that a "partial shield" method which has been used in Los Angeles recently for other work may be able to be applied with some resultant saving, but not with the spectacular savings hoped for. Therefore, efforts appear in order to minimize the amount of underground construction as much as possible.

The studies of the cost of the various facilities and equipment are continuing and will culminate in comparative cost estimates of the three systems at the conclusion of the next phase of the program.

CONCLUSIONS AND RECOMMENDATIONS

Since this a progress report after only ninety (90) days of work on the initial phase of the Rapid Transit Program, it is not possible to report firm conclusions on all of the aspects of the work at this time. However, there are certain conclusions and recommendations that can be made. These are:

1. Our work to this point cpnvinces us of the need for rapid transit in the Los Angeles Metropolitan Area and we see no reason why a satisfactory system cannot be engineered and constructed.

2. The criteria and minimum requirements for this system should be as outlined in our report.
3. The conventional two-rail system, the suspended split-rail monorail and the overriding-saddlebag monorail warrant further detailed comparative analysis.
4. Our study of recent developments in the electronics field has led us to conclude that a system of automatic train control and operation with its great potentialities of savings is practical and feasible and should be investigated further.
5. The direct current type of power and propulsion system is the most practical and economical and should be adopted.
6. The cost of underground construction causes us to lean at this point toward overhead construction wherever possible.
7. The several alternative route alignments that are afforded in each of the four corridors should be further comparatively analyzed to determine the best alignment within each corridor.
8. The planning for the ultimate transit system master plan and for service to the Central City must be completed at an early date.

We recommend that the next phase of the program be initiated forthwith and be scheduled to accomplish the following:

1. Detailed analysis and selection of the transit system and equipment best adaptable to the needs of Los Angeles.
2. Selection of a specific recommended route within each of the four corridors and within the Central Business District.
3. Development of cost information.

We propose a period of four months to accomplish the foregoing.

At the conclusion of this progress report, we gratefully acknowledge the cooperation and assistance of many agencies and individuals in the work that has been done. We are confident that this same level of cooperation in the succeeding phases of the program will point the way to the successful implementation of the Los Angeles Rapid Transit Program.

TRANSIT PLANNING

TRANSIT PLANNING

SECTION II - TRANSIT PLANNING AND CRITERIA

A. An Integrated Transportation System

The most efficient transportation system which we can conceive as serving the Los Angeles Metropolitan Area would be a completely integrated complex, with each transport component operating at its optimum speed and capacity. In such a system, we might visualize "home to work" trips within the major travel corridors being accomplished through the use of rapid transit trains. We can further visualize the stations at outer limits of such travel corridors providing for connections with feeder bus lines, for "kiss 'n ride" operation and "park and ride" operation. For longer distance commuting beyond the 25-30 mile radius from the Central City Area, we visualize service to the relatively low volumes through use of helicopters, coordinated with the rapid transit trains at key interchange stations. We anticipate the continued vital contribution of the automobile for individual transportation on travel patterns of low density and for short neighborhood trips which cannot economically be provided for by a mass transportation system.

Within our Central City Area, it is entirely reasonable to visualize a system for off-surface passenger distribution with stations located at no greater distance apart than 600 feet and generally coordinated with some major building or commercial activity. Such a secondary distribution system would uniformly distribute passengers to within approximately one block of their ultimate destination.

In our studies we are planning toward the realization of this integrated transportation complex. The material in the following section of this preliminary report is intended to indicate the procedures being used in drawing out significant factors affecting the planning of a mass rapid transit system for the Los Angeles Metropolitan Area.

B. Development of Transit System Criteria

The development of criteria for a rapid transit system is logically divided into two principal areas of consideration: (1) the minimum requirements for a rapid transit system; and (2) community acceptance standards which would influence both the type of transit equipment and the area through which it might be operated.

The following listing sets forth our recommendation for minimum requirements for a rapid transit system which would provide a truly modern and effective rapid transit system.

1. Speed Factors:

   (a) Maximum of 75 to 80 miles per hour.

   (b) Average scheduled of 45 miles per hour.

   (c) Acceleration rate - 3.0 to 3.7 miles per hour, per second.

   (d) Deceleration rate - 4.5 miles per hour, per second.

2. Capacity Factors:

   (a) 30,000 seats per lane, per hour.

   (b) Capable of 90 second headways.

   (c) Maximum station stop - 20 seconds.

   (d) Operate on grade-separated rights-of-way.

3. <u>Convenience Factors</u>:

(a) Careful design of interchange stations for ease in transfer.

(b) Escalators from lower to higher levels.

(c) Parking areas adjacent to outer limit stations.

(d) Distribution system in central business district.

(e) Integration with surface bus feeders throughout.

4. <u>Comfort Factors</u>:

(a) Adequate seat dimensions.

(b) Internal temperature control.

(c) Low noise levels.

(d) Pleasing appearance.

(e) Smooth riding qualities.

(f) Provide seats for majority of passengers.

5. <u>Safety Factors</u>:

(a) Automatic train control with fail-safe features.

(b) Easy evacuation of train in case of emergency.

6. <u>Aesthetic Factors</u>:

(a) Stations and way structures must be pleasing in appearance.

(b) Trains must be ultra modern in exterior and interior design.

7. <u>Maintenance and Operation Factors</u>:

(a) Lightweight equipment.

(b) Interchangeability of equipment between lines.

(c) Line connections to central maintenance area.

(d) No more or less than one operator per train.

(e) Collection of fares must be practical and convenient.

(f) Power and propulsion system must produce minimum of noise and smog.

The foregoing minimum requirements cover the principal areas being considered in our attempt to develop a modern rapid transit system which will assume its proper role in the Los Angeles area.

Speed is recognized as the dominant factor and must be produced for the system to develop patronage. The system must have high capacity capability in order to function properly in the short rush-hour periods.

Convenience and comfort are essential to the success of a rapid transit facility in this era of escalation and air conditioning. We must provide a tangible asset to the commuter by the addition of from one to two hours of time per day for reading or napping, assuming that such activities cannot be accomplished while driving, and rarely on a bus.

Other considerations which are important from both the passenger and operator viewpoint are safety, aethestics and types of equipment.

Development of community acceptance standards or criteria has been carried on by Victor Gruen Associates under our direction. Excerpts from their report which is included in full in Volume II, Technical Data are as follows:

"The man who at the moment is not using the system and whose environment is invaded by the system has a radically different set of concerns (from those of the passenger). In general, he would wish it to be some place else altogether. Since this is impossible in all cases, he sets a declining series of standards, starting with a system totally noiseless and invisible, through a system not pleasant but tolerable down to a system intolerable in one or more respects."

"A barely tolerable system will place huge sections of the Metropolitan area in jeopardy" ______________ and _____________ "No city can afford the resultant land loss, tax loss and general defloration that results."

"An ideal system, unnoticed and unheard, also places a burden on the community" _______________ from ___________ "heavy maintenance cost, extremely high capital costs, etc."

"Assume for a moment three continental buses coupled together, accelerating rapidly to reach 75 mph speeds " _____________"such a conveyance creates noise, physiological, distrubance and physical interference."

"The most unobtrusive location for a line is underground and if it is so located no external problem exist. The maximum visual problem will exist if the line is overhead. The surface line would present the problem of next magnitude and open cut or combination section of cut and earth-fill berm would begin to approach the subway minimum."

"The factors having greatest influence on the rapid transit system's acceptance by the community --- from an external standpoint, are:

Noise	Traffic Interference
Visual Disturbance	Neighborhood Disruption
Air Turbulence	Utility Interference
Vibration	Aesthetics
Danger	

Summary

"A surface line --- is limited in its application to open, relatively uninhabited areas or industrial areas where traffic interference and noise are not major considerations."

"An elevated system --- can be used in open areas, in all heavy and some light industrial zones, and could possibly be used in commercial areas if screened for visual distrubances and if train speeds were radically reduced to lessen noise, turbulence and vibration."

"The open cut sections --- minimizes or eliminates all other problems related to land use and community acceptance (except underground utility interference)."

"The subway, though very costly, totally eliminates all factors relating to external acceptance."

DMJM will utilize both the minimum requirements for a rapid transit system and the community acceptance standards throughout the course of our detailed studies of transit equipment and corridor alignments. Final recommendations should indicate the best possible type of transit system operating in the most suitable and acceptable alignments from both the passenger and non-passenger points of view.

C. Ultimate Transit System Requirements

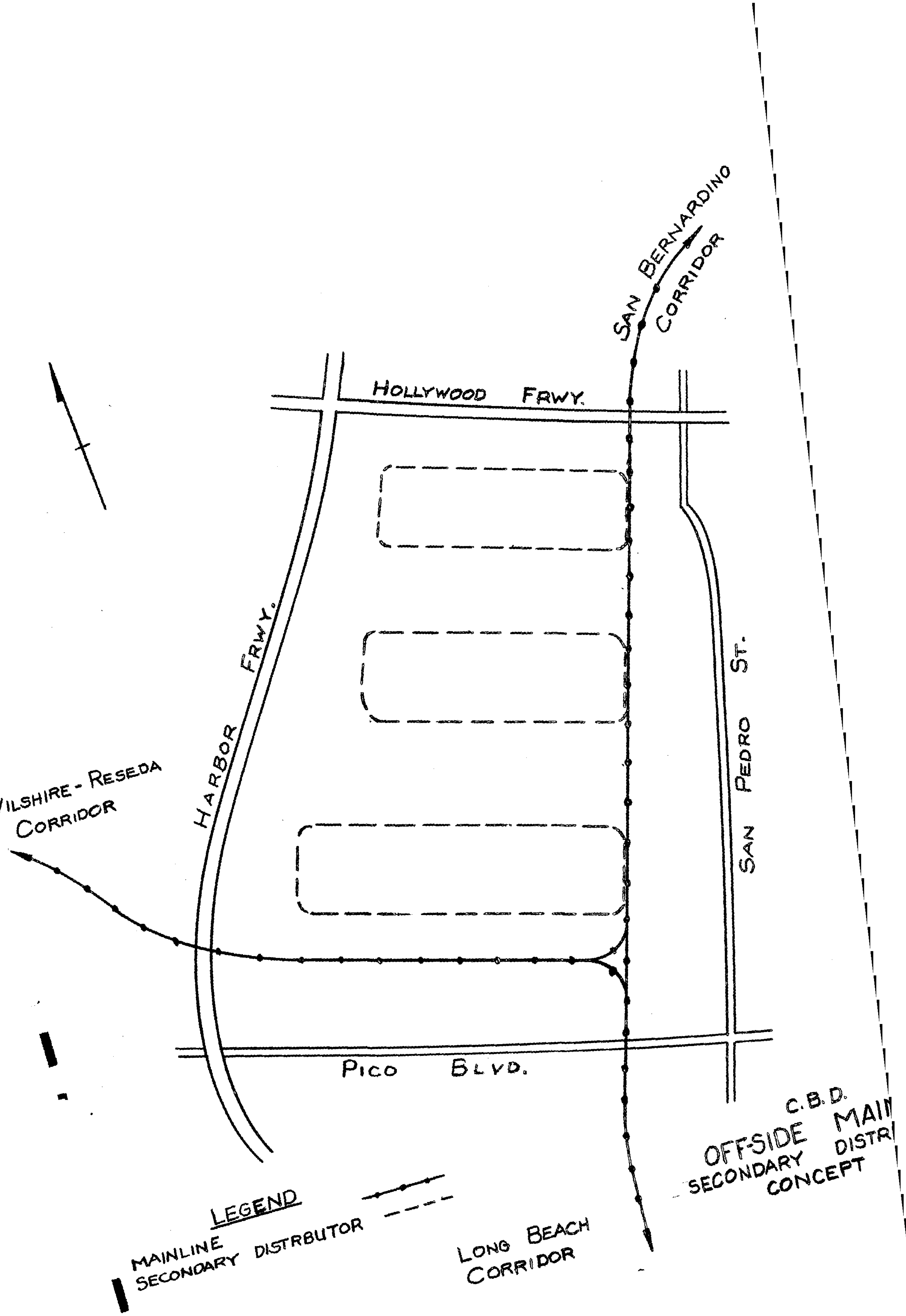
The planning aspects of this program have been considered on the basis that initial segments of the over-all system should not be undertaken before thorough consideration is given to a logical ultimate plan of rapid transit facilities. We have, therefore, reviewed in detail traffic studies and reports prepared by Coverdale & Colpitts. We have also conferred at length with the representatives of the California State Division of Highways, City of Los Angeles Departments of Planning and Traffic, and the Los Angeles County Planning Department. We have conferred with the planners currently working on Los Angeles Central City Concepts and reviewed aspects of planned new zoning resulting from freeway construction. These many conferences have convinced us of the necessity for continued coordination of our planning efforts with such agencies. We have prepared several alternate ultimate plan concepts and will be pleased to review such material as required. However, we have not as yet selected one plan to be recommended for adoption. A review of these ultimate plan concepts reveals Central City area planning problems beyond those immediately apparent when considering only present transit service to the Central City. It is also evident that the Central City area becomes the interchange for rapid transit facilities which, if improperly planned, could ultimately cause severe congestion in the rapid transit facility.

It is our belief that congested areas on the ultimate rapid transit system can be avoided by intelligent long-range planning.

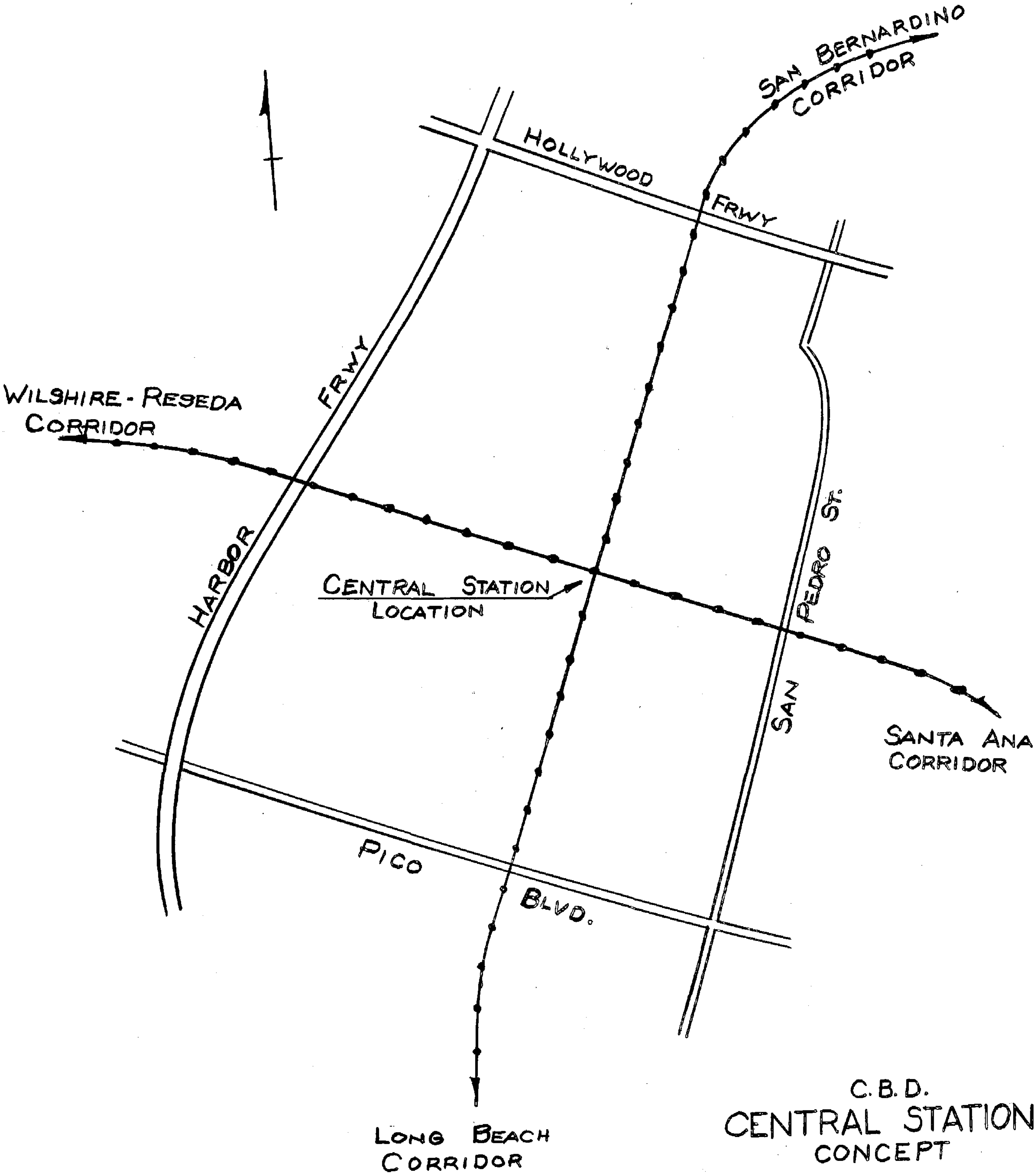
In regard to the type of equipment and the type of service which would be provided in the ultimate plan, we are giving primary consideration to a trunk line rapid transit system with bus feeders. Attention is also being directed toward the "flexible" concept and the "full coverage" concept of transit service. We also anticipate the development of major parking areas adjacent to outlying stations in order that the "park and ride" operation can be accomplished.

D. Central City Transit Concepts

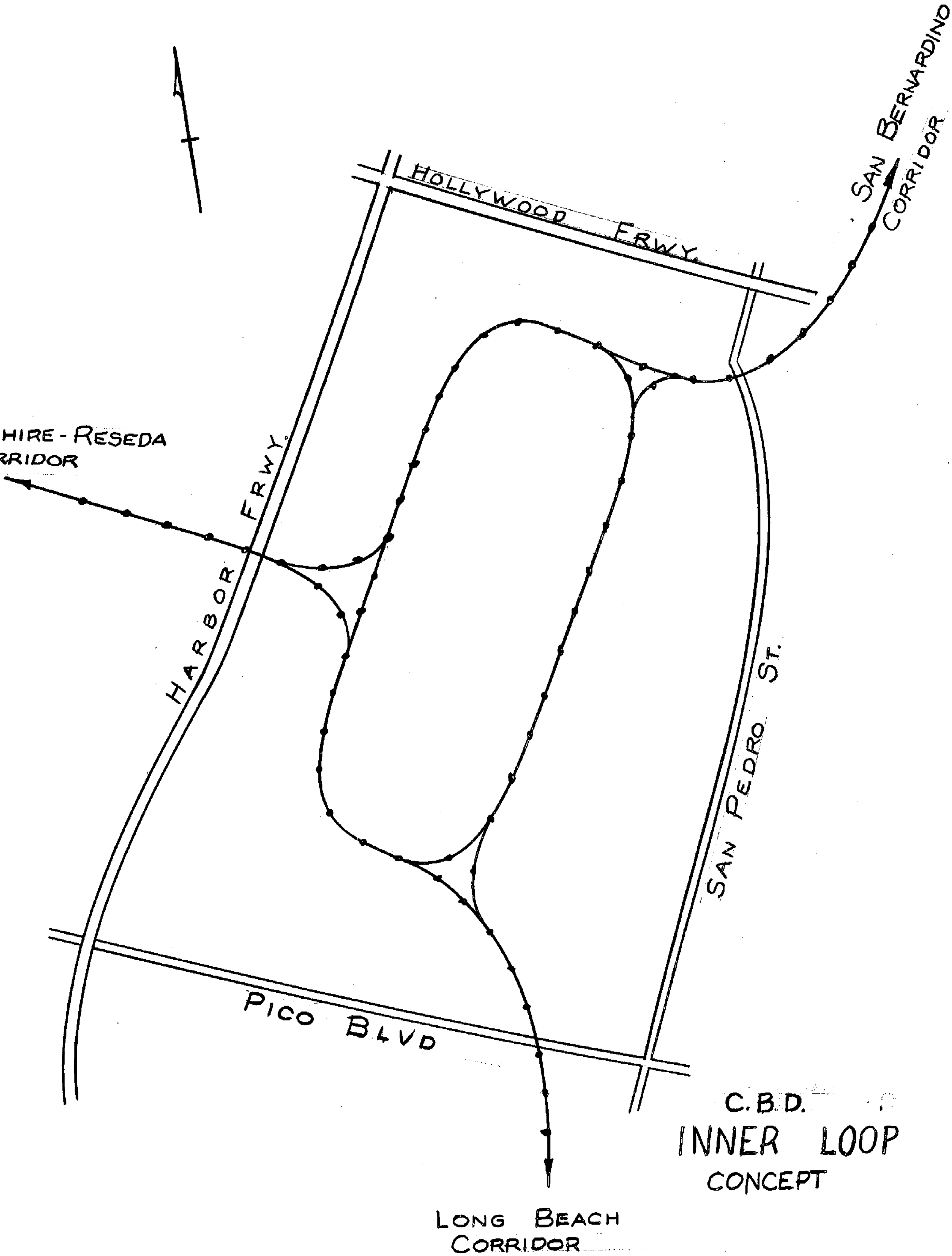
As noted before, the consideration of an ultimate plan reveals the necessity for extreme care in planning the initial phase of a rapid transit system in the Central City area, so that expansion of the system can be accomplished without interference to service or adding cost unnecessarily. In order to evaluate the required service to and through the Central City area, we have prepared a number of alternate plans, each of which has outstanding advantages. These plans are shown in sketch form on the following pages.



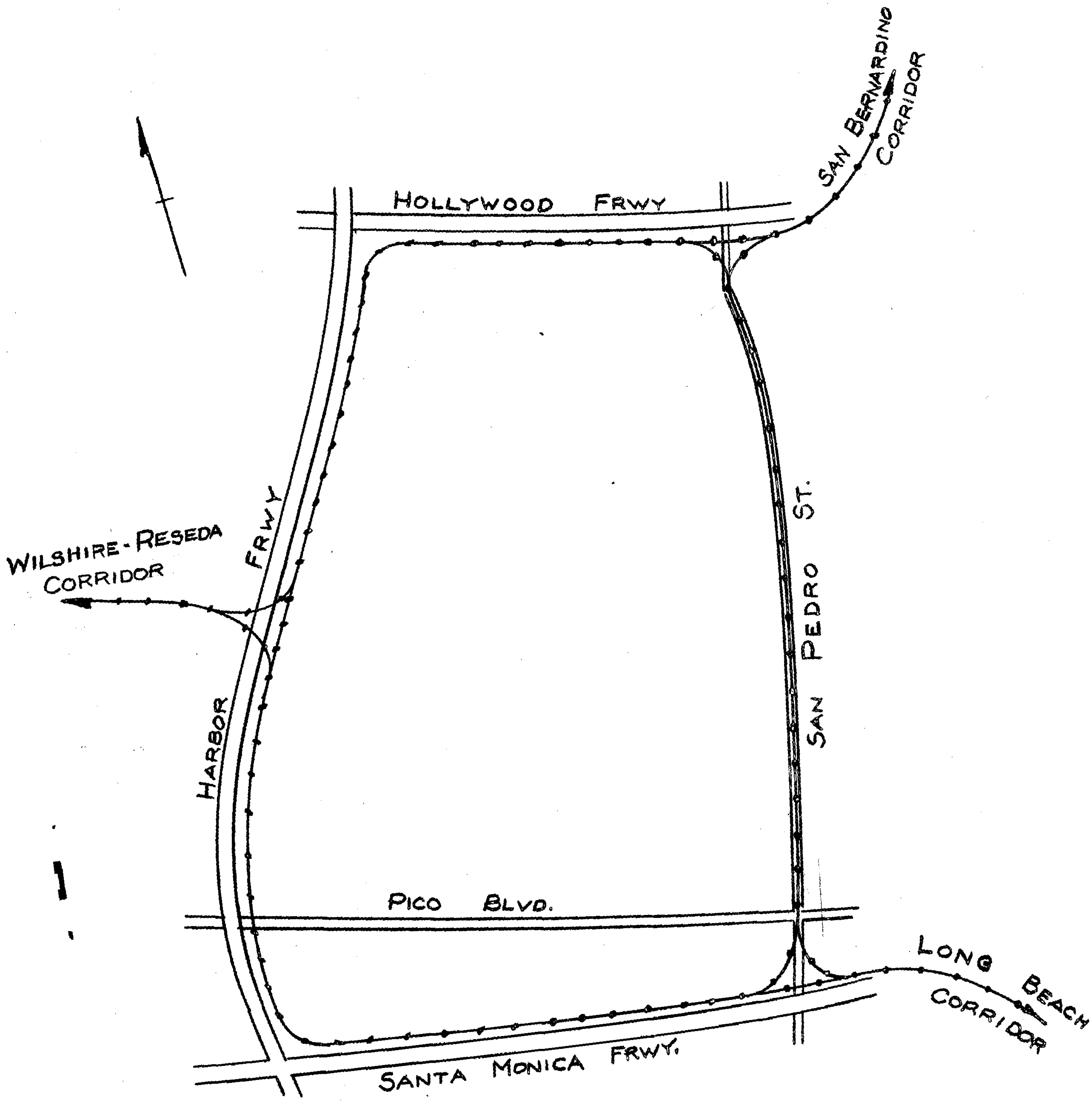
SAN BERNARDINO CORRIDOR
HOLLYWOOD FRWY.
HARBOR FRWY.
SAN PEDRO ST.
WILSHIRE - RESEDA CORRIDOR
PICO BLVD.
LONG BEACH CORRIDOR
LEGEND
MAINLINE
SECONDARY DISTRBUTOR
C.B.D.
OFF-SIDE MAI
SECONDARY DISTR
CONCEPT



C. B. D.
CENTRAL STATION
CONCEPT



C.B.D.
INNER LOOP
CONCEPT



C.B.D.
OUTER LOOP
CONCEPT

Basically, these systems fall into four dominant configurations; i.e., inner loop, outer loop with secondary distribution, central station and off-side mainline with secondary distribution.

Current studies now being processed should gauge the effect on real estate values and other developments by each of these configurations and also the probable effect on property values of elevated vs. sub-surface construction within the Central City area. These studies are being carried on by the Victor Gruen organization in conjunction with our planning work.

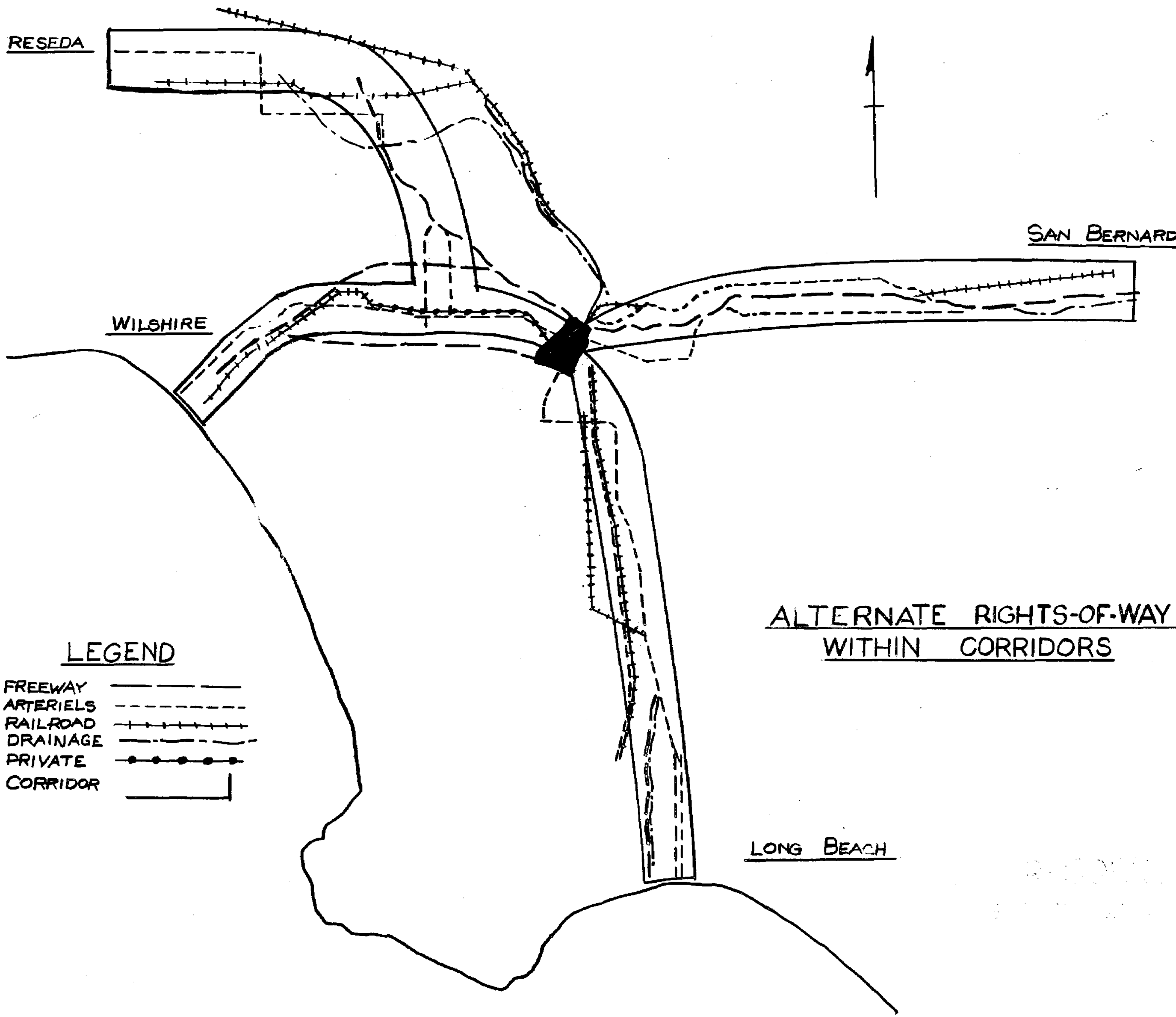
While the above evaluation has not been completed, there are strong indications that station locations, number of stations, and relation of stations to business activity will be dominant factors in the over-all estimate of the value of rapid transit to the Central City.

We are also reviewing the possible necessity for a secondary distribution system to operate at the same grade as main line rapid transit.

E. Corridor Considerations

The scope of our study has limited us to the four corridors; namely, Reseda via Cahuenga and Wilshire, Wilshire, Long Beach, and San Bernardino, insofar as detailed consideration of alignments is concerned.

During the course of our work, we have prepared maps indicating alternate right-of-way alignments within each of these corridors. The following sketch indicated these alternate alignments and reveals the extent of


RESEDA
SAN BERNARDINO
WILSHIRE
LONG BEACH
ALTERNATE RIGHTS-OF-WAY
WITHIN CORRIDORS
LEGEND
FREEWAY
ARTERIELS
RAILROAD
DRAINAGE
PRIVATE
CORRIDOR

existing railroad rights-of-way and other forms of rights-of-way which are under study. For reference purposes, we have prepared several maps setting forth present and future freeway alignments, railroad rights-of-way locations and arterial street locations which can be considered for potential rapid transit use. These maps are available for review in our office.

In order to set forth potential configurations of the initial development of a rapid transit system, we have further developed alternate alignment possibilities illustrating the dominant use of one or another type of right-of-way. Our detailed studies to follow will make possible the combination of segments of the most adaptable type of rights-of-way into a final conclusive alignment recommendation.

Consideration and study has been undertaken for all the dominant corridors of travel for purposes of conformancy with a logical ultimate mass rapid transit service. Extensive investigations have been directed to those four corridors specifically designated for this phase of the work, and brief summarization of the problems and potentialities encountered in these corridors are given as follows:

<u>Freeway</u>

The freeway system for the Los Angeles Metropolitan Area may be classified into three stages of development in evaluating its potential use for rapid transit, namely: existing freeways, adopted freeway routes and proposed future freeways. The latter stage offers the best opportunity for cooperative official effort in the planning of a fully integrated auto-rapid transit system. Generally, in this case, the planning and design of the Freeway is in such a preliminary state that necessary changes can still be made. Conversely, the first two stages would, in most cases, require either expensive physical changes or broad revisions of adopted design. In our current investigation of each corridor, we have not decisively ruled out any of these three possible uses. However, we have made a preliminary investigation of the comparative merits of each with respect to what can be reasonably accomplished within the existing and planned freeway rights-of-way to incorporate the rapid transit system. Some of these are evaluated elsewhere in this report and have been discussed with State Division of Highways representatives.

Each of the four corridors have been examined for possible location of transit within Freeways. Specifically, we found that along the Long Beach corridor, the future Industrial Freeway follows closely transit trip desires and fully integrated designs can still be accomplished. Also, the use of adjacent, relatively clear land along the existing Long Beach Freeway, south of the City of Lynwood, is considered feasible. In all other corridors, the use of Freeways becomes a more difficult solution, either they are already constructed, or the planned routes are not located in the best transit service alignment. For instance, the Santa Monica and future Beverly Hills Freeways parallel the Wilshire Corridor, but because a line generally following Wilshire Blvd. is considered the best transit service route, these have not received strong consideration. The Hollywood and Ventura Freeways were investigated as potential transit routes through the Reseda Corridor. In most part, these two freeways are either existing or are in the advance design stages so that their use is limited. More detailed discussion of structural problems is set forth in a later section of this report.

Within the San Bernardino Corridor, the San Bernardino Freeway median provides a good alignment for transit service between the Long Beach Freeway interchange and El Monte, a distance of 6-1/2 miles. However, plans of the Division of Highways call for an additional traffic lane adjacent to the existing railroad that will reduce the median to 50 feet. Similar problems encountered along other existing freeways are present in this corridor, except in the one section mentioned above.

Arterials

General criteria used in evaluating arterial streets as potential Rapid Transit routes included:

1. Alignment, with respect to transit passenger service.
2. Width.
3. Length within the corridor.
4. Type of land uses fronting the street.

Several possible arterials within each corridor have been examined and their merits compared. Among those recommended for further study from a transit service stand-point are Wilshire and Olympic Boulevards in the Wilshire Corridor; La Brea Avenue, Vine Street, Vineland Avenue, Chandler Blvd., Van Nuys Avenue, and Sherman Way in the Reseda Corridor;

Long Beach Boulevard, Alameda Street, sections of Broadway, Main Street and Vernon Avenue, in the Long Beach Corridor; and Valley Boulevard, Garvey Boulevard, segments of Brooklyn Avenue and Monterey Pass Road in the San Bernardino Corridor. Because of the many variances in widths, lengths and land uses along each of these streets, detailed comparative analysis must still be carried further to detail their relative merits and potential as rapid transit routes. The various aspects of way structures and aesthetic effects are discussed in other sections of this report.

Private Right-of-Way

Some factors involved in the selection and study of private rights-of-way for Rapid Transit alignment include transit service, property values, and land use. Generally, three types of rights-of-way have been examined:

1. Row within commercial and residential areas.
2. Strips adjacent to existing freeways, railroads, or arterial streets.
3. Strips along flood control channels, rivers or other utility barriers.

Within the Wilshire Corridor, we have concentrated our studies in the area within two blocks of Wilshire Boulevard. Since no suitable freeway or railroad right-of-way is to be found along most of the Wilshire Corridor, a serious study of private right-of-way potential is necessary.

There are many land strips along sections of the freeways, railroads and arterial streets which are potentially available for a Rapid Transit alignment. Some of the more important areas we have studied include those adjacent to the Long Beach Freeway, sections in the Cahuenga Pass area, lands next to the San Diego Freeway north of Ventura Boulevard, and portions adjacent to the San Bernardino Freeway in Baldwin Park and West Covina. With respect to property adjacent to railroads we have examined potential strips along the Pacific Electric line to Long Beach, the Southern Pacific Railroad lines in the San Fernando Valley and along Valley Boulevard in the San Bernardino Corridor. Studies involving strips adjacent to arterial streets are preliminary and require additional investigation.

Railroad Rights-of-Way

Potential use of railroad property can be classified into two types:

1. Existing operating lines.
2. Abandoned rail lines.

Field investigations have been made along such operating lines as the Pacific Electric along the San Bernardino Freeway, the Southern Pacific line parallel to Valley Boulevard, the Pacific Electric property in the Long Beach Corridor and the Southern Pacific and Pacific Electric lines in the San Fernando Valley. Preliminary investigation has been made of abandoned rail lines including those of the Pacific Electric in the west Los Angeles area along Venice Boulevard, and San Vicente Boulevard.

While our work on rail line rights-of-way is not complete, indications are that the Pacific Electric lines along the San Bernardino and Long Beach Corridors offer reasonable possibilities for rapid transit alignments. They are generally in proper transit service alignment and some grade separation has been accomplished. Problems concerning way structures, station locations, integration of yard facilities and freight and passenger equipment scheduling need for further evaluation.

A significant part of the consideration of alignments within corridors is the land use and community acceptance studies being developed with the assistance of Victor Gruen Associates. These land use studies will indicate those areas presently in transition or which might be available so as not to disrupt community activities. Land use work maps have been prepared and are currently being used as an aid to our evaluation.

F. Recommendations for Further Work

1. Finalize community acceptance criteria and system criteria.
2. Complete evaluation of Central City concepts and select the most suitable plan.
3. Refine the ultimate transit system requirements and set forth the most desirable plan.
4. Make detailed studies of corridor alignment alternates and select most suitable alignments and station locations.
5. Make further evaluation of flexible and full coverage concepts of transit.

TRANSIT SYSTEM

TRANSIT SYSTEM

SECTION III

TRANSIT SYSTEMS

A. INTRODUCTION

The determination of the best type of mass rapid transit system for the Los Angeles Metropolitan Area is a complex problem. This city, perhaps more so than any other, is free of governing precedents that would obviously dictate the solution to the type of system that should be applied. Two fundamental aspects that must be considered in the choice of any transit system for application to a specific area are: (1) the basic merits of the system itself, and (2) the physical factors inherent in the route to which the transit system must be applied. Fortunately, for Los Angeles, a complete freedom of choice is possible concerning the former, and diverse alternatives are available from which to recommend suitable solutions to the latter.

The Los Angeles Metropolitan Transit Authority has evidenced its determination to have the most modern possible transit system for this area and have directed us to explore fully all of the possibilities of recent developments in rapid transit to see if any have sufficient merit to be considered for the basis of that transit system.

The Authority, in delegating this work to us, requested an initial screening of transit systems in order to ascertain those systems meriting a closer examination. This has been done, and the results will be reported in this section of the report.

The review and evaluation of these transit systems has been done on a completely impartial basis in order to determine the advantages and benefits of any new ideas in transit systems, recognizing that whatever is proposed must ultimately form the basis of an operable transit system which would have to be constructed within the relatively near future. However, an active search has been made to find if there is anything new and untried which would have real merit for detailed investigation even though development may not have been done.

In this search of modern transit systems, we have been aided by our Consultants, particularly: Gibbs & Hill, Mr. Harold Otis, and Colonel Sidney Bingham. We have received transit system presentations by anyone who wanted to make a formal presentation to the Authority of his system. In addition to this, we have had informal discussions with manufacturers, persons and firms who might have ideas as to transit equipment, but did not wish to make a specific recommendation for a system to the Authority. In addition, we have seen several ideas that, while not being actively proposed by any single proponent, appeared worthy of consideration, and these were, therefore, included in the evaluation.

The method of approach that is utilized in undertaking a review and evaluation of this kind is as follows:

1. Determination and study of the local situation and physical limitations and problems to determine specifically what is required in this area.

2. Next, a general review of what has been done by others; and for existing systems, a determination of the good and bad points and problems involved.

3. Then, a search is conducted for all new systems and ideas to see what has been developed; what is the current thinking on rapid transit systems, and what is proposed by all the proponents of rapid transit systems.

4. At the conclusion of this, all of this material is then compared and evaluated and the best features of existing and proposed systems are combined, and a final review is made by the engineer to determine how these can be improved upon.

We will cover in this section a general review of the existing rapid transit systems throughout the world. This is certainly not a complete listing of all rapid transit in every major city in the world, but it will include the systems that are of major importance.

We will next cover the development of transit system criteria. Following this will be a general review of all the transit systems presented to us with our preliminary findings regarding some of the details of the transit equipment and, finally, our recommendations for the limited number of systems meriting a detailed comparative analysis and our recommendation for further work to be done.

Reference is made to the Transit Planning and Transit Facilities Section for additional details on our local conditions which would influence the choice of a rapid transit system.

B. TRANSIT SYSTEM CONCEPTS

Before an evaluation of transit systems can be made, certain ground rules or criteria must first be established in order to determine the general concept.

The work of Coverdale & Colpitts for the origin and destination traffic studies set forth certain premises. These were:

1. That the rapid transit facility to be selected would use its own grade separated right-of-way.

2. That the rapid transit facility to be selected would have a top speed of approximately 80 miles per hour and that its acceleration and deceleration rates would not be less than 3 miles per hour per second.

During the course of our on determination of the requirements for ultimate transit service, we have found that there are three general concepts of rapid transit service that could be considered for application to the Los Angeles Metropolitan Transit problem. These are listed as follows:

1. The Trunk-Line Feeder Bus Concept

2. A Flexible Bus System

3. The "So-Called" 100% Coverage System

The Trunk-Line Feeder Bus Concept is the one used in New York, Chicago, London and many other of the major cities in the world. It depends on a major trunk-line service of grade separated rapid transit served at both ends by feeder and distribution systems.

The flexible bus concept is presently being used in the Los Angeles area, although by this application it is not strictly mass rapid transit. In order to be so, it must have its own grade separation right-of-way; but the advantage of the flexible bus system is that the vehicles serving the feeder and distribution systems are also used for the trunk-line rapid transit service, thus eliminating the necessity for transfers.

The 100% coverage concept is based on the assumption that rapid transit must serve at least two-thirds of the trips in any daily period and, therefore, in order to serve these with the multitude or variety of origins and destinations, an extensive system covering the entire area is necessary.

Each of these concepts requires a study of the equipment necessary for application thereto. This study has revealed that, in general, the concepts for the application of equipment to the 100% coverage and to the trunk-line corridor system are not too far apart; and therefore, in this study, the evaluation of equipment has been generally the determination of the equipment applicable to these two systems. The flexible bus system obviously must utilize the buses and, therefore, the review of equipment for this transit concept has been confined primarily to a review of bus systems for this. There are only two really different types of bus systems. These are the trolley bus and the bus utilizing the internal combustion engine.

Since the trolley bus really is not a flexible bus system, and since it must have structure delivering power wherever it goes, it has been determined that this should not be considered as equipment for the flexible bus system. Therefore, the principal direction of the review of equipment is for application to either the trunk-line corridor transit concept or the 100% coverage concept.

Mention will be made in the chapters about some of the studies of internal combustion bus equipment, but this does not involve the wide review of the multitude of transit equipment that is involved in the other two concepts.

C. TRANSIT SYSTEM CRITERIA AND EVALUATION FACTORS

There are certain requirements apparent for equipment to be considered to form the basis for the Los Angeles rapid transit system. These requirements are:

1. Freedom from interference from other traffic
2. No depressive environment

3. Pleasing aesthetics, both for user and non-user
4. Susceptibility to automation
5. No insolvable technical or engineering problems with development sufficiently advanced

As has been pointed out above, the evaluation of the transit equipment requires certain criteria. Some of this has been set forth in the basic assumption of the Coverdale & Colpitts' work; other criteria has been developed during the course of this work and is outlined in the previous section.

It is the responsibility of this study to evaluate each of the many proposed systems and accurately compare factors of cost, comfort, flexibility, aesthetics, rider appeal, speed, operating expense, reliability, noise and vibration, and other essential items. Some of the evaluation factors that are used are as follows:

1. <u>Car Equipment</u>
   - a. Propulsion
   - b. Transmission
   - c. Suspension
   - d. Car Weight
   - e. Acceleration
   - f. Speed
   - g. Braking
   - h. Passenger capacity of car

i. Maintenance and operating cost per passenger mile

j. Capital cost

2. Way and Equipment

a. Type of support

b. Switching procedure

c. Yard facilities

d. Train make-up

e. Station requirements

f. End-of-line turnaround procedure

g. Signal and communication system

h. Power transmission

i. Communications

j. Emergency factors

k. Maintenance and operation costs

l. Capital cost

3. Intangible Evaluation Factors

a. Comfort

b. Convenience

c. Rider appeal

d. Community acceptance

At the outset of the program, a criteria for evaluation of equipment and structural requirements was developed by the staff in order to secure information from all proponents of systems on a uniform basis.

A series of 75 questions were asked in this questionnaire dealing with such subjects as operating and performance, characteristics of the vehicle, dimension and suspension, trucks and bogies, propulsion system, signaling control, communications, cost estimates, patent situation, structural requirements, and operating characteristics. These are all evaluation factors that deal with the basic merits of the transit equipment or system in itself. In making any final evaluation of the equipment, the physical factors of the routes and area to which the system must be applied must be also considered. The requirements for adaptability to underground,surface or elevated construction must be considered.

One other factor which must be taken into account in evaluation of equipment is when the equipment will be needed. The presumption is made that rapid transit will be needed in the Los Angeles area by 1965 and that any equipment or system considered must be susceptible to development and construction by that time.

Another factor involved in the evaluation of equipment is the degree of development which that equipment has undergone; whether or not it has actually been successfully applied to rapid transit operation; whether or not a test facility is currently in operation susceptible of evaluation; whether or not any development of engineering work has been done. All of this must be taken into account in order to insure that the equipment chosen can be actually put in successful operation by the target date. This necessity for the operation by the target date 1965 does not relieve the requirement of a truly modern system which can be operated and expanded over a long period of time.

D. REVIEW OF TRANSIT SYSTEMS

1. General

In order to make the review of transit systems and equipment as comprehensive as possible, a broad search was made for inventors and proponents of transit systems, as well as a review of the major transit systems already existing in the world. Invitations were accorded to individuals who had previously indicated to the Authority that they had a transit system or an idea to present. In addition to this invitations were sent out to any others known to the staff to have previously worked on transit systems. A review of literature was conducted in order to ascertain any others that should be contacted during the course of the survey. It is felt that the results are fairly comprehensive, even though all of the possible ideas and inventions affecting rapid transit may not have been found. Those systems, equipments, and ideas that were considered are thought to be representative of the latest and best thinking for new systems, as advocated by proponents, new ideas from equipment manufacturers, and the best that can be gleaned from existing transit systems.

It is anticipated that from time to time during the further work that must be done, other transit system proponents will request hearings. It is thought that such a hearing would be accorded them in order to insure that nothing is missed.

2. The following is a list of systems that were considered:

a. Conventional Rail System

1. * Hastings Plane-O-Rail
2. * Norton Aerial Transit
3. General Motors Aero-Train
4. A.C.F. Talgo Train
5. [1] Paris Metro
6. Lockheed
7. * E. J. Smith Midget Subway

b. Suspended System - Asymmetric

1. Wilbo Industries - MAN
2. * Greene Monorail Inc.
3. * Goodell Monorail
4. [1] Tokyo Monorail

c. Suspended System - Symmetric

1. * Davino Monorail
2. * S.R.V. Monorail
3. Fussell Monorail
4. A. F. Vinje
5. T. R. Webb

d. Suspended System - Symmetric Split Rail

1. * S.A.F.A.G.E.
2. Northrup

e. Supported Systems - Overhead or Side Stabilized

1. Kearney Monorail
2. * Mono-Tri-Rail
3. U. S. Monorail
4. Lafferty Monorail

f. Supported System - Overriding

1. * ALWEG
2. * Lockheed
3. * Hendrik de Kanter
4. Hawes Monorail

g. Conveyor Belt System

1. Turner Moving Walk
2. Stephens-Adamson Carveyor
3. Mathews Moving Walk

h. Miscellaneous Systems

1. * Overhead Duct - L. E. Setzer
2. Ground Effect Vehicle - Ideonics Inc.
3. Helicopters - Los Angeles Airways

i. Transit System Ideas

1. E. M. Khoury
2. R. W. Bockman
3. H. E. White
4. A. Opalek
5. R. Swan
6. W.H.T. Holden
7. Mrs. N. Russell
8. Mrs. A. Dickerson
9. W. A. Shannon

j. Bus System

1. General Motors

2. Flexble Coach Company

3. St. Louis Car Company

4. Pullman Standard Company

* Formal System Presentations

1 Equipment Used on Existing Systems

E. PRELIMINARY EVALUATION OF TRANSIT SYSTEMS

1. General

The criteria that the rapid transit system or equipment must satisfy has been given previously as have the various evaluation factors which must be taken into account in choosing the rapid transit system. The process of choice that has been decided upon consists of: first, the initial screening of systems to a limited number really warranting detailed analysis, and secondly, a detailed comparative analysis of this limited number of systems.

This preliminary evaluation then to determine those systems meriting the more detailed analysis takes into account primarily the factors of the features of the transit system equipment itself, without extensive consideration of the cost of the system unless gross factors are involved, nor the factors involving the specific application to the Los Angeles area, other than that which is obvious. These latter two factors form the basis for a detailed study to come later.

2. Conventional Rail Facilities

The conventional rail system is so named because it is the system which uses two steel rails normally spaced 4' 8½" apart, and which is the basis for the majority of all rapid transit and railroad systems presently existing.

One of the fallacies that has been noted during this survey is the tendency to make comparison of monorail and other systems with the antiquated elevated railroad facilities that were constructed near the turn of the century.

Still others have indicated that the only alternative to monorail is the "prohibitively expensive" subway. On the other hand, proponents of conventional two rail facilities have made much of the possibilities of ground level operation, and operation over existing railroad rights-of-way, without having the complete knowledge of all of the factors involved.

It should be noted that a conventional rail system can be used for above ground, grade, or underground operation and that with modern design techniques, the equipment and structure can be made as aesthetically pleasing as most any other system. This is not to say that there are also not problems involved in the use of conventional rail systems. Some of the problems involve safety and noise control. In order to make a realistic comparison, all factors must be taken into account.

Existing Systems

Almost without exception, mass rapid transit facilities now existing in the world are of the conventional two rail type. Many of these facilities were designed for their more available alternates to this two rail system and subsequently, the original type of facility has dictated the type of extension. Most of the major cities of the world have two rail conventional transit facilities of either the subway or elevated type or have commuter railroads in operation. Perhaps the most famous transit systems in the world are those in New York and Paris.

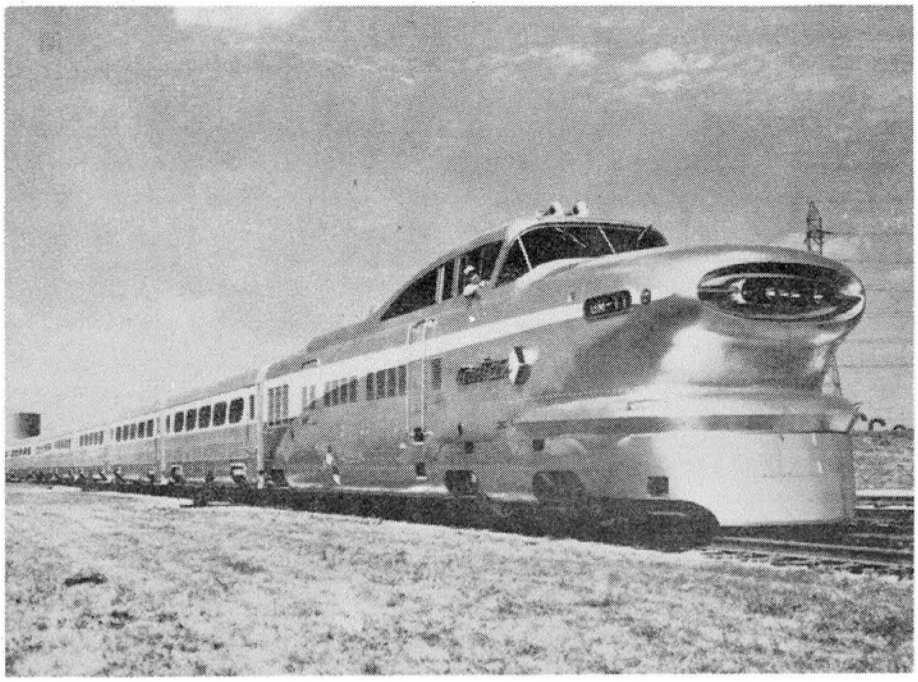
Much has been done in the way of research and development toward the securing of modern, lightweight, high speed conventional transit equipment, the solution of the problems of noise and safety, and development of automated railroad systems. However, much room for improvement exists, and further work must be done along the lines of developing a system which can fulfill all the requirements of a truly modern rapid transit system.

It appears also that perhaps in some respects there has not been enough incentive for other rapid transit system operators to develop truly lightweight, high speed equipment, since with existing structures, the savings in weight cannot be reflected in any savings of structure. Savings of weight do have some affect on the cost of operation, but since the equipment must be inter-mixed with the existing equipment, it must be designed to take connecting loads of the existing heavyweight cars; therefore, it has been difficult, if not impossible to use lightweight equipment on existing systems.

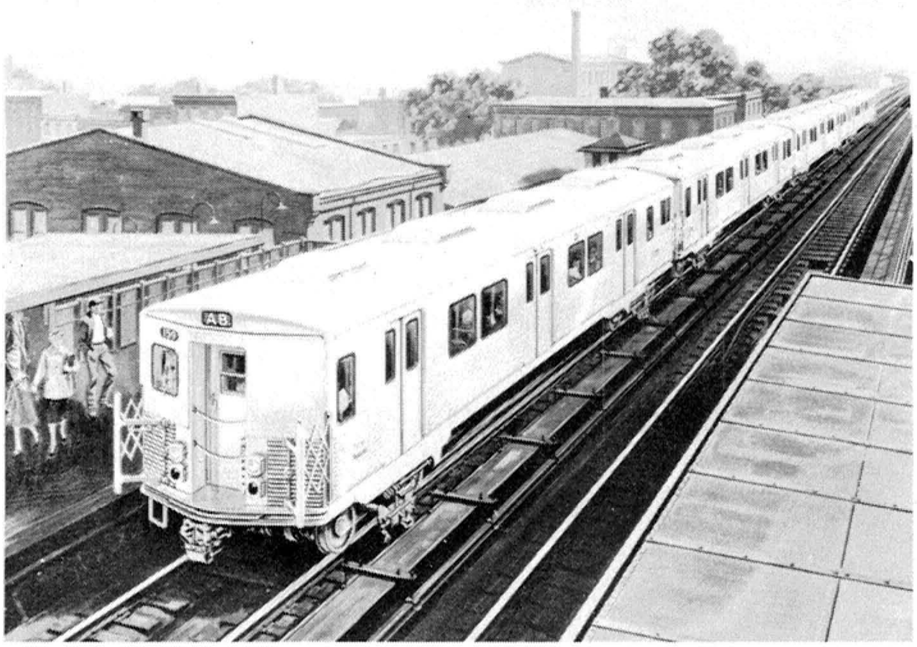
New Railroad Equipment

In recent years considerable publicity has been given to two new experimental trains that were developed to try to give modernized passenger railroad service. These were the American Car and Foundry Company Talgo Train and the General Motors Aero-Train. (See Figure III-1)

The Talgo Train has been in operation in Spain for almost ten years now. The basic design of this equipment involves a train made up of short articulated cars pulled by a lightweight locomotive. In order to achieve the lowering of the center of gravity, there is only one truck or bogie under each car. The other end of the car being supported on the truck of the car ahead. This and other developments have provided an extremely lightweight train. The General Motors Aero-Train was designed on a different principal. This was the principal of using standard railroad steel underframes, with an aluminum body in such a way that a major reduction of weight could be achieved. In addition, a new type of air ride suspension was applied to the rail equipment in order to improve the suspension characteristics. The combination of the heavy underframe with the lightweight body provided an extremely low center of gravity. Neither the Aero-Train nor the Talgo Train have been particularly well accepted by the American railroads for various reasons. Their use cannot be considered for rapid transit facilities since they both employ train locomotive principles that cannot be economically



GENERAL MOTORS "AEROTRAIN"

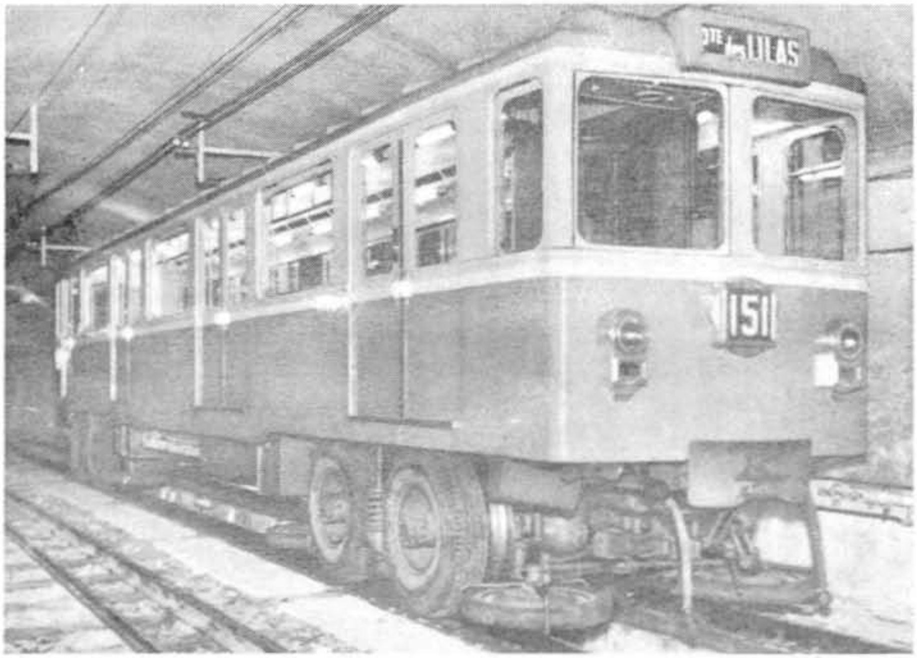


BUDD CO. RAPID TRANSIT CARS OF RECENT DESIGN used for rapid transit. However, both embody interesting ideas that might have application to modern design of rapid transit equipment. These should be studied further.

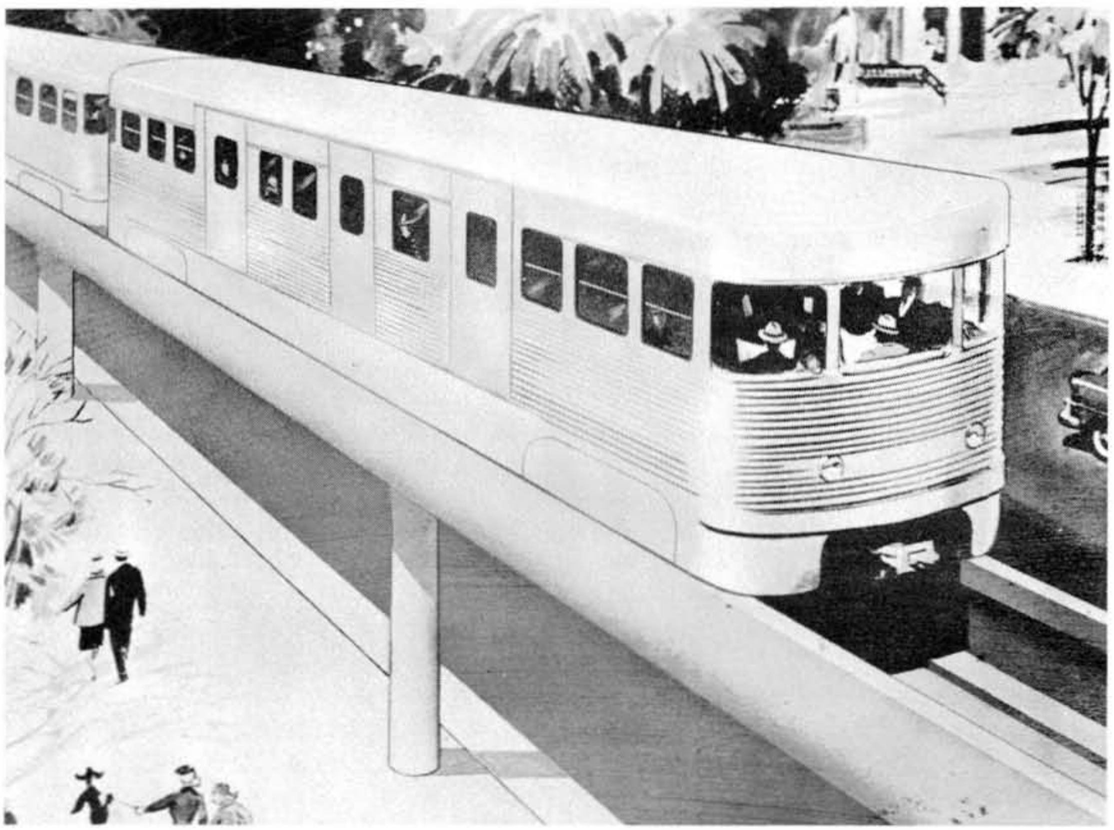
Systems Proposed for Los Angeles

The two formal presentations of conventional rail systems for Los Angeles were the "Hastings Plane-O-Rail" which would use a modern design of two rail equipment on a specially cushioned track, and the "Norton Aerial Transit System".

This latter system is included in the conventional rail category, although it uses pneumatic tired equipment. However, the trucks are guided by steel flanges mounted by the side of the pneumatic tires. The steel guide flanges allow the use of conventional switching. Mr. Norton proposes complete automatic control with a special block system. Another novel feature of the Aerial Transit System is the provision to guard against derailment. Mr. Norton's group of operators and engineers felt that a positive prevention against derailment was necessary for a modern high speed transit system. Therefore, they made the supporting structure to a channel shape and then, by having the axles of the trucks protrude under the flanges of the channel, they keep the truck from leaving the channel. This method is not absolutely foolproof, since under such a condition, the cars would have a tendency to shear away from the trucks under a derailment situation. The Norton Aerial Transit System is still in the concept stage but its use of pneumatic tired equipment with the attendant possibility of quiet and smooth operation is an interesting consideration.



PARIS METRO CAR
Experimental Pneumatic Tired Car Used on One Line of the Paris Metro



NORTON AERIAL TRANSIT
Elevated Trainway Using Pneumatic Tired Vehicles

Figure III-2

The idea of train operation on pneumatic tired equipment, however, is not new. An experimental pneumatic tired vehicle has been tested for some time on a special roadbed on Line No. 11 of the Paris Metro. This equipment uses horizontal pneumatic tires for guidance rather than the steel flanges, although flanges are provided to take care of flat tires when they occur and are used for switching. There have been other test installations in Europe, using pneumatic tired equipment and it is understood that the new subways in Milan, Italy, and Haifa, Israel, will have pneumatic tired equipment.

The use of pneumatic tired equipment is not necessarily a panacea, however, since such use brings other problems of increased rolling resistance and a higher operating maintenance expense. It is felt that further study should be given to the problems and potentialities of the use of pneumatic tired equipment. (See Figure III-2 for illustrations of the Norton System and the Paris Metro Car.)

The interesting feature of the Hastings proposal is the use of a precision-built roadbed which reportedly gives a substantial reduction in the initial cost and maintenance cost of roadbeds for conventional rail facilities. This system would replace the conventional tie and ballast with a concrete beam supporting a conventional rail, cushioned with rubber. The rubber cushioning idea has also been used elsewhere in Toronto, Philadelphia, and in other places. However, it has not always been successful.

In recent years, there has been some emphasis on the development of lightweight high speed cars to be put into service in existing rapid transit lines. The Chicago Transit Authority has recently put into operation four high speed lightweight experimental rapid transit cars with specially designed motors controls, trucks, gear drives, axles, braking and bearing installations, and auxiliary braking. These cars weigh in the neighborhood of 42,000 pounds, which is extremely lightweight as far as conventional transit vehicles are concerned, but do not appear to exhaust the full potentialities of truly lightweight equipment.

The potentialities of the development of truly lightweight equipment has interested several of the major airplane companies who have indicated a capability of developing lightweight cars, as much as half of the weight of the lightest cars now in use; so that it appears that there are real potentialities for the development of new equipment which would be light in weight and could result in substantial savings of structure.

Comments and General Evaluation

Certainly the wide spread use and acceptance of the conventional two rail system would indicate that it should be one of the systems included in a detailed comparative analysis. However, it could be asked as to why if it is so widely accepted, should any other system be studied. The answer lies in two factors: safety and noise. There have been many examples of accidents involving even modern equipment and every effort should be made to find a system that offers the most in rail safety. The noise problem also is something where great strides have been noted, but these have been effective primarily for equipment used at low speeds, and many of the innovations would not be effective on high speed systems.

The potentialities of the use of rubber tired equipment are very interesting, but this also poses many problems which should be studied further along with possibilities inherent in the use of rubber cushioning for steel rails.

The advantages of the conventional two rail system are listed as follows:

a. Proven equipment, since the majority of the transit system throughout the world use conventional rail.

b. Equipment developed and readily available at minimum of cost.

c. Ease of switching

d. Adaptable to existing railroads and ground level operation.

The disadvantages of the conventional two rail system are as follows:

a. Difficulty of providing positive derailment protection

b. Problem of noise

c. No truly lightweight equipment is available, which would necessitate new designs in development. This could cost

TABLE I EXISTING MONORAIL SYSTEMS

TYPE	LENGTH	MAXIMUM SPEED	TYPE OF SERVICE	YEAR CONSTRUCTED	LOCATION	PROPULSION	WHEELS	GUIDE WHEELS
1. Suspended Asymmetrical	8.2 Miles	30 MPH	Revenue Passenger	1903	Germany, Wuppertal	Electric D.C. Variable Speed	Single Tandem, Double Flange Wheels	-No- Traction Wheel is Self-Guiding
2. Suspended Asymmetrical	1600 Feet	25 MPH	Fair Attraction and Test	1956	Dallas, Texas	Gasoline Engine	Rubber Tired Wheels	-Yes- Rubber Tires
3. Suspended Asymmetrical	1000 Feet	25 MPH	Public Park	1957	Tokyo, Japan Veno Park	Electric D.C. Variable Speed	Single Tandem Rubber Tire Wheels	-Yes- Rubber Tires $1\frac{1}{2}$ Rows
4. Supported Saddlebag	1 Mile	60 MPH	Test Track	1959	Cologne, Germany	Electric D.C. Variable Speed	Double Tandem, Rubber Tire Wheels	-Yes- Rubber Tires 2 Rows
5. Supported Saddlebag	1 Mile	21 MPH	Amusement Park	1959	Anaheim, Calif.	Electric D.C. Variable Speed	Double Tandem, Rubber Tire Wheels	-Yes- Rubber Tires 2 Rows
6. Supported Saddlebag	1000 Feet	25 MPH	Test Track	1957	Houston, Texas	Gasoline Engine	Rubber Tire Wheels	-Yes- Rubber Tires
7. Suspended Split Rail	1.2 Miles	66 MPH	Test Track	1959	France	Electric D.C. Variable Speed	Rubber Tire Wheels	-Yes- Rubber Tires 1 Row

practically as much as equipment for an entirely new system.

d. Has a connotation in the public mind of being old-fashioned.

3. Monorail Systems

a. General

In the description that follow, an attempt has been made to limit the discussions to those things pertinent to what may be unique or special, rather than giving complete descriptions of the equipment.

b. Brief History of Monorail

The history of the development and promotion of monorail systems would fill several volumes. Some of the highlights will be given here and the interested reader is referred to other publications[1] for a more comprehensive review.

One of the earliest monorail systems was the over-running system of a French engineer named Lartigue, which was built for an exhibition in 1833. This system was later applied to a 9½ mileline constructed in Ireland in 1883. The vehicles were supported by a 27 pound steel rail mounted on a trestle on either side of which were mounted stabilizing guide rails. The system was capable of a top speed of 27 miles per hour. It went out of service in 1929.

Around the turn of the century, an Irish engineer named Louis Brennen developed a true supported monorail using a single 70

1 "Unusual Railways", Wilson & Day, Macmillan

pound rail laid on the ground. The vehicles were stabilized with two gyroscopes. An experimental installation achieved a speed of 22 miles per hour.

Monorail in the United States is believed to have started in 1886 when the St. Paul Monorail was built to provide access to a real estate development. In 1887, a proposal was made to construct a suspended monorail system of the asymmetric type in Los Angeles. A section of supported overhead stabilized monorail was actually built near New York in 1909. Known as the City Island Monorail, it was operated for but a few months where the structure collapsed while the car was negotiating a curve.

The classic example of the operating monorail system, is, of course, the Wuppertal Schwebebahn (swinging railroad). This facility was designed by the German engineer Eugene Langen to fit the sinuous alignment of the Wupper River. The river occupied the only free space available, and the only way to use that space was to erect some type of elevated railway. Because of the many sharp curves of the river, standard elevated trains were impractical. After experimental work on other systems Langen decided on an asymmetrical suspended monorail. The initial 2.8 mile section began operating in March of 1901 and the remainder of the 8.3 mile line was completed and in operation in June of 1903. It has been in continuous service ever since carrying over 700 million passengers without a derailment and with only one fatal accident not attributable to the system itself. The line has a maximum speed of 24 miles per hour with an average speed of 18 miles an hour. The line has curves as sharp as 246 feet in radius. Each track is one-way for its entire length with turnarounds at each end. There is a switch at one of the terminals to shunt trains into shops for maintenance and parking. The switch operates smoothly, but is cumbersome. It has apparently fulfilled all expectations of the original designers and has enjoyed a continuous increase in traffic.

c. Monorail Systems Presently Operating or Under Test

There are three types of monorail systems for which there are presently operating facilities that can be inspected and evaluated. Included in the proponents of a general type may be individuals or firms not actually having an operating or test installation, but as long as there is at least one such installation, then the general type is included together with all of the proponents. Recommendations, when they are made, will usually be on the basis of the general type of system rather than a specific proponent. This is done for several reasons. First, such a procedure assumes that no one proponent has the ultimate system and that the system finally chosen will be subjected to further creative engineering in order to insure that all of the latest development are incorporated in the system. However, if a general type of system is recommended, this does not necessarily include all of the proponents of that general type. Each proponent's system must be examined in order to ascertain if there are features of his system which might make it less satisfactory than the general type. This will be illustrated further in the discussions below.

1. Suspended Monorail - Asymmetric (See Figure III-3)

For this type of monorail system, there were three proponents:

Goodell Monorail, Inc.

Greene Monorail, Inc.

Wilbo Industries, MAN

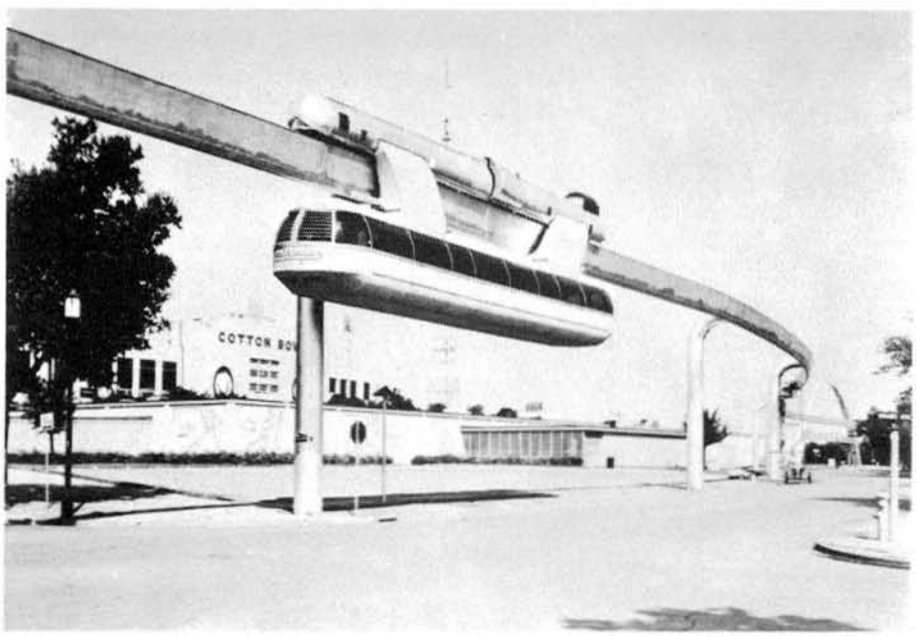
In addition to the systems of these proponents, studies were made of the existing system at Wuppertal, Germany and the Tokyo Zoo Monorail.

These proponents and existing systems can be divided into two basic equipment categories:

Equipment Free to Sway	- Wuppertal
	- Wilbo Industries, MAN
	- Greene Monorail, Inc.
Equipment Sway Restricted	- Goodell Monorail, Inc.
	- Tokyo Monorail

Of the equipment free to sway, the Wuppertal line as has mentioned before is one of the few true monorails. It has admirably served the peculiar need for which it was designed. However, before considering its application elsewhere, it is necessary to give a closer examination in order to ascertain its advantages and disadvantages. While it was designed in

<u>CLASSICAL MONORAIL - SUSPENDED ASYMMETRICAL</u>
View of Monorail Operating in Wuppertal, Germany Since 1903



<u>CLASSICAL MONORAIL - SUSPENDED ASYMMETRICAL</u>
Monorail Installation at Dallas Fair Grounds

order to allow higher speeds on curves by taking advantage of the pendulous property it is actually not a really high speed operation that would be comparable to the needs of Los Angeles. The maximum speed is only 25 miles per hour and even at that speed caution must be exercised in braking and the equipment used is entirely inadequate by modern standards.

The proposal of the Wilbo Industries, MAN group represents the manufacturers of the original equipment at Wuppertal and they have designed a modernized version that would provide for larger high speed equipment. They do not appear to have solved the three principal objections, however.
These are: (1) control of sway, particularly at stations, (2) switching, and (3) one-way operation.

The pendulous property of the suspended monorail is not entirely an advantage. There is a limit to the amount of sway that the car occupants regard as comfortable, and a definite limit of the amount of sway that can be tolerated at stations. In addition, the swaying property requires increased clearances in tunnels and other tight places. The Wuppertal and newer designs have had to incorporate a stop to prevent sway more than a certain amount (usually 15^{o}). The Wuppertal cars must slow down while approaching stations and control is achieved at stations by engaging a plow in the bottom of the cars into a groove in the platform below. This prevents the car from swinging during loading and unloading.

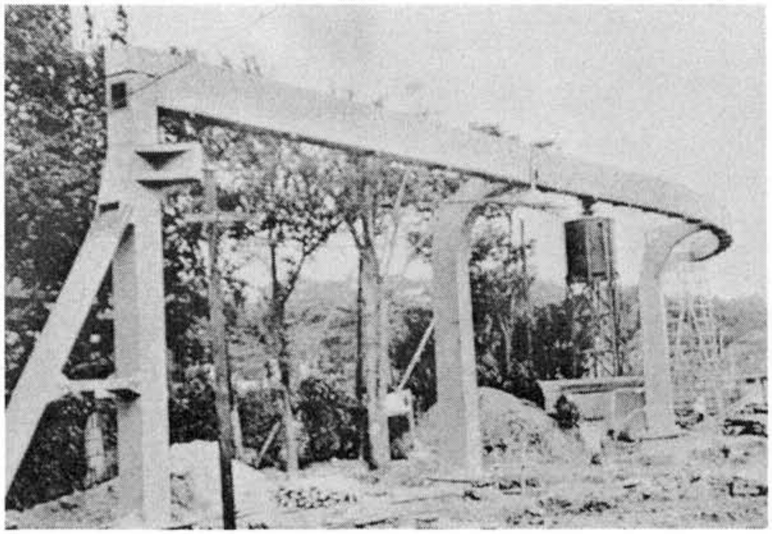
There is presently no adequate switch developed for this design. The switches at Wuppertal are slow, cumbersome affairs which are used only to shunt cars into storage and repair areas. Modern proponents admit the necessity of developing a switch that would permit high speed branch line operation. All efforts, in this direction to date, have resulted in massive turntable designs that leave much to be desired.

The third disadvantage of the asymmetric monorail is the necessity for one way operation. This eliminates the use of crossovers and requires turnarounds at the end of each line. It reduces substantially the possibilities of flexibility of operation.

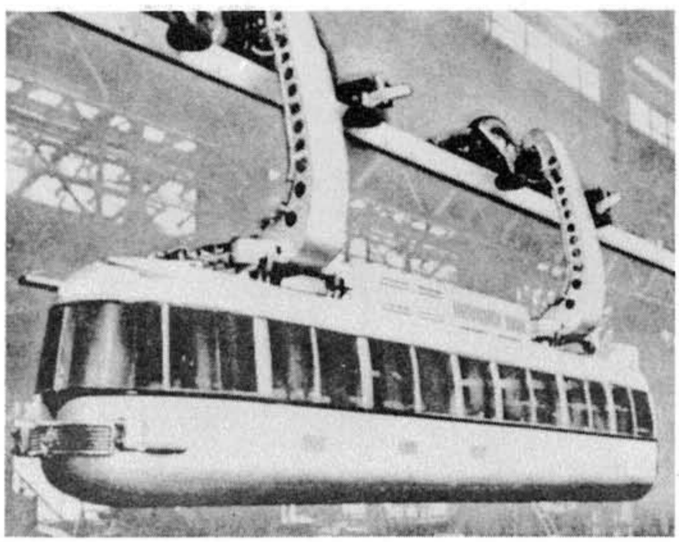
Sway control systems were developed in order to control some of the undesirable features of the original classic design primarily from the standpoint of the control of sway in curves and at stations. In doing so, they have introduced other problems. These will be taken up in the next paragraphs.

The principal example of this modification of the original monorail is the Houston-Dallas Monorail as developed by Goodell Monorail. A 1000' test installation of this system is in daily operation at the Dallas Fairgrounds. A similar type of installation is in operation in the Zoo in Tokyo. (See Figure III-4) This system uses pneumatic tires and an internal combustion engine for propulsion. The car is suspended symmetrically from the top rail but is not the pendulous monorail as at Wuppertal. Two weight carrying wheels are used for the Dallas system and the guide wheels are placed along the beam in order to control sway. The Tokyo system uses a single set of pneumatic wheels running on top of the beam with guide wheels on either side. The Tokyo monorail also uses electric traction rather than the internal combustion engine. In even the short test installation with attendant low speeds, the attempt to control sway by providing guide wheels and securing the bogie to the top rail does not appear to have been too successful. Some sway still apparently occurs even at low speeds and a tendency to oscillation is apparently introduced. Once the guide wheels are used, then the equipment becomes subjected to all the vagueries of the structure. Any mis-alignments in the structure are immediately transmitted into the cars effecting the ride.

It must be said that of the three principal disadvantages of the asymmetrical monorail, the pneumatic tired variation have apparently made or contributed somewhat toward the control of sway, but the other disadvantages of switching



TOKYO MONORAIL
View of Car Showing Hangers and Trucks



TOKYO MONORAIL
Structure Under Construction

and one-way operation have not been effected. Of the "so-called" modern systems, there is no high speed test installation that can be studied and evaluated. The longest existing installation is 1000' and the maximum speed for this is not any more than the original Wuppertal line. The pneumatic tired installation at Houston has had problems with adhesion to the rail in wet weather.

In view of the disadvantages and problems inherent in the asymmetrical design and the lack of a modern high speed test installation, it is recommended that no further consideration be given to this type of system.

2. <u>Suspended Monorail - Symmetric Split Rail</u>

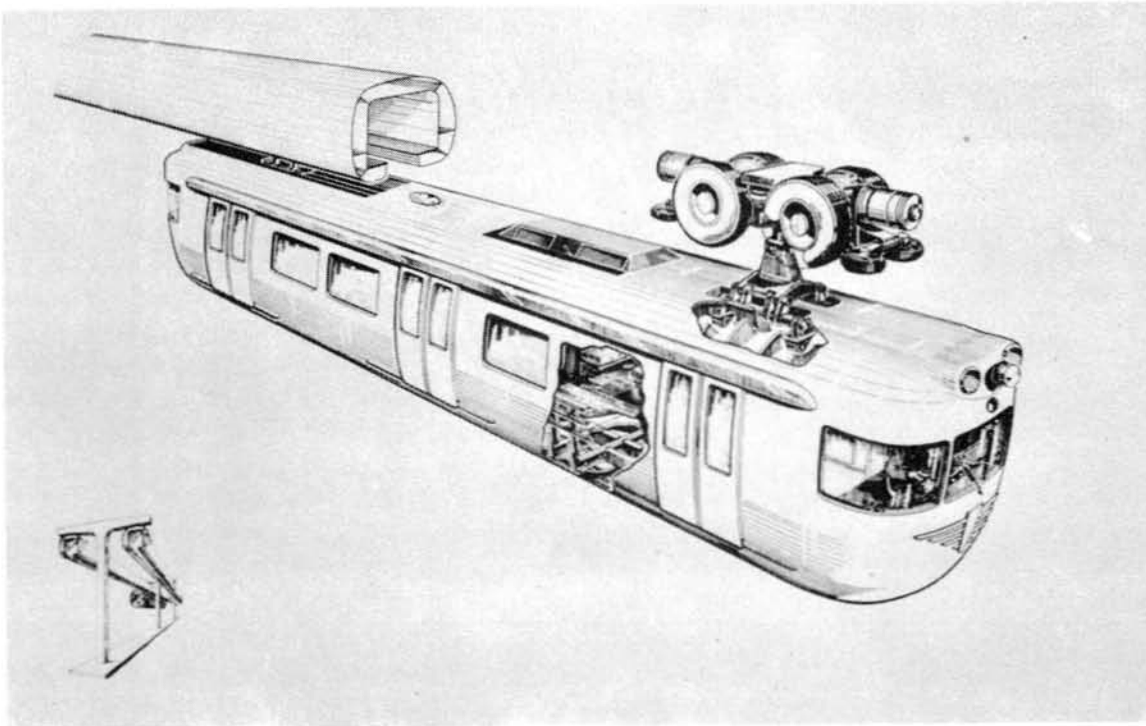
This type of suspended system had one active proponent, a French group known as the Societe Lyonnaise des Eaux et de L'Eclairage. In addition the staff studied the split rail proposal made by Northrup in Seattle and the split rail designs made some time ago by our consultant, Gibbs & Hill. This system type is illustrated by Figure III-5. Actually the split rail design is not a true monorail at all. It is in effect a narrow gauge railroad with the cars suspended beneath the roadbed. The system is included in the section of systems operating or under test by virtue of the 1.2 mile test installation of the French group now being completed south of Paris. Neither the Northrup or the Gibbs &

Hill designs have been fully developed or test facilities constructed.

The French group which includes some of the giants of French industry with some subsidy from the French Government have been doing engineering and development work on a split rail system for some time. This work has culminated in the construction of a 1.2 mile test installation in France which will permit testing of vehicles at speeds of over 60 miles per hour. This group proposes the use of pneumatic tired bogies similar to those used in the experimental line of the Paris Metro. The cars are suspended from the bogies using a primary and a secondary suspension system for sway control. The trucks are enclosed in a box girder with a wide slot in the bottom. The bogie tires run on either side of the slot on the bottom flanges of the girder. Some super elevation is introduced at curves and this together with an interesting hydraulic servo system control the sway. They have developed a switch that can be operated in ten seconds and which is of much simpler design than the classic Wuppertal switch. The use of pneumatic tires enables grades of up to twenty percent to be negotiated at the expense of some increase of rolling resistance. However, the use of the pneumatic tired bogie requires a larger beam than some of the other systems. Since this system was one of the few that presented complete technical details, it enabled a more thorough analysis which is included in the technical portion of the report.

The Northrup gyro glide system as proposed for Seattle and the Gibbs & Hill split rail design are quite similar except for the propulsion systems. The use of the gyro propulsion system is covered elsewhere in the report and will not be repeated here. For these systems, flanged wheels run on rails attached to the inside of the box, on either side of the bottom slot through which are suspended the car hangers. The Northrup design would use gyro stabilization to control sway.

The principal advantages of the split rail design over the asymmetrical appear to be in the matter of more positive control of sway, more derailment protection, the capability of two-way operation, improved noise control, and more fully developed switching. There are some problems however. The box girder is somewhat larger than the beams for other systems although the design does provide for a more positive control of noise. Some maintenance problem may exist due to the difficulty of access to the interior of the girder. The use of pneumatic tires is not necessarily a requirement for the system and the problems involved in such use would have to be studied further. However, the basic split rail principle appears to be a substantial improvement over the



SUSPENDED MONORAIL - SPLIT RAIL
View of Car and Bogie Proposed by SAFAGE

SUSPENDED MONORAIL - SPLIT RAIL
Design of a Split-Rail System by Northrup

Figure III-5

asymmetrical design and as such it is felt that it should be included in any group of systems meriting more detailed study. Certainly the new French test track should be carefully investigated as it will not only give information on the split rail principle but on the efficacy of pneumatic tires for high speed operation as well.

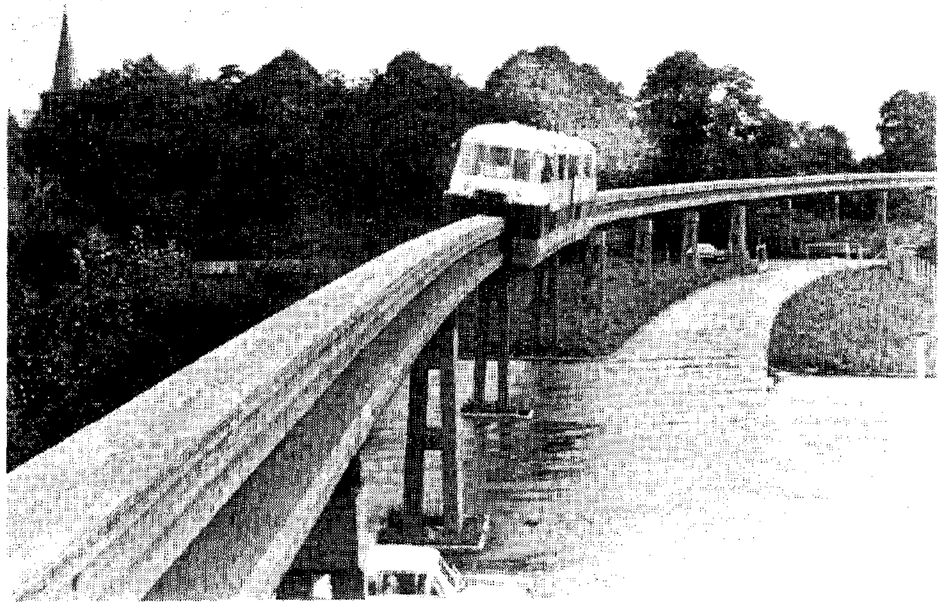
3. <u>Supported Monorail Overriding Saddlebag</u>

This supported system has had three active proponents: Alweg; Lockheed; and Hendrick de Kanter. In addition the staff studied the supported system as proposed by Alan Hawes for Seattle. This system type is illustrated by Figure III-6. The system type is included in the category of systems operating or under test because of the Alweg test installations near Cologne, Germany, and the Disneyland facility in Anaheim, California.

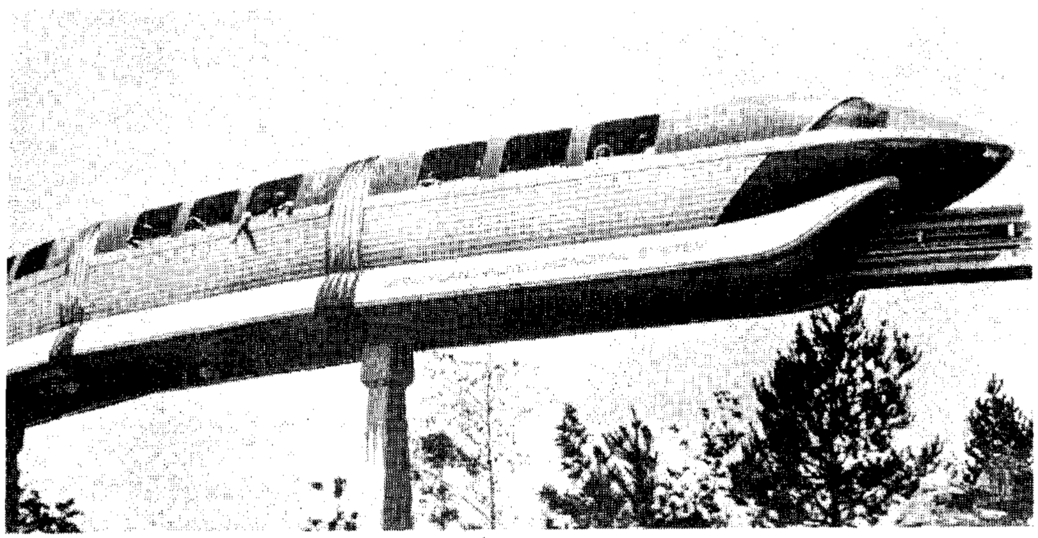
The Alweg system is a comparatively recent development of a supported system using the overriding or saddlebag principle. The system is sponsored by Dr. Axel Wenner-Gren. Most of the engineering and testing of the equipment has been done in Germany. It also is not a true monorail, since it must use guide or stabilizing wheels. The system has been under operational test since 1952 when a 2/5 scale model was installed on a 6000-foot oval test track. In 1957, a full-scale test track slightly over one mile was constructed.

The original scale model is reported to have achieved speeds of up to 80 miles per hour with quiet, smooth operation. The full-scale test track is not a loop and speeds are limited to about 60 miles per hour. In addition to these test installations, a 3600-foot Alweg facility has been installed at Disneyland to serve as a ride. This does not have full-scale equipment and has sharp curves of less than 200-foot radius which limit the speed to less than 25 miles per hour. The Disneyland operation is impressive from the standpoint of quietness of operation. The Alweg car is carried by large pneumatic tires running on top of the supporting beam. With this design it is impossible to have a level floor in the car, and some loss of seating capacity and flexibility results. Also these tires cannot be changed without taking the vehicle into the shop. A new design is presently being studied in Germany that may eliminate this objection. For this system several switch designs have been worked out that would operate approximately 10 seconds.

Several designs for supported overriding systems have been developed by the Lockheed Aircraft Company. (See Figure III-7) One originally proposed for Seattle would have been similar to the Alweg system. A modified system now proposed by them for both Seattle and Los Angeles would eliminate the bump of the car. The Lockheed system uses



SUPPORTED MONORAIL - OVERRIDING
Alweg Full-Scale Test Installation Near Cologne, Germany



SUPPORTED MONORAIL - OVERRIDING
Disneyland Alweg Installation

steel wheels and rails rather than pneumatic tires. An interesting feature of the Lockheed proposal is their proposed use of extremely lightweight equipment. Such use would result in reduction of cost of supporting structure. The Lockheed system was selected for application to the Seattle Century 21 Fair but so far a contract has not actually been executed. No test installation exists although Lockheed has evidently done considerable development work on the system.

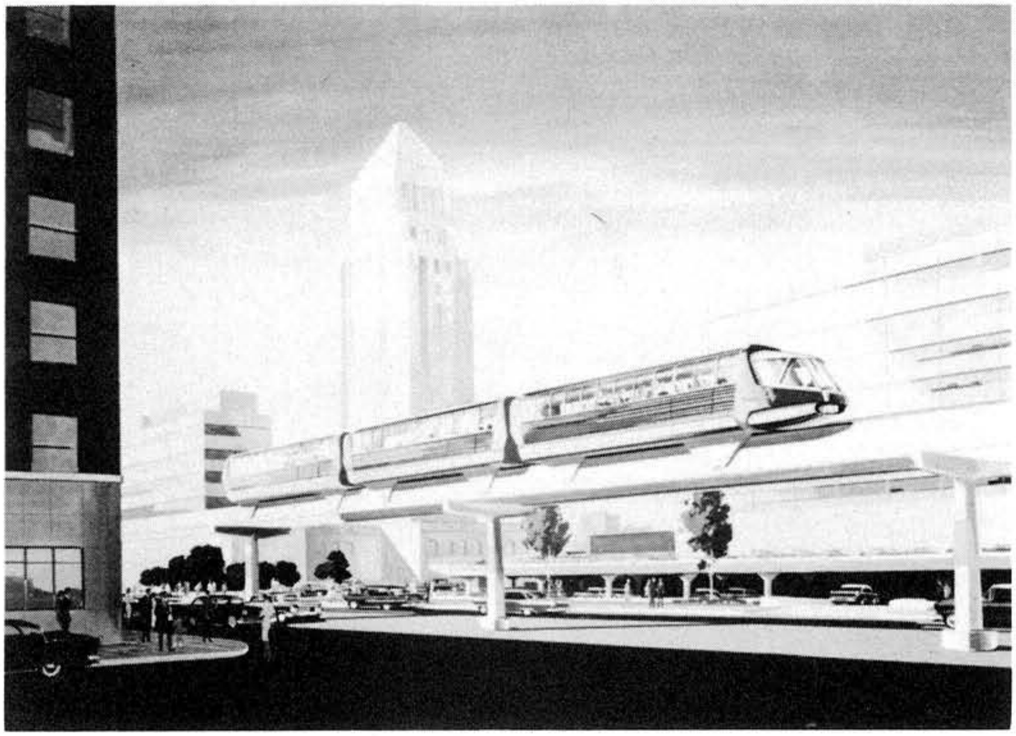
The design proposed by Hendrick de Kanter for Los Angeles and by Alan Hawes for Seattle would also eliminate the wheel projection into the car floor by placing the wheels on the lower flanges of a type of "tee" beam. This introduces some complications into the design of the bogie.

The advantages of the overriding system appear to be:

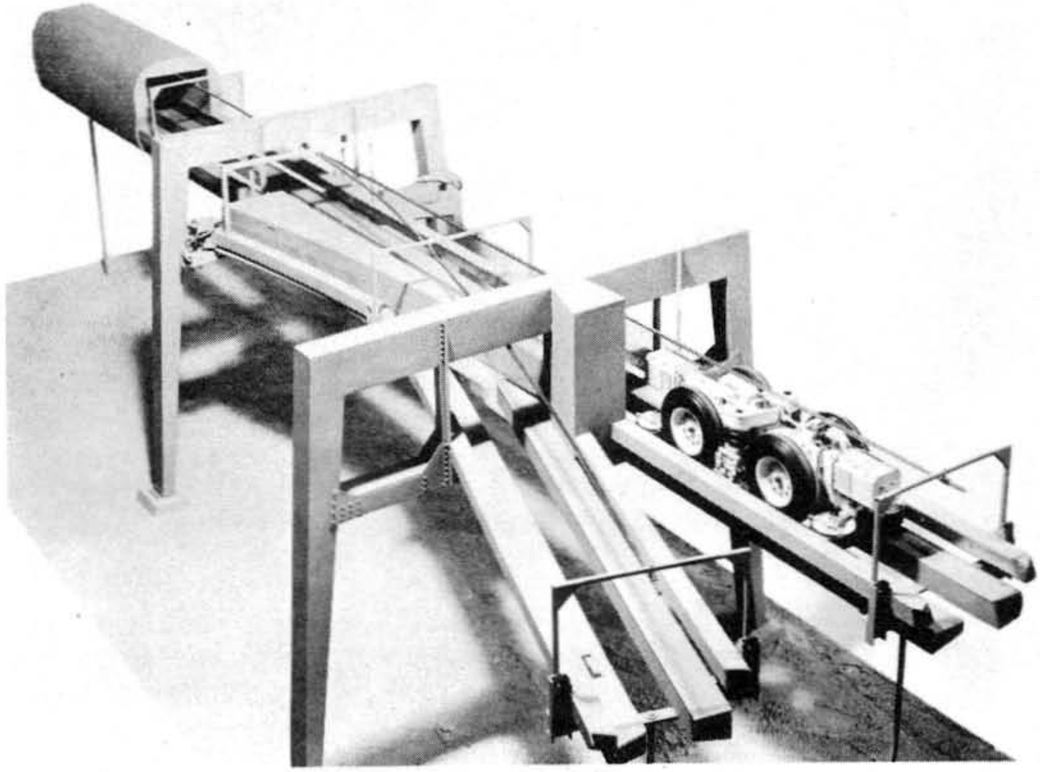
- Sway control
- Supporting structure less in cost than suspended structure and requires smaller beam
- Quiet operation
- Switching developed
- Capable of two-way operation
- Existing test installations and history of operational testing

The disadvantages of the overriding system appear to be:

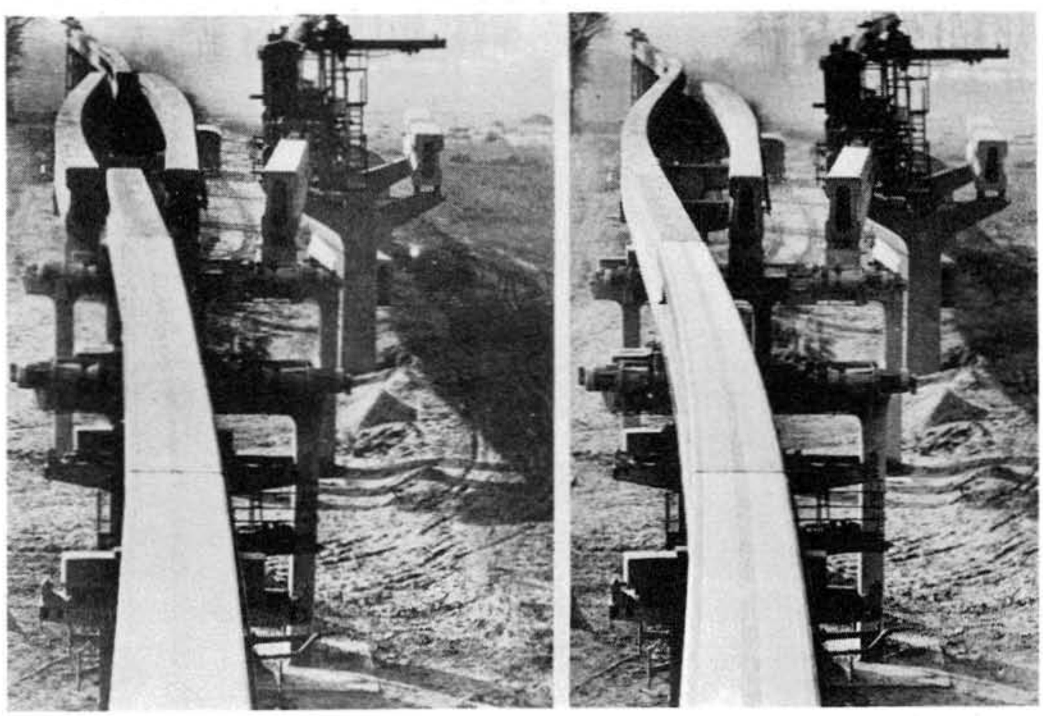
- An irregularity of the beam affects the smoothness of



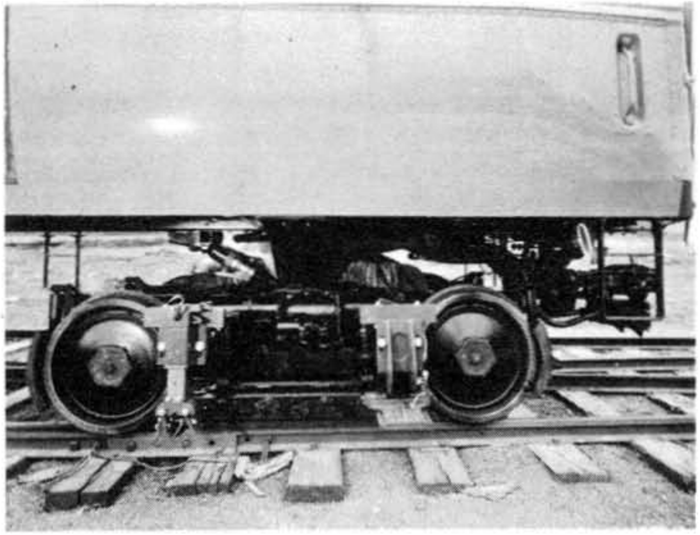
SUPPORTED MONORAIL - OVERRIDING
System Proposed for Los Angeles by Lockheed



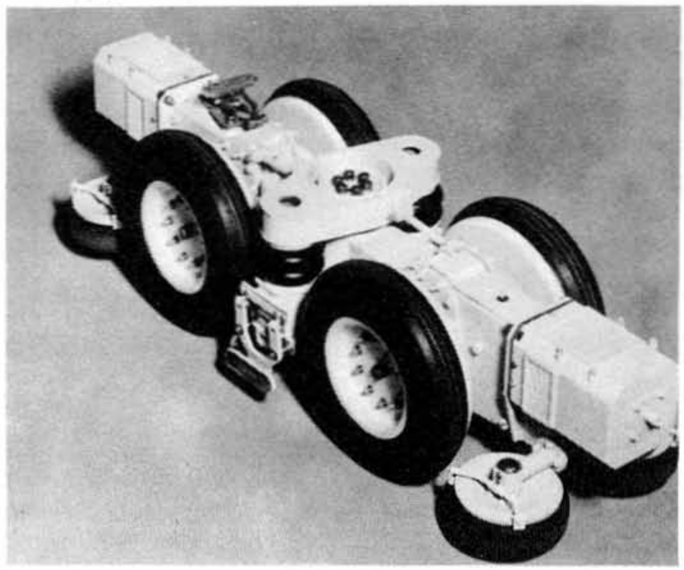
<u>SUSPENDED MONORAIL SWITCH</u>
Split Rail Switch Design Developed by SAFAGE



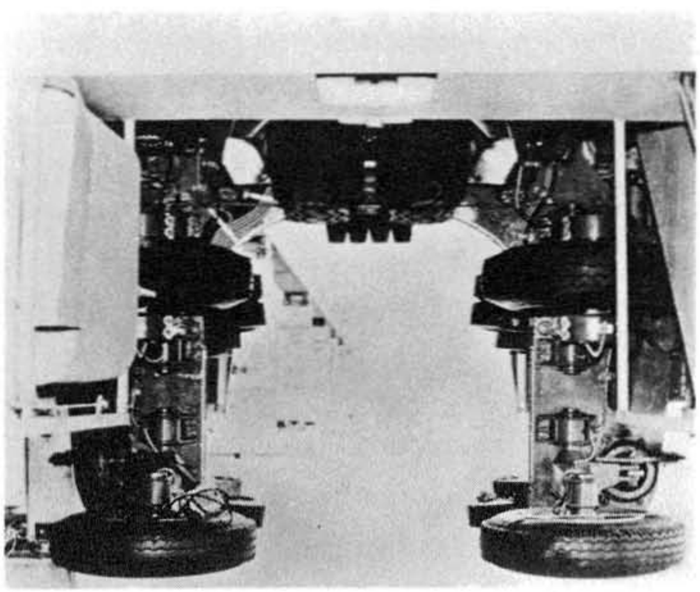
<u>SUPPORTED MONORAIL SWITCH</u>
Flexible Monorail Switch Developed by ALWEG



CONVENTIONAL RAIL (Left)
Rapid Transit Car Truck
St. Louis Car Company



SUSPENDED MONORAIL (Right)
SAFAGE Truck



SUPPORTED MONORAIL (Left)
Alweg Truck

Figure III-9

operation requiring expensive erection and casting techniques

- Designs incorporating smooth floor cars have not been tested
- Difficult to make provisions for escape from cars in an emergency
- Switching slow and expensive
- Beam surfaces carry stabilizing wheels and therefore must be curved and warped around curves and will require guiding of joints to achieve a smooth ride

The basic principle of the overriding system also appear to be an improvement over the asymmetrical design. Systems of this type have been more thoroughly tested than other modern monorail systems and give indications that they might require a less expensive structure than suspended systems. For these reasons, it is felt that the overriding system should be included in those systems to be given comparative analysis.

d. Other Monorail Systems

In the category of other monorail systems which do not have operating or test installations which can be studied are the suspended systems - symmetric and the supported systems - overhead or side stabilized.

These will be taken up in the following paragraphs.

1. Suspended Systems - Symmetric

This system type had two active proponents in the Davino Monorail and the S.R.V. Monorail. In addition, the staff reviewed the systems of Henry Fussell and Mrs. R. C. Lafferty. These systems are reviewed in the Technical Data section of the report. Suffice it to say that the systems have not yet been engineered, much less developed to the point of test installations. An analysis of the basic principle involved in each shows nothing outstanding that would warrant further consideration by the Authority for application to Los Angeles.

2. Supported Systems - Overhead or Side Stabilized

A system in this category was proposed by the Mono-Tri-Rail Corporation of Pasadena, which was, in effect, a supported narrow gauge railroad with side stabilization. In addition to this system, the staff reviewed the Kearney Monorail system and the U. S. Monorail System, both of the supported type with overhead stabilization. These systems are reviewed in the Technical Data section of the report. The comments made for the previous system category are applicable and these systems do not appear to merit further study.

4. Transit Systems - Miscellaneous

a. General

In addition to the systems that have already been taken up there were several systems presented or considered that do not fall into any of the above categories. These are the more exotic or unconventional systems in an unconventional field and include proposals for captive aircraft, helicopters, ground effect vehicles, moving belts, etc. However, in order to insure that no possibility was overlooked, each of these was carefully evaulated also to see if there was any possible potentiality for application in the mass rapid transit field.

b. Conveyor Belt Systems

The first type of system to be considered under this miscellaneous category are those that may be of some adaptation of conveyor systems or moving sidewalks. Among proponents were the "Turner Moving Walk", "Mathews Moving Walk", and "Stephens-Adamson Carveyor and Speedwalk". These could not be studied seriously because they are not mass rapid transit systems. They are too slow for application to the requirements of rapid trunk-line systems. However, the Stephens-Adamson Carveyor and Speedwalk Systems have interesting possibilities for use as secondary distribution systems. Both the carveyor and the Speedwalk have been engineered and developed and a test installation has been constructed at Aurora, Illinois. A full-scale installation of the carveyor was designed by the New York Transit Authority for use as a Time Square Shuttle but for reasons that are not readily apparent, it was not built.

The Speedwalk is used at Disneyland for the approach to the monorail station and appears to be working quite satisfactorily. If it is found that some sort of secondary distribution transit system will be needed to supplement the primary service, then the use of a carveyor type facility and speedwalk should be given further consideration.

c. Ground Effect Vehicles

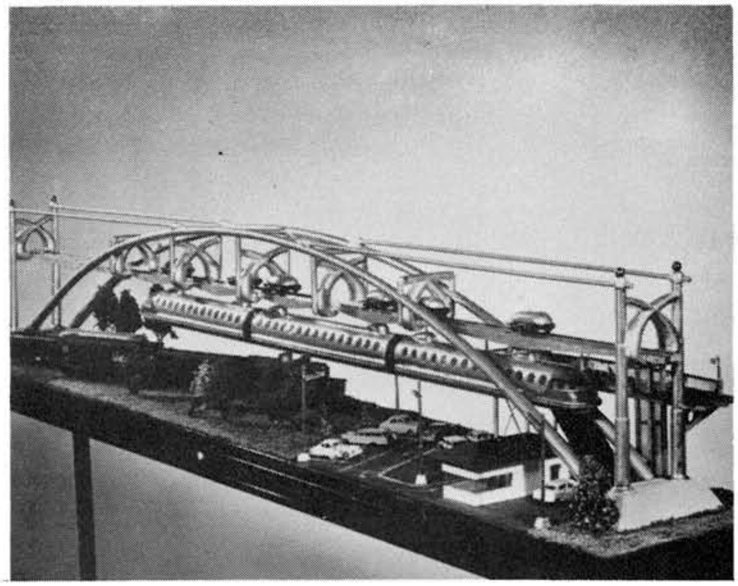
This newest entry in the transportation field presents the challenging possibility of high speed operation without wheels. The principle involves the suspension and propulsion of a vehicle with low pressure low velocity air. A local proponent of this type of system is Ideonics, Inc., who have conceived of a transit vehicle operating with air suspension and with a novel propulsion system. Unfortunately, the idea is still only in the concept stage and much work would have to be done in order to prove whether it is practical or not. A preliminary review indicates that higher power output would probably be necessary because of the support power requirement. Convair, Curtiss Wright, and the Ford Motor Company have also been working on ground effect vehicles but development is only in the initial phases. However the system does present interesting possibilities.

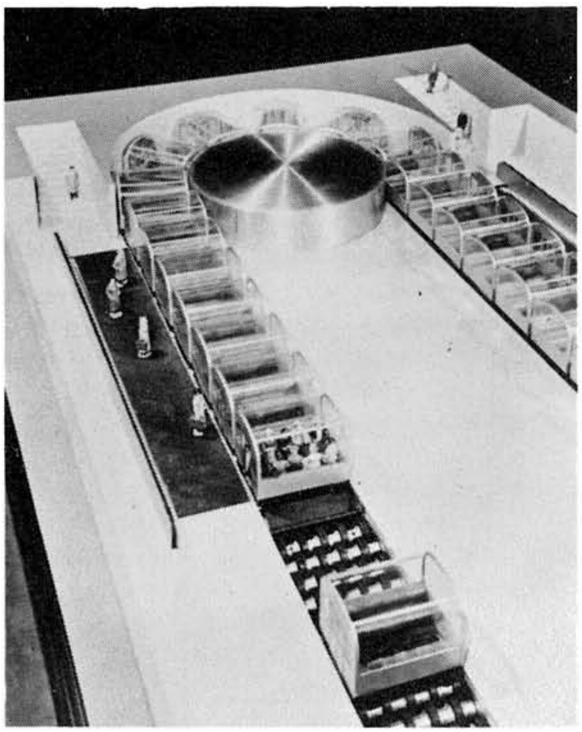
Another system not yet developed is air duct system as proposed

DREAMLINER BUS
View Showing Modern Bus Equipment Currently in Operation by MTA

Figure III-10

S.R.V. Duo-Rail System
(Right)





Stephens-Adamson Carveyor System
(Left)

Air Support Vehicle
Ideonics, Inc.
(Right)

Figure III-11

by L. E. Setzer which involves the interesting concept of the propulsion of car capsules within tubes by air propulsion.

There is no question but what helicopters will play a major role in the over-all transportation picture of the future; already they have taken over a good portion of the long-haul bus movement at the International Airports at the major cities in the United States and throughout the world. These are shuttle helicopter services as the New York Airways service and the Los Angeles Airways presently run from the airport to points within the city.

Already on the horizon are short inter-city runs and indeed this sort of service is already in operation in Belgium and is proposed for Los Angeles and other cities in the United States. The ultimate concept of use of helicopters is for commuter service and it is at this point that we feel that this potentiality is far in the future. For example, presently a 26 passenger helicopter costs in the neighborhood of $500,000, and there appears to be just no way that this sort of an expensive vehicle can be used for mass rapid transit. Fares would have to be certainly exorbitant and out of the reach of the average commuter; so, this system will have to remain in the luxury class for years to come, but this is certainly not to say that it does not have its part in the transportation picture.

Of the other systems we have studied, we see two that warrant a detailed comparison with a modern conventional rail facility for the reason that they appear to offer the promise of increased safety in operation and the possibility of a more favorable acceptance by the community. Thus, we recommend that a detailed comparative analysis be made of the three systems in order that sufficient cost and functional information can be collected to make the final choice of the system best adapted to the needs of the Los Angeles Metropolitan Area.

These three systems are:

ALTERNATE A - Conventional Rail - Modern Design

ALTERNATE B - Suspended Monorail - Split Rail

ALTERNATE C - Supported Monorail - Overriding

We also see some merit in further consideration of the ground effect vehicles because of the interesting potentialities which they present. In addition, during this next phase, presentations of new transit system ideas should continue to be received in order to insure that nothing is overlooked.

TRANSIT FACILITIES

TRANSIT FACILITIES

SECTION IV

TRANSIT FACILITIES

A. INTRODUCTION

This section of the report deals with facilities necessary to the operation of the rapid transit system. The scope of work includes a review of requirements for way structures, stations and maintenance yards, and the effects of alignment on these structures.

Way structures considered in this preliminary investigation have been limited to generalized forms for suspended monorail, supported monorail, conventional dual rail, and bus systems. Detailed analysis of structures for each system have not been performed, due to the lack of specific information on equipment performance, weight and dimensions. Rational assumptions have been made for equipment characteristics which permit the comparative study contained herein. Detailed investigation will be made as information becomes available and rights-of-way are more clearly defined.

B. TYPES OF WAY STRUCTURES

Way structures necessary to the operation of the rapid transit system fall into three categories, elevated, surface and sub-surface. All conditions must provide complete grade separated operation. Expanding these three categories, way structures for each of the conditions will develop the following configurations:

1. Elevated

   (a) Continuous bridging structure.

   (b) Continuous filled ground with crossing bridge structures.

2. Surface

(a) Continuous bridging structure for suspended monorail system.

(b) Crossing bridge structures.

3. Subsurface

(a) Continuous open cut with crossing bridge structures. Continuous bridge structure required for suspended monorail system.

(b) Tunnel.

1. Elevated Systems

a. Continuous Bridging Structure

Way structures which support any elevated system of rapid transit must be of pleasing appearance. Large, massive structures with many laced members which obstruct light and air are not acceptable solutions to the problem. Community acceptance of elevated way structures in built-up areas can only be expected if such structures do not detract from the surroundings. This requirement virtually eliminates the use of large open trussed members and the "Forest of Columns" which has been found objectionable in the past, even though it may be the most economical solution for support structures.

All systems proposed for further study include recommendations for the use of "T" type support columns and moderate depth beams. Certain members may be shaped to present a minimum silhouette and, thereby, the least obstruction to vision. System comparisons, for purposes of preliminary investigation are, therefore, based on this type of support structure.

A typical span of support beams of 100 feet has been used for structure comparisons. This figure is probably the shortest practical span which will permit crossing intersecting streets without creating an undesirable obstruction to motor vehicle and pedestrian traffic. Longer spans will be necessary in many locations such as the Los Angeles River, the Rio Hondo, and crossing certain freeway sections. Frequency of long span requirements is a function of right-of-way conditions and will be a consideration in choosing alignments.

b. Continuous Filled Ground with Crossing Bridge Structures

Way structures necessary to this form of right-of-way are primarily crossing bridge structures similar to that of freeway design. Conventional rail-systems would be earth supported.

Supported monorail would require a continuous beam-way of lighter construction than required for the continuous elevated bridge configuration of 100' span. Additional right-of-way width is also required for this system to permit the location of an access road for maintenance purposes as the support beam-way will not allow passage of surface maintenance vehicles. Suspended monorail is not particularly applicable for this form of right-of-way, due to the continuous bridging structure requirement for support.

2. Surface Systems

At grade alignment of a transit system is limited to private right-of-way. Crossing requirements of such right-of-way requires under or overpass facilities with the attendant need for additional real estate for approach structures.

Way structures required are the same as those for elevated continuous filled ground conditions; however, suspended monorail may have application here.

3. Sub-Surface Systems

(a) Open Cut

Open cut is another form adapted to private right-of-way only. Crossing and way structures, similar to continuous elevated fill configurations, are required. Extensive storm drainage works may be involved with this system in addition to relocation of buried utilities.

(b) Tunnel

Tunnel or subway structures are complex and may take different forms depending on types of soils, number of tracks and access conditions. Location would be limited, where possible, to beneath public streets except at the ends where "day lighted" in open cut and private right-of-way is required. Tunnel structures are dealt with in detail in a separate section of this report.

C. SPECIFIC REQUIREMENTS FOR WAY STRUCTURES

Rights-of-way have been divided into five specific forms for studying effects of alignment conditions on way structures. Right-of-way types are: freeway, private, public street, railroad and tunnel.

1. <u>Freeway Right-of-Way-Median</u>

The majority of Los Angeles freeways now in operation have been constructed with minimum width medians.

The addition of a supporting column for an elevated transit system in such narrow medians may reduce the clearance to traffic lanes to the danger point. The accompanying Figures IV-1 through IV-4 graphically illustrate this condition.

A second consideration is that of crossing bridges which require an increase in the vertical clearance of the transit system. The normal clearance of 15 feet above the traveled way must be raised to 14 feet above the crossing bridge. An extreme example of this condition occurs at Mulholland Bridge in Cahuenga Pass where required height above ground is increased to approximately 45 feet, due to the bridge level. An average condition might be 35 feet.

Another consideration is that of interruption of traffic flow on the freeway during construction of way structures and line maintenance after completion of the system. Foundations for an elevated system are massive and would extend under adjacent traffic lanes. The time required for construction of any one foundation is not great, but multiplied by the number of supports required for the system, the time becomes quite extended. Maintenance access in existing freeways would have to be gained through traffic lanes and in many cases actually performed from this location causing hazardous conditions to freeway traffic. If it is determined desirable to locate rapid transit within the median of future freeways, it is probable that a 10 foot access road should be included as part of the transit system right-of-way to remove this problem of obstruction.

Additional right-of-way width required for this alignment is also shown in the accompanying figures.

A significant factor in the consideration of elevated transit alignment adjacent to a freeway is that of diversion of driver's attention. The high speed and relatively frequent stops of a transit vehicle above traffic on the freeway may divert the automobile driver's attention, and thereby generate congestion or accidents. This problem might be overcome by the addition of a screen to obscure the transit vehicle from adjacent traffic. However, a device of this nature presents a maintenance problem in addition to cost and aesthetic considerations.

2. Freeway Right-of-Way-Shoulder

Conditions for shoulder alignment are very similar to those for median. Many areas of freeway utilize retained side slopes with minimum clearance to structures on adjacent property. Way structure heights could be reduced slightly in some conditions but in general, alignment along this line for any distance may prove difficult, if not impossible, because of side clearances.

Examples of restricted side clearances are Santa Ana-San Bernardino Freeway from Broadway to approximately State Street and the general area of South San Gabriel and Alhambra.

3. Private Right-Of-Way

Private right-of-way, elevated or depressed would be similar to that found on the Harbor Freeway at Washington Blvd., and Figueroa Streets respectively. Crossing structures of the same general type as found along this freeway would be required.

From the standpoint of economics, these crossing structures must be limited to major locations of crossing movement.

The undesirable condition of cutting a community into segments by a continuous barrier has already been fairly well established.

It is also generally agreed that locating a transit system in open cut is more acceptable than elevating on fill because of reduced noise, impairment of light and ventilation.

Foundation conditions for monorail systems would also be improved where filled ground does not occur. Open cut, however, would require more extensive relocation of underground utilities and installation of storm drainage system.

Surface level private right-of-way would present conditions similar to those of the San Bernardino Freeway in the vicinity of Alhambra where both over and underpass bridges are used. This configuration of right-of-way involves the least width of real estate except at crossing structure locations where additional width is necessary for approach ramps. Minimum width of right-of-way required for surface alignment will probably be established by community acceptance criteria rather than physical dimensions of the system.

4. Public Street - Right-Of-Way

Structures necessary for support of rapid transit systems above a public street require separation from motor vehicle traffic. Separation is usually made by the construction of a median. The median width indicated in the accompanying sketches is estimated to be a minimum consistent with safety.

Minimum street widths required to accommodate this system with parking and traffic lanes each side is 50 feet. 70 foot width is required for 2 lanes of traffic each way. The governing condition will, in all probability, be proximity of the transit vehicle to adjacent property. This distance is to be determined by the Community Acceptance Criteria.

The assumed 100 foot span of support beams will permit clear-unobstructed intersections but will not provide for turn-out lanes in the median of the type currently installed on many arterial streets, due to the short setback of columns at intersections.

Curb alignment of an elevated system presents a different problem, in that the transit system would probably be split to operate one direction on each side of the street. Support structures would be doubled in number. Foundations for these structures would probably require more relocation of utilities than median supports. Some difficulty should be anticipated also from the close proximity of property lines which might require eccentric foundations.

To areas which have narrow sidewalks, the addition of 2' to 3' diameter columns would be objectionable to pedestrian circulation. This disadvantage may be partially overcome by the extension of transit supports to include street lighting, power and signal circuits now supported by the familiar "telephone pole". Greatest influence on selection of curb alignment will undoubtedly be the clearance requirement to adjacent property line.

5. Railroad Right-Of-Way

A great deal of interest has been shown regarding the use of space above existing operating railroads. Way structures for this type of system must clear the top of the railroad track by 22'6", in accordance with Public Utilities Commission regulation. Certain sections of track in Southern California have a requirement of 23'8" clearance. Six inches is generally added to these heights to permit realignment of track. Where crossing bridge structures exist, transit way structures must be raised to clear cross traffic.

Where multiple tracks exist, side clearance requirements may become critical with the introduction of bridge type piers to support the overhead track.

Maintenance and construction access is a major determinant in consideration of this system. In many cases, rights-of-way are narrow which would be a major problem, particularly for construction. It must be assumed until otherwise determined, that rail lines must remain operative at all times. Construction costs, therefore, would be high, particularly for foundations.

The effects of derailment on the railroad must also be determined relative to transit system safety. This condition is a function of the type of service on the rail line.

6. Tunnel

Contrary to a popular impression, it is possible to build tunnels in Los Angeles. Many tunnels exist and new tunnel construction is under way at this time. An example of a transit tunnel similar to the type anticipated in current studies is the "subway" connecting to the Subway Terminal Building in downtown Los Angeles.

Clearance requirements which limit other forms of right-of-way have little or no effect in selecting tunnel alignment. Primary concern is soil conditions and their relationship to tunnel excavation, underpinning of adjacent surface structures, and support of surface traffic above the excavation. Relocation of underground utilities may be of major significance particularly if cut and cover procedures are used for construction.

A detailed report of tunneling conditions developed by the firm of Mason & Hanger-Silas Mason in association with Daniel, Mann, Johnson, & Mendenhall is included in the appendix of this report.

C. GEOLOGY AND FOUNDATION CONDITIONS

Preliminary investigation of geologic and foundation conditions indicate different forms of foundations will be required in the several geographical areas to be serviced by the rapid transit system. The geologic conditions in the Los Angeles Basis, as indicated by our Consultants, LeRoy Crandall and Associates, cannot be classed as ideal. Knowledge gained from their investigation is necessary to the evaluation of tunneling conditions, determination of foundation costs, and construction problems of way structures. However, the influence of the type of right-of-way, and hence the height of support structures will have greater impact on the cost of foundations than the specific conditions of subsurface soils.

In the interest of brevity, elaboration on this subject has been limited. The reader is referred to the report of LeRoy Crandall and Associates which is appended to this report for detailed information.

D. DESIGN CRITERIA

Facilities for the rapid transit system include way structures for line operation, passenger stations, storage and maintenance yards for rolling stock, and power substation structures necessary for the operation of the system.

Standards for design of such items as bridges for street traffic are well defined by government regulation or recognized standards of practice. However, many way structures do not have clearly defined standards from which design may progress. Rolling stock size, weight, passenger capacity, maintenance consideration, total units in the system, off peak storage track requirement, etc., are all contributing factors to establishing the needed criteria. Therefore, assumptions have been made, based on current practice, to establish comparison data suitable for any of the configurations of rail rapid transit recommended for further investigation.

The assumptions for operating rail equipment are as follows:

1. Car length 60 ± feet, width 10 feet. Height 12 feet.
2. Weight of loaded car 60,000 lbs. (Note: Weight assumed is based on equipment now available. Reduction in weight in ultimate design is anticipated).
3. Maximum acceleration - 3.5 miles per hour per second.
4. Maximum deceleration - 5.0 miles per hour per second.
5. Maximum train 6 cars - station platform = length 330' to 380'.
6. Total required cars operating in the system - 360 (based on 48 mi. of track - 4 min. headway).
7. Maintenance percentage - 8%.
8. Total cars required for system - 390.
9. Storage track requirement - 75% of total operating stock = 270 cars.
10. Maintenance yard track requirement - 10%.

1. WAY STRUCTURES

Based on the foregoing assumptions, way structures will be designed for the following load conditions:

Case I	D+L+T+I	D = Dead Load
		L = Live Load
Case II	D + S	T = Torsion from Live Load
		I = Live Load Impact
Case III	Case I + W	W = Wind
Case IV	Case I + Te	S = Seismic
Case V	Case I + A	Te = Temperature
		A = Rail Longitudinal Accleration

Application of acceleration loads in Case V for governing condition will occur when trains from opposite directions are required to stop under emergency conditions on tracks of common support.

Additional load conditions such as stream flow, buoyancy, earth pressure and settlement will be considered where structures may be subjected to these loads.

Allowable working stresses assigned to materials will be increased 33-1/3% for Case II and V, 25% for Case III, and 40% for Case IV, in agreement with current practice for loads of this frequency and duration.

Values for the above loads have assigned as follows:

Live Load	30,000 lbs. at alternate centers of 27' and 33' (truck centers)
Torsion	10% of live load. NOTE: This load is subject to extreme variation dependant on the system used i.e., suspended monorail, supported monorail, etc., and speed permitted in curves. 10% of live load has been used for reasonable comparison.
Impact	25% of live load. Final design of the system will require extensive investigation of this load and its relation to dynamic response in the support structure.
Wind	15 pounds per square foot of projected area.
Seismic	0.133 of dead load.
Temperature	100°F range.
Rail Longitudinal	
Acceleration	(A) - 23% of live load. NOTE: This value is based on maximum deceleration of 5 miles per hour per second.

From the above loading conditions, supporting structures have been estimated for each of the systems proposed. Dimensions of support members shown on figures IV-1 thru IV-4 are probable figures for the conditions illustrated, and are sufficiently accurate for preliminary planning. As specific information becomes available on right-of-way alignment and operating equipment, the way structure design will be refined to commensurate accuracy.

PASSENGER STATIONS

Design of passenger stations is primarily a problem in adaptability of space to the movement of people with minimum congestion and maximum speed. Passenger densities, as reported by Coverdale & Colpitts, have been used to establish train capacity, and headway. From this data it appears that station platform lengths will probably range from 330' to 380' in length. Platform width is determined by minimum safe width and access stair requirements.

Traffic density for station design is subject to extreme variation depending on many variables, one of which is present installations vs. ultimately planned system. Economics and space limitations are also of prime importance. Until reasonably accurate alignment is chosen and traffic estimates made for such alignment, actual station layouts cannot be made and preliminary layouts have been developed for planning purposes. Figures IV-5 and IV-6 are examples of stations which may be applicable to the central business district for subway alignment. The estimated capacity of these stations is 40,000 passengers per hour with only moderate congestion. Assuming trains at 4 minute headways, no congestion would occur at 20,000 passengers per hour. These volumes are proportional to traffic which may be anticipated if the rapid transit system is installed on an incremental basis.

Figure IV-7 is a concept layout for an outlying station including secondary transportation functions of feeder bus lines, parking for park and ride, and car pickup. Minimum design for safety and convenience establishes loading platform and access space rather than traffic density thru the station. For this reason, this station layout is capable of handling approximately 5,000 passengers per hour, a number well in excess of the actual traffic anticipated at an outlying location.

All of the station layouts presented are preliminary concepts of space and access. Changes may be anticipated as the actual factors of availability of space for construction, public acceptance criteria, fare collection method, etc., become known. Passenger convenience and economics of construction must also be balanced for each station location.

Basically, whether a station is elevated or depressed from adjacent grade level, the floor space requirement for any particular passenger load is the same. Variation in station structure is notable for changes in type of right-of-way and rapid transit system.

An elevated station serving a suspended monorail would require increased ground clearance, for example, over public street due to the depth of support framing for boarding platforms. This situation does not exist for supported systems, because clearance height is established by rail support beams which are of greater depth than required for platform framing.

Stations, access ramps, stairs, etc., must adhere to the same clearance requirements as imposed on way structures. If median alignment along a freeway or public street is used, a bridging ramp must be installed to adjacent sidewalks or parking areas.

Length of such bridges may be as much as 100 feet. Vertical rise of stairs or escalators would be in the range of 16' to 44'. The extreme of 44' is encountered when a station with center platform is used and access is made by bridging over transit equipment as well as adjacent traveled way.

Station layouts studied include both "common" and "through loading" systems. Common loading confines on and off train traffic to one platform. "Through loading" loads from one platform and discharges to another platform on the opposite side of the train. Through loading is capable of handling higher traffic volumes without congestion than common loading; however, this system does not appear to be economical for densities estimated in this system. For maximum economy of space and operation, it is probable that all stations should use a central platform handling traffic in both directions.

MAINTENANCE AND STORAGE REQUIREMENTS

Initial ideas of the location and extent of storage track and maintenance facilities are outlined here as a guide to further study. Actual requirements will be determined from performance data of equipment and traffic demand.

Consideration is being given to locating a central maintenance center on the MTS property north of Macy Street. Sufficient space is probably available for this function and its location appears well situated for servicing all corridors of traffic. Some difficulty may be anticipated in gaining access to this property, but the advantages of this location warrant extensive study.

Storage yard capacity for off peak hours and night low level operation is based on 75% of equipment as non-operative. Track length required is approximately 3-1/2 miles and should be distributed throughout the system on the basis of demand.

It appears advantageous to consider locating storage track adjacent to presently operating yards of the MTA at the end of the transit corridors, in order to minimize operating expense. Such a condition might exist in the vicinity of Holt Avenue in El Monte where it may be possible to reclaim ground adjacent to the Rio Hondo.

Another form of storage track, usually referred to as a "lay-up track", will also be included. The function of this track is to remove a disabled vehicle or train from the main line. Track of this type is usually located adjacent to station at 2-1/2 mile intervals and will also permit "turn around" of scheduled trains if desired.

E. CONSTRUCTION CONSIDERATIONS

Materials and methods of construction for way structures which meet the requirements of economy, aesthetics, speed of construction and structure strength are steel and concrete with a maximum utilization of prefabrication technique. Maximum use of standardized span lengths and column heights for re-use of steel jigs and concrete forms promote economy and rapid construction. Also, extensive use of drilling methods would permit rapid installation of foundations.

Speed of construction is of paramount importance because of public interest to have the system operative at the earliest possible date. It is also important that normal surface traffic be disrupted for the shortest possible time.

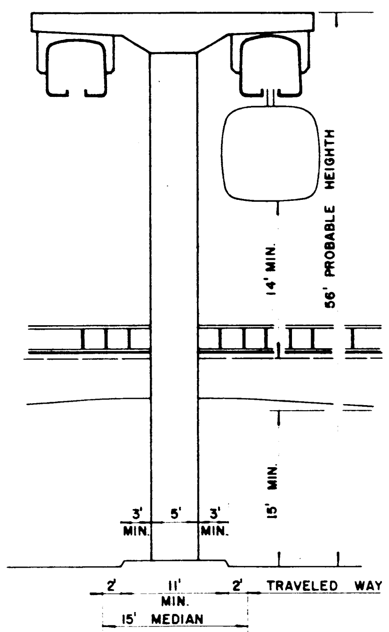
In addition to the problem of erecting the structures in the selected rights-of-way, the conditions affecting movement of materials to the point of use must be evaluated. Supporting girders for an elevated system would require special equipment due to length and weight, for shipment from fabrication yards to the location of construction. In some areas it may be necessary to move such materials only a night. A similar condition is found in the movement of large volumes of excavation in open cut or fill type of right-of-way.

Before final selection of materials for structures is made, it will be necessary to determine the effects of maintenance costs for each material proposed and evaluate total costs for construction and operation over the assumed life of the system. Although first cost is of major importance, it is usually impractical to use materials which require expensive maintenance.

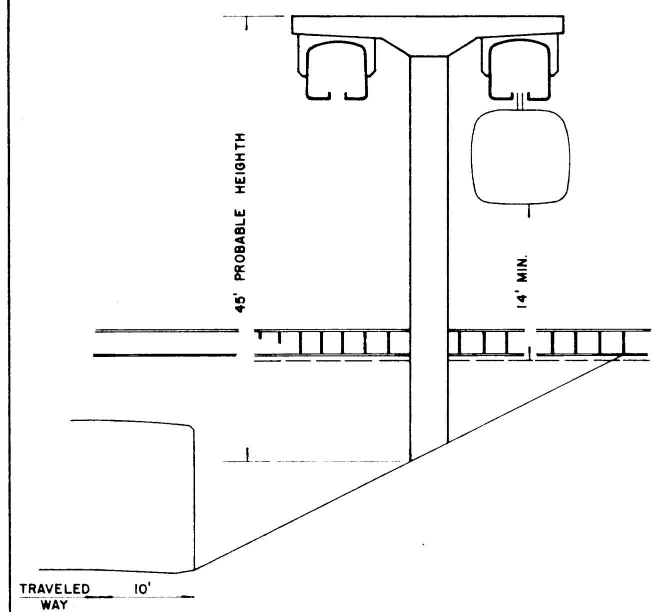
F. SUMMARY

Ultimately, the form of right-of-way for the rapid transit system must be chosen on the basis of maximum service to the user, acceptability to the adjacent property and economics of facilities on which the system will operate.

Many forms of rights-of-way have been suggested for rapid transit by layman and professional, and in some cases costs of construction have been quoted on the suggested rights-of-way. Generally costs quoted have been based on idealized conditions and do not reflect the necessity of additional heights to clear structures crossing the right-of-way. Figures IV-1 through IV-4 indicate some of these conditions of clearance. Briefly, it is not possible to accurately estimate the cost of facilities for the rapid transit system without having a reasonably accurate alignment of right-of-way established. Preliminary cost estimates may be misleading due to the multitude of assumptions on items such as the height previously mentioned, utility relocation, proportion of curved and tangent track, station frequency, etc. Cost estimates which have not been based on specific consideration of alignment must be used with extreme care or entirely erroneous conclusions may result.

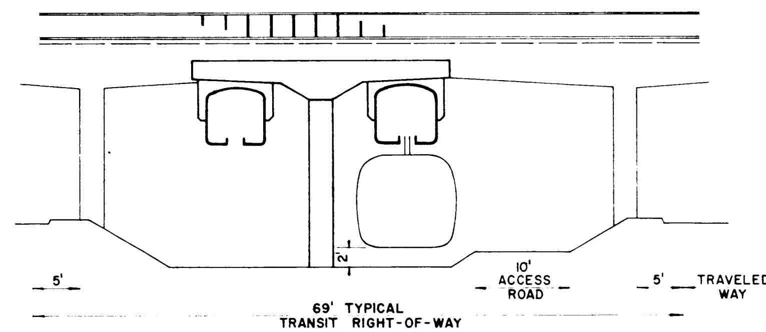


TYPICAL MEDIAN STRUCTURE AT STREET CROSSING



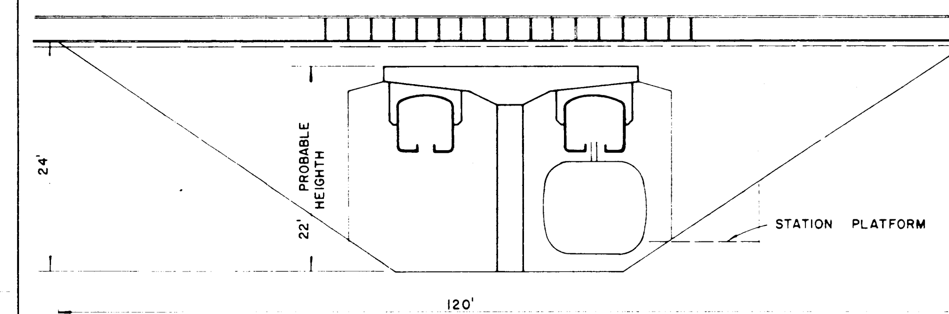
TYPICAL SHOULDER STRUCTURE

EXISTING FREEWAY RIGHT-OF-WAY



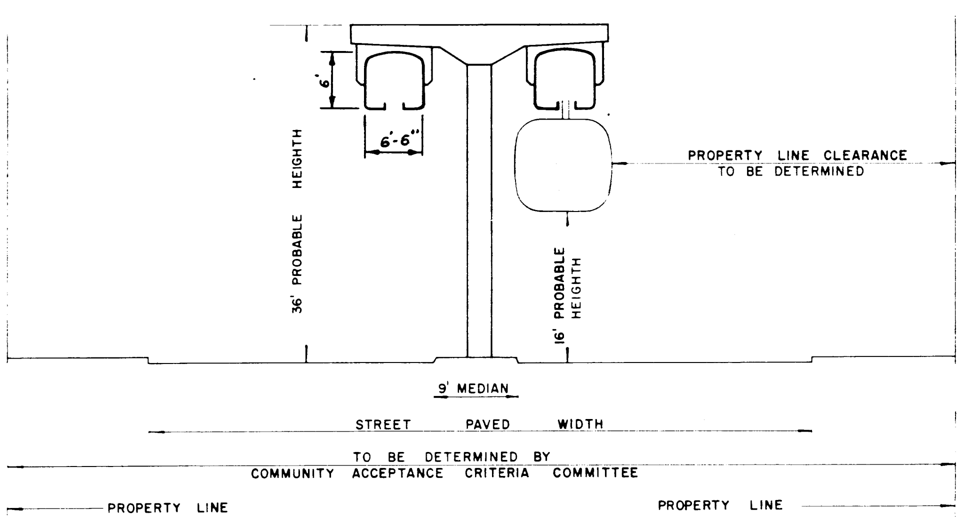
COMBINED RIGHT-OF-WAY IN FUTURE FREEWAY MEDIAN

FREEWAY RIGHT-OF-WAY ALIGNMENT

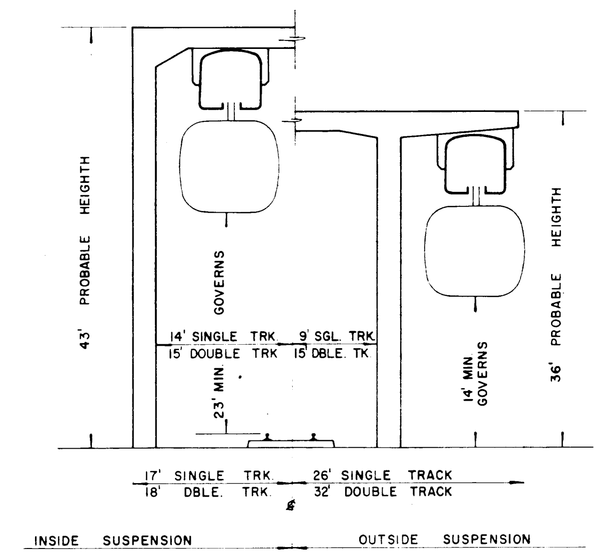


DEPRESSED PRIVATE RIGHT-OF-WAY

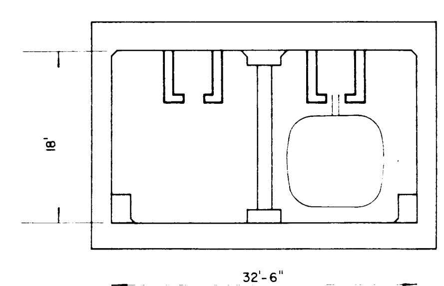
(ELEVATED PRIVATE RIGHT-OF-WAY SIMILAR TO PUBLIC STREET CONDITION. RIGHT-OF-WAY WIDTH TO DETERMINED BY COMMUNITY ACCEPTANCE CRITERIA COMMITTEE)



RIGHT-OF-WAY IN MEDIAN OF PUBLIC STREET

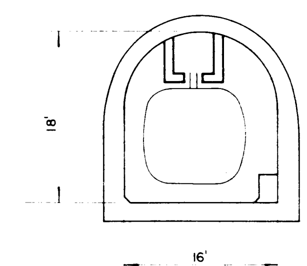


SUSPENDED OVER RAILROAD RIGHT-OF-WAY



TYPICAL DOUBLE TRACK TUNNEL

(THREE & FOUR TRACK TUNNELS SIMILAR)



TYPICAL SINGLE TRACK TUNNEL

SUSPENDED MONORAIL CONCEPT

REVISION	DATE	DESCRIPTION	DFT'SMN

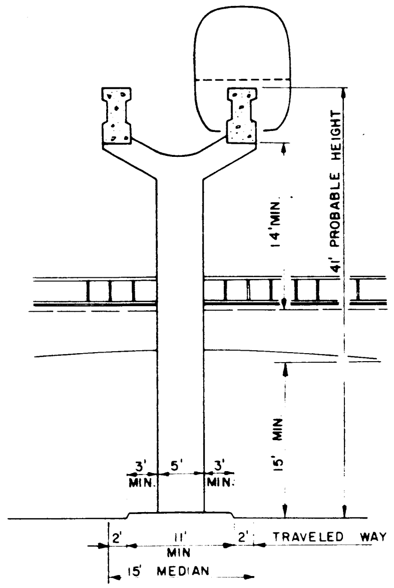
DANIEL, MANN, JOHNSON, & MENDENHALL

ARCHITECTS & ENGINEERS

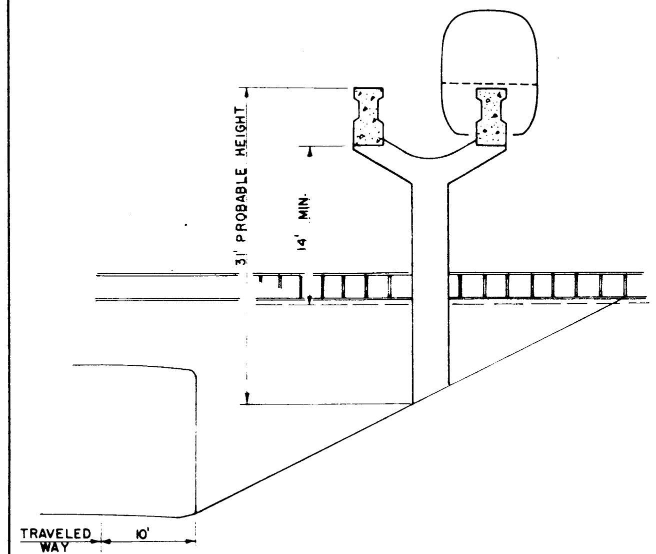
3325 WILSHIRE BOULEVARD - LOS ANGELES 5, CALIFORNIA - TELEPHONE DUNKIRK 1-3663

PREPARED FOR

JOB TITLE	LAMTA RAPID TRANSIT PROGRAM	DRAWN BY	JOB NO. 626-1-1
SHEET TITLE	**PRELIMINARY**	CHECKED BY	SHEET NO. FIG IV-1
		APPROVED BY	DATE JAN 25, 1960

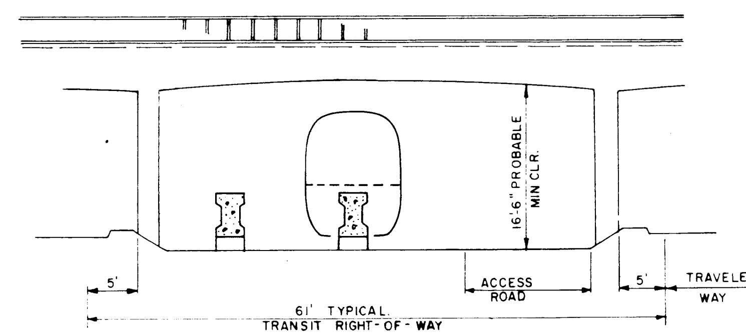


TYPICAL MEDIAN STRUCTURE AT STREET CROSSING



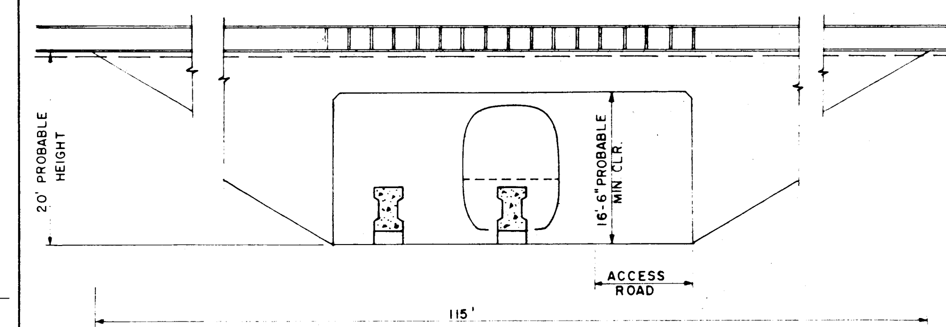
TYPICAL SHOULDER STRUCTURE

EXISTING FREEWAY RIGHT-OF-WAY



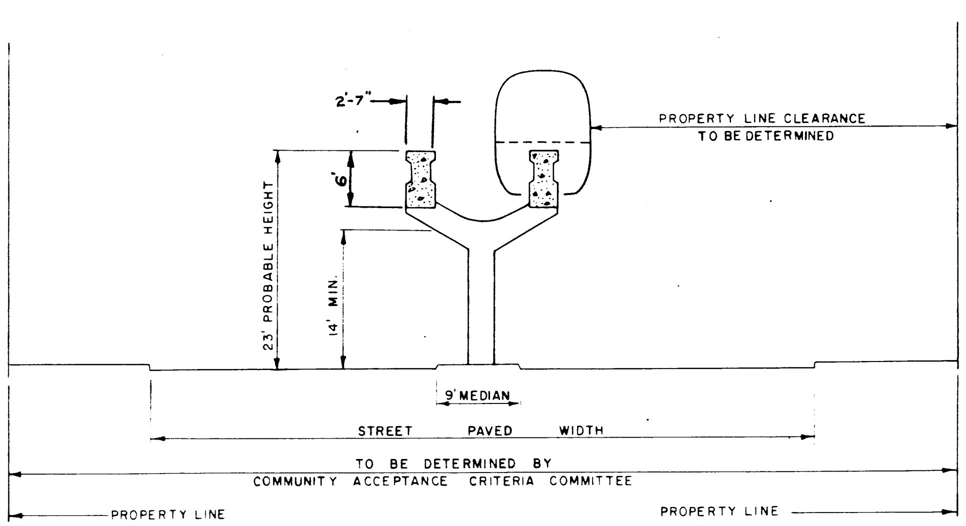
COMBINED RIGHT-OF-WAY IN FUTURE FREEWAY MEDIAN

FREEWAY RIGHT-OF-WAY ALIGNMENT

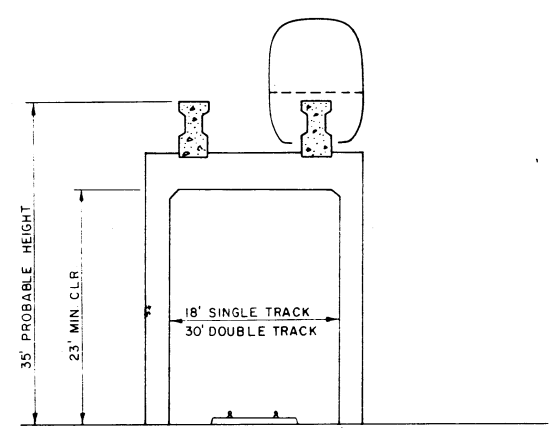


DEPRESSED PRIVATE RIGHT-OF-WAY

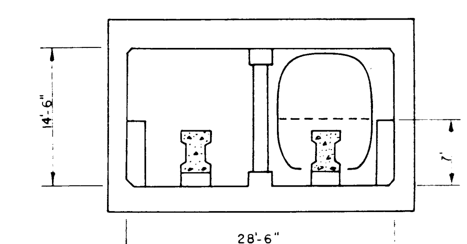
(ELEVATED RIGHT-OF-WAY SIMILAR)



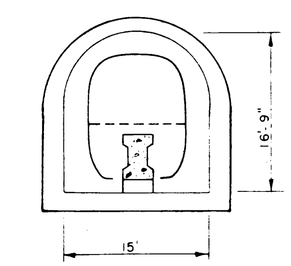
RIGHT-OF-WAY IN MEDIAN OF PUBLIC STREET



SUPPORTED OVER RAILROAD RIGHT-OF-WAY



TYPICAL DOUBLE TRACK TUNNEL



TYPICAL SINGLE TRACK TUNNEL

SUPPORTED MONORAIL CONCEPT

REVISION	DATE	DESCRIPTION	CPTMN

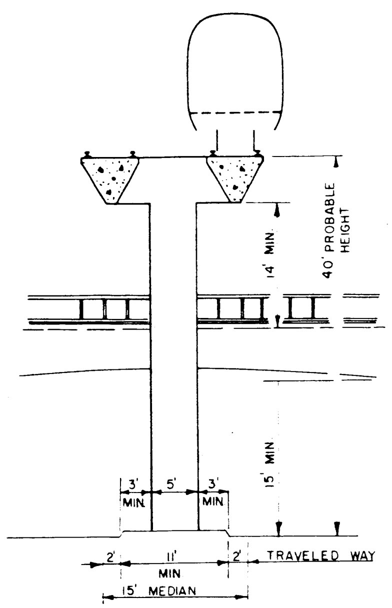
DANIEL, MANN, JOHNSON, & MENDENHALL

ARCHITECTS & ENGINEERS

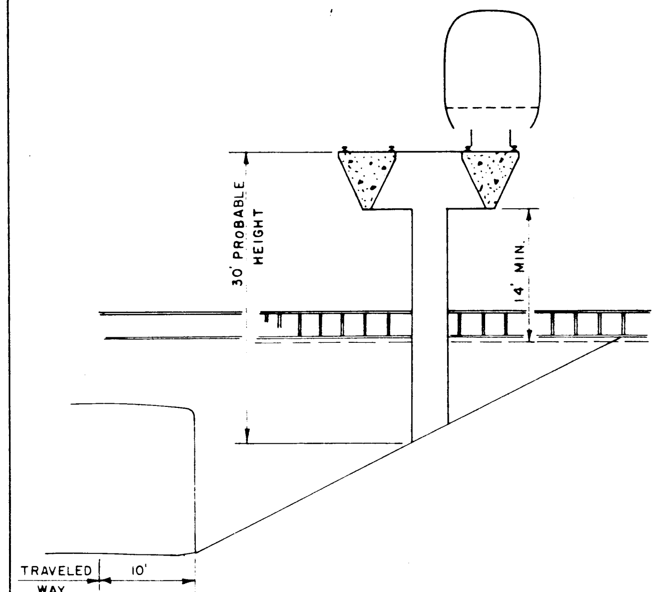
3325 WILSHIRE BOULEVARD – LOS ANGELES 5, CALIFORNIA – TELEPHONE DUNKIRK 1-3663

PREPARED FOR

JOB TITLE: LAMTA RAPID TRANSIT PROGRAM	DRAWN BY: L. KORDA	JOB NO: 626-1-1
SHEET TITLE: **PRELIMINARY**	CHECKED BY:	SHEET NO: FIG IV-2
	APPROVED BY:	DATE: JAN 25, 1960

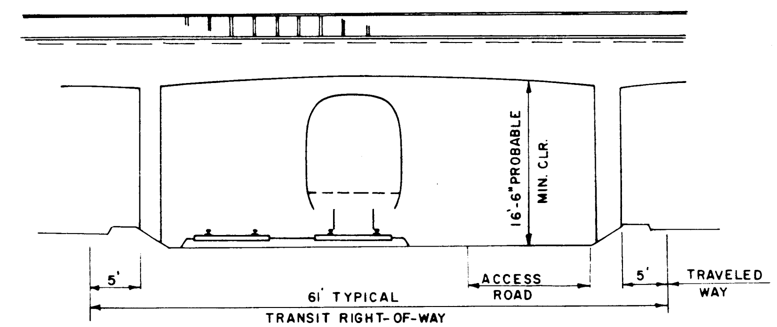


TYPICAL MEDIAN STRUCTURE AT STREET CROSSING



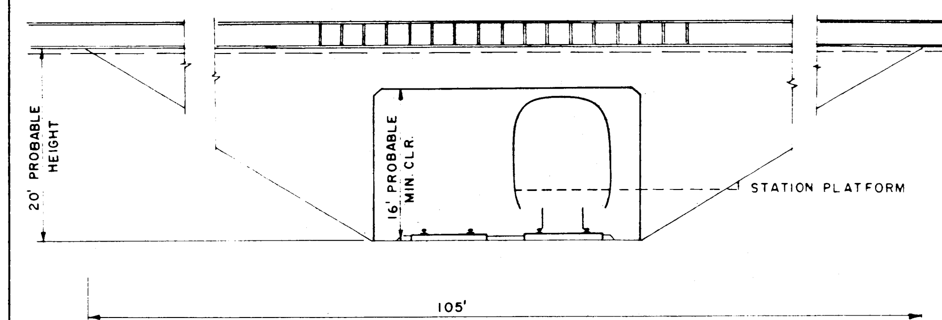
TYPICAL SHOULDER STRUCTURE

EXISTING FREEWAY RIGHT-OF-WAY

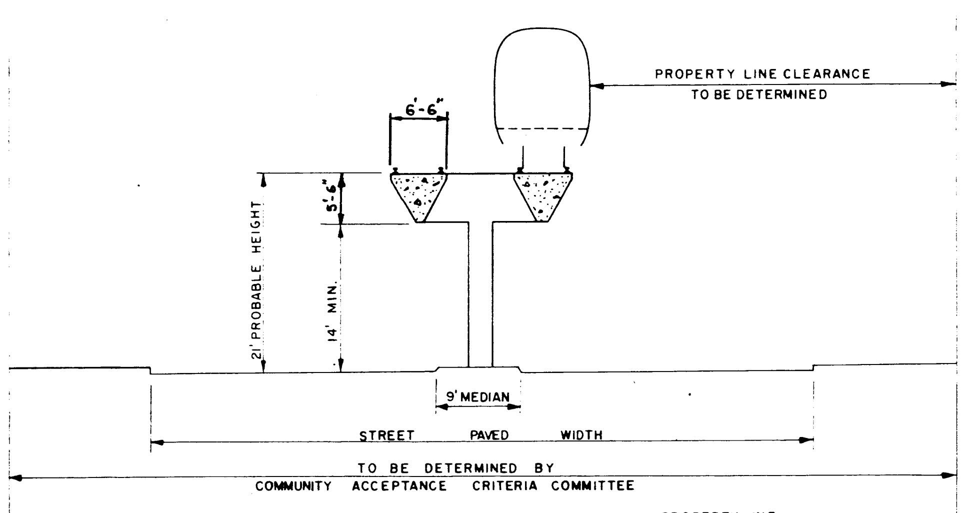


COMBINED RIGHT-OF-WAY IN FUTURE FREEWAY MEDIAN

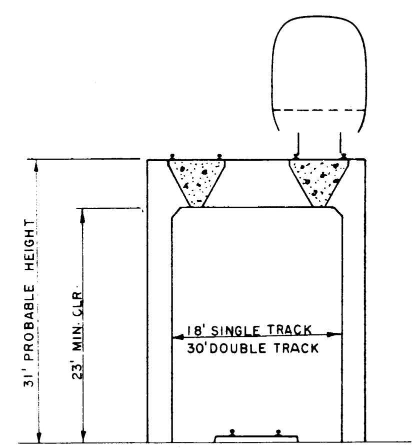
FREEWAY RIGHT-OF-WAY ALIGNMENT



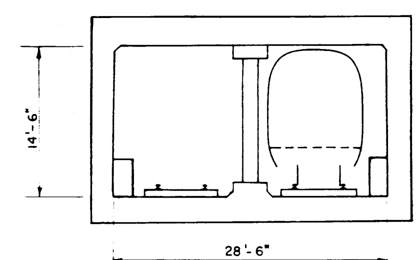
DEPRESSED PRIVATE RIGHT-OF-WAY
(ELEVATED RIGHT-OF-WAY SIMILAR)



RIGHT-OF-WAY IN MEDIAN OF PUBLIC STREET

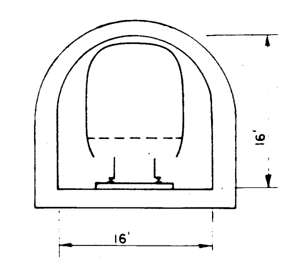


SUPPORTED OVER RAILROAD RIGHT-OF-WAY



TYPICAL DOUBLE TRACK TUNNEL

(THREE AND FOUR TRACK TUNNELS SIMILAR)



TYPICAL SINGLE TRACK TUNNEL

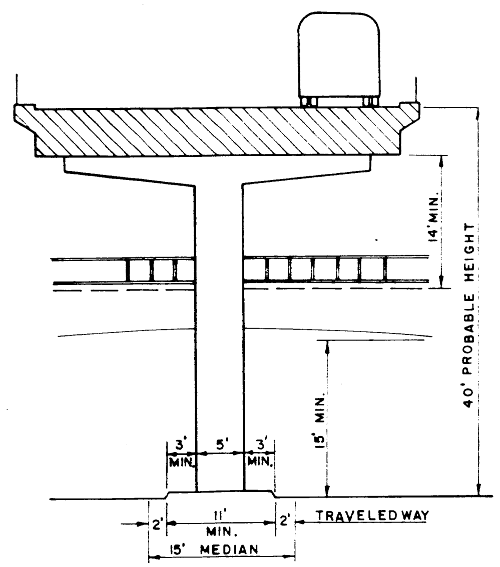
CONVENTIONAL RAIL CONCEPT

REVISION	DATE	DESCRIPTION	APPTMN

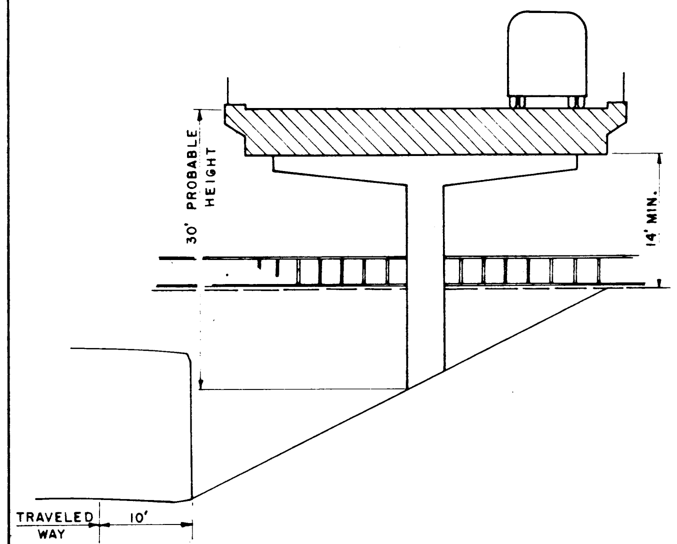
DANIEL, MANN, JOHNSON, & MENDENHALL
ARCHITECTS & ENGINEERS
3325 WILSHIRE BOULEVARD - LOS ANGELES 5, CALIFORNIA - TELEPHONE DUNKIRK 1-3663

PREPARED FOR

JOB TITLE: LAMTA RAPID TRANSIT PROGRAM	DRAWN BY: L. KORDA	JOB NO: 626-1-1
SHEET TITLE: **PRELIMINARY**	CHECKED BY:	SHEET NO: FIG IV-3
	APPROVED BY:	DATE: JAN 25, 1960

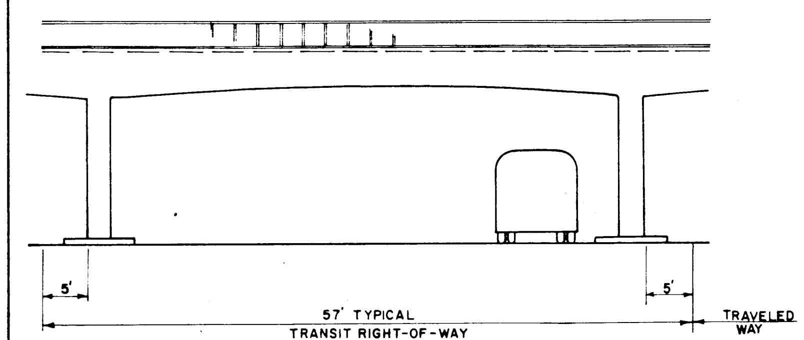


TYPICAL MEDIAN STRUCTURE AT STREET CROSSING



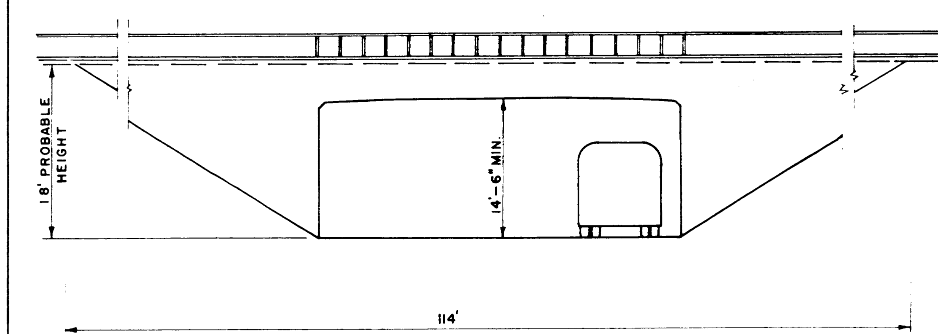
TYPICAL SHOULDER STRUCTURE

EXISTING FREEWAY RIGHT-OF-WAY



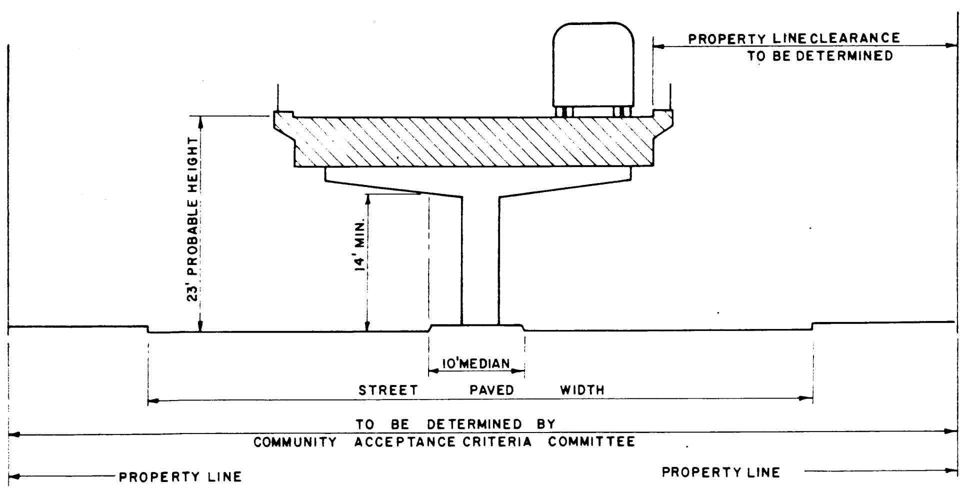
COMBINED RIGHT-OF-WAY IN FUTURE FREEWAY MEDIAN

FREEWAY RIGHT-OF-WAY ALIGNMENT

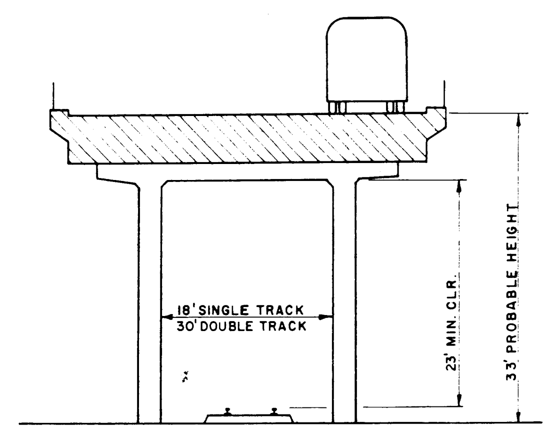


DEPRESSED PRIVATE RIGHT-OF-WAY

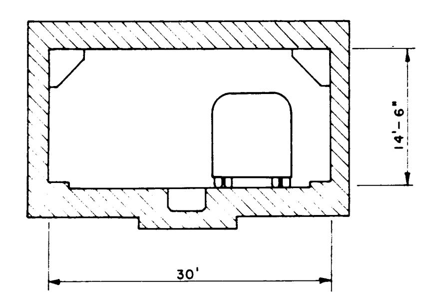
(ELEVATED RIGHT-OF-WAY SIMILAR)



RIGHT-OF-WAY IN MEDIAN OF PUBLIC STREET



SUPPORTED OVER RAILROAD RIGHT-OF-WAY



TYPICAL TWO LANE TUNNEL

BUS CONCEPT

REVISION	DATE	DESCRIPTION

DANIEL, MANN, JOHNSON, & MENDENHALL

ARCHITECTS & ENGINEERS

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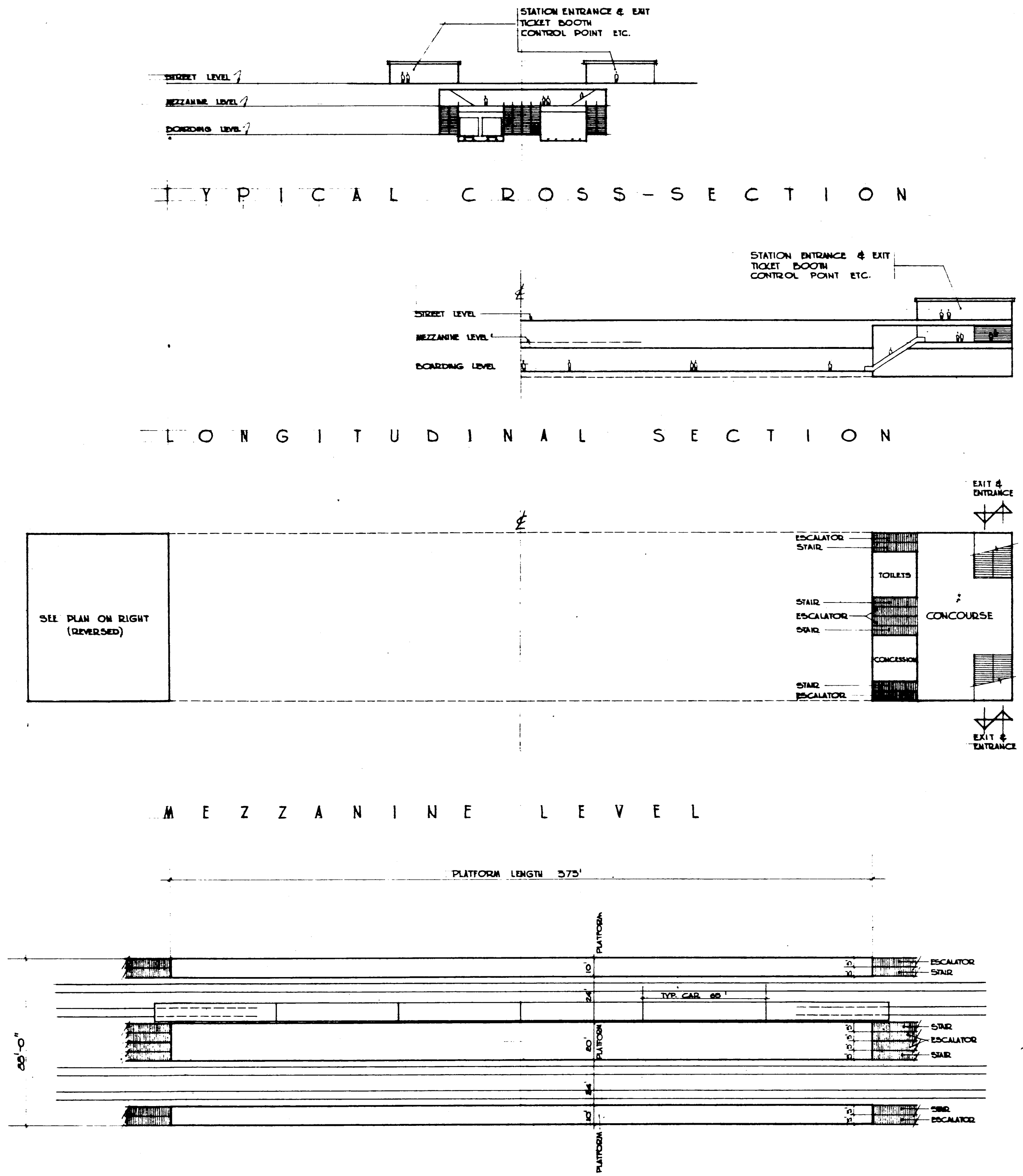
PREPARED FOR

JOB TITLE: LAMTA RAPID TRANSIT PROGRAM

SHEET TITLE: **PRELIMINARY**

DRAWN BY	L. Korda	JOB NO.	626-1-1
CHECKED BY		SHEET NO.	FIG IV-4
APPROVED BY		DATE	JAN 25, 1960



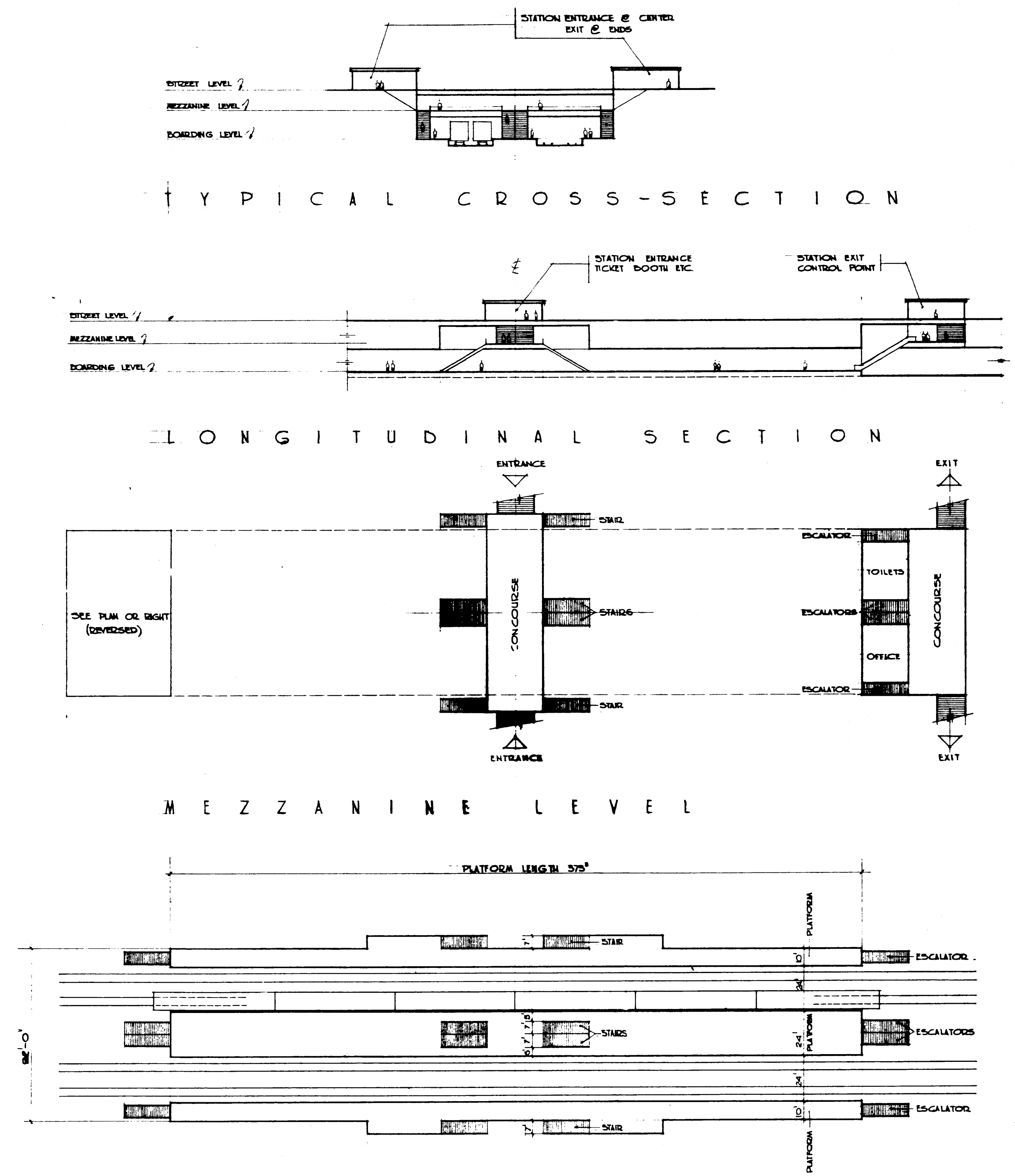
BOARDING LEVEL

SCALE 1/30" TO 1'-0"

NOTE :
ALL ESCALATORS TRAVEL IN THE DIRECTION OF TRAFFIC

SCHEME 'A'

TYPICAL CBD STATION
CONCEPT



BOARDING LEVEL

SCALE : 1/30" TO 1'-0"

NOTE
TRAFFIC ONE WAY AT ALL TIME ; STAIRS DOWN
ESCALATORS UP

SCHEME 'B'

REVISION	DATE	DESCRIPTION	INITIAL

DANIEL, MANN, JOHNSON, & MENDENHALL
ARCHITECTS & ENGINEERS
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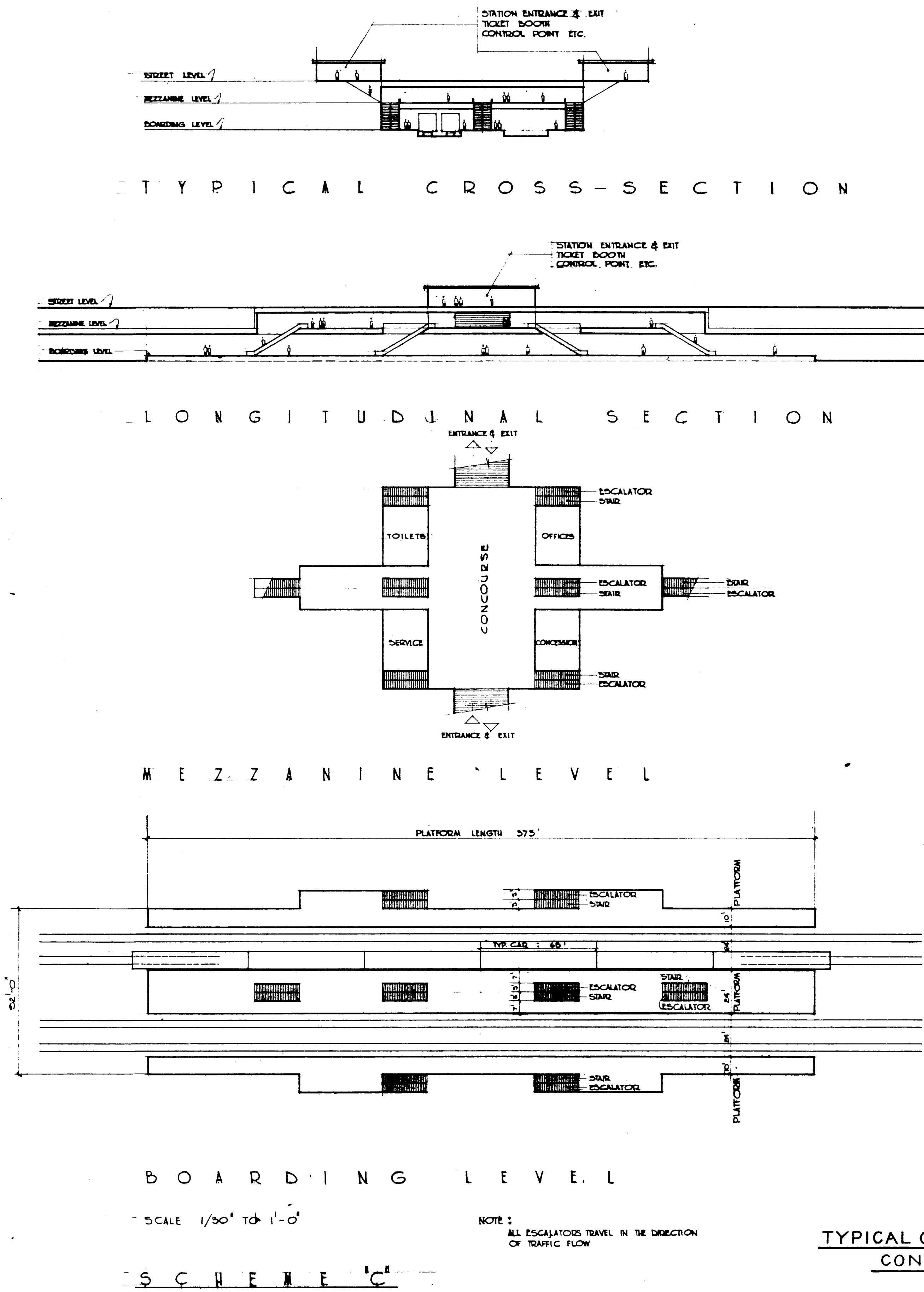
PREPARED FOR

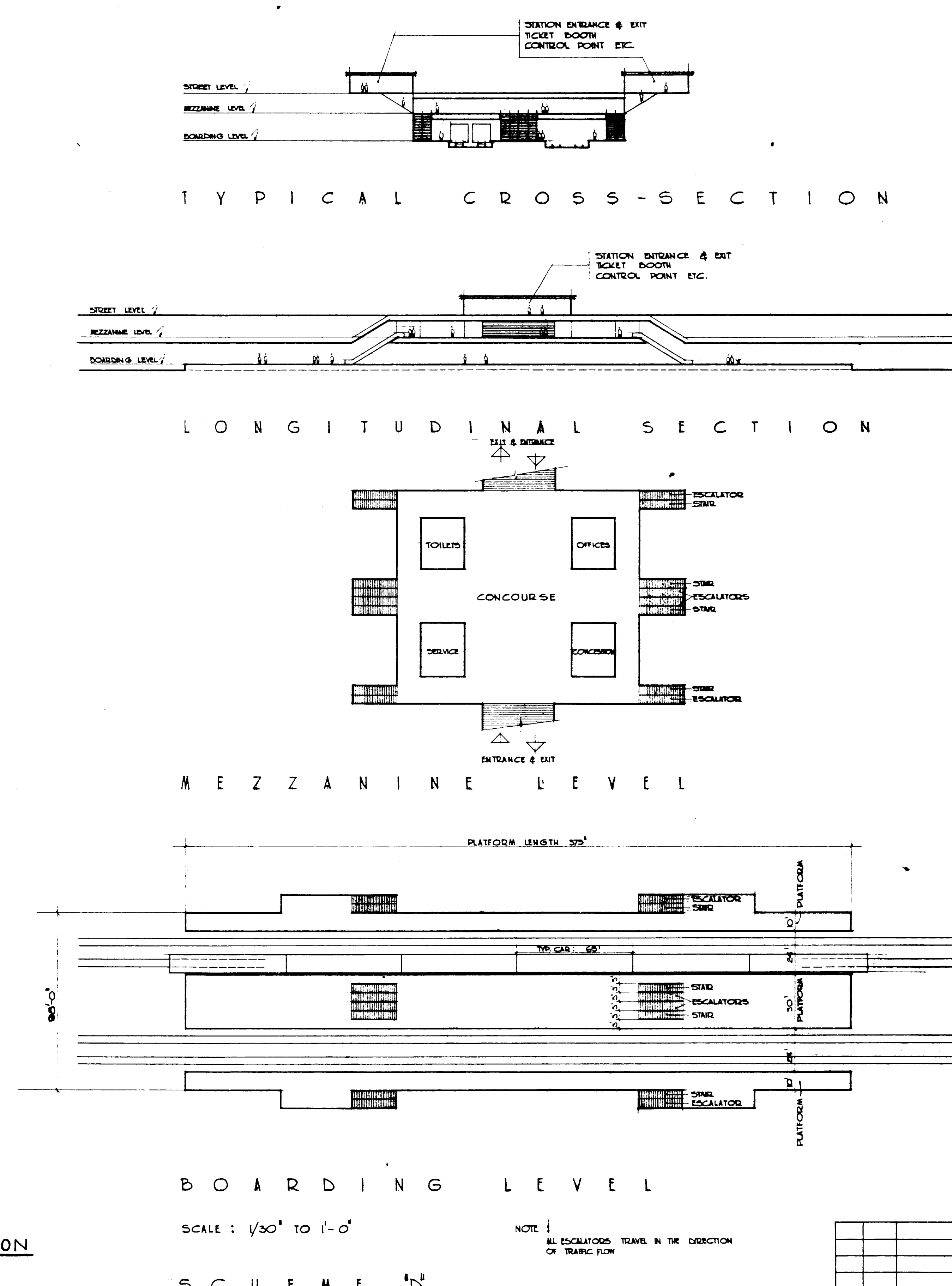
JOB TITLE: LAMTA RAPID TRANSIT PROGRAM
SHEET TITLE: **PRELIMINARY**

DRAWN BY
CHECKED BY
APPROVED BY

JOB NO. 626-1-1
SHEET NO. FIG IV-5
DATE JAN 25, 1960



TYPICAL CBD STATION
CONCEPT



REVISION	DATE	DESCRIPTION	OFFTAN

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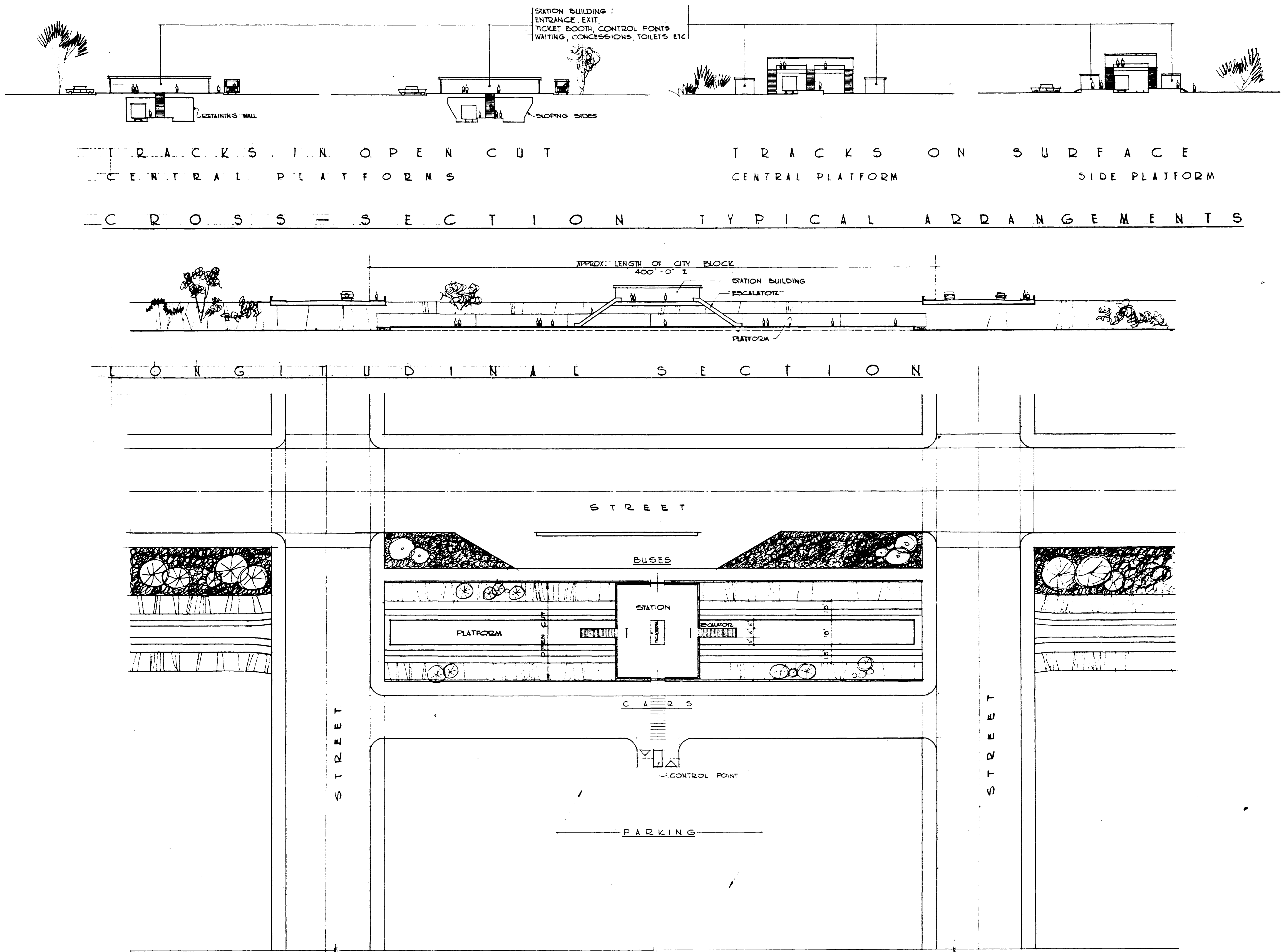
PREPARED FOR

JOB TITLE: LAMTA RAPID TRANSIT PROGRAM
SHEET TITLE: **PRELIMINARY**

DRAWN BY	JOB NO. 626-1-1
CHECKED BY	SHEET NO. FIG IV-6
APPROVED BY	DATE JAN 25, 1960



PLAN SCALE 1/30" TO 1'-0"

TYPICAL OUTLYING STATION CONCEPT

REVISION	DATE	DESCRIPTION	INITIAL

DANIEL, MANN, JOHNSON, & MENDENHALL
ARCHITECTS & ENGINEERS
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PREPARED FOR

JOB TITLE: LAMTA RAPID TRANSIT PROGRAM
SHEET TITLE: **PRELIMINARY**

DRAWN BY	JOB NO. 626-1-1
CHECKED BY	SHEET NO. FIG IV-7
APPROVED BY	DATE JAN 25, 1960

APPENDIX

APPENDIX

For Appendix Material:

See Volume II - Technical Data