

TCRP

REPORT 145

TRANSIT
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PROGRAM

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Reinventing the Urban Interstate: A New Paradigm for Multimodal Corridors

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TCRP REPORT 145

**Reinventing the Urban Interstate:
A New Paradigm
for Multimodal Corridors**

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TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions*, published in 1987 and based on a study sponsored by the Urban Mass Transportation Administration—now the Federal Transit Administration (FTA). A report by the American Public Transportation Association (APTA), *Transportation 2000*, also recognized the need for local, problem-solving research. TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of TCRP includes a variety of transit research fields including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA, the National Academies, acting through the Transportation Research Board (TRB); and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Committee.

Research problem statements for TCRP are solicited periodically but may be submitted to TRB by anyone at any time. It is the responsibility of the TOPS Committee to formulate the research program by identifying the highest priority projects. As part of the evaluation, the TOPS Committee defines funding levels and expected products.

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The TCRP provides a forum where transit agencies can cooperatively address common operational problems. The TCRP results support and complement other ongoing transit research and training programs.

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FOREWORD

By Dianne Schwager

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TCRP Report 145: Reinventing the Urban Interstate: A New Paradigm for Multimodal Corridors presents strategies for planning, designing, building, and operating multimodal corridors—freeways and high-capacity transit lines running parallel in the same travel corridors. This report will be of interest to urban and transportation planners and policy-makers in large urban areas.

The objectives of this research were to (1) evaluate the potential for rehabilitating and reconstructing portions of interstate freeways and similar freeways in urbanized areas of the United States as multimodal transportation facilities and (2) develop strategies to plan and implement these facilities. These facilities might be better used, if the facilities offered passenger mobility by multiple modes and were better integrated into communities.

The new paradigm emphasizes building transit lines and supporting pedestrian and bicycle facilities with the following goals:

- Enhancing corridor transportation capacity and performance without adding freeway capacity, by building and operating transit lines (including bus rapid transit, light rail, heavy rail, and commuter rail);
- Building and operating successful transit systems in multimodal corridors that attract high transit ridership and encourage livability and environmental sustainability; and
- Transforming a corridor's land uses and activities to a more transit-oriented pattern.

As discussed in the research report, a new paradigm multimodal corridor would take one of three forms:

- **Transit-oriented multimodal corridors**, which are designed to give transit a performance advantage in serving short- and medium-length trips, while the freeway is given a performance advantage for serving long-haul corridor trips.
- **Park-and-ride access multimodal corridors**, which are designed to provide high levels of automobile access within, and high transit speeds through, the corridor.
- **Transit-optimized/freeway-constrained multimodal corridors**, which are designed to give transit a performance advantage in the corridor by constraining the capacity and performance of the freeway.

The new paradigm for multimodal corridors offers insights into how freeways and transit can be structured to effectively carve out travel market niches where modes can work together and thrive in a corridor.

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Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.

S U M M A R Y

Reinventing the Urban Interstate: A New Paradigm for Multimodal Corridors

Research Goals and Objectives

The objectives of this research were to (1) evaluate the potential for rehabilitating and reconstructing portions of interstate freeways and similar freeways in the urbanized areas in the United States as new paradigm multimodal transportation facilities and (2) develop strategies to plan and implement these facilities. These facilities might be better used by people, if the facilities offer passenger mobility by multiple modes and are better integrated into communities.

A New Paradigm for Multimodal Corridors

Our transportation system and the communities that depend on it are facing serious challenges. People are stuck in traffic—consuming oil, polluting the air, and wasting time. Our transportation infrastructure is aging and inadequate under the weight of increasing travel demand. Our automobile-dominant transportation system becomes inefficient and ineffective during peak hours and emergencies—the times when it is needed most. Public transit is often too slow and limited in coverage to attract automobile users.

This report presents a new paradigm for planning, designing, building, and operating multimodal corridors—freeways and high-capacity transit lines running parallel in the same travel corridors (hereafter called “multimodal corridors”). The new paradigm emphasizes building transit lines and supporting pedestrian and bicycle facilities with the following goals:

- **Enhancing corridor transportation capacity and performance** without adding freeway capacity, by building and operating transit lines (including bus rapid transit, light rail, heavy rail and commuter rail)
- Building and operating successful transit systems in multimodal corridors that attract **high transit ridership** and encourage **livability and environmental sustainability**
- Transforming a corridor’s land uses and activities to a more **transit-oriented pattern**.

The old paradigm developed transit lines to compete directly with their freeway neighbors for long-haul corridor trips and as a congestion reliever service. New paradigm multimodal corridors provide market segmentation—distinct, separated, and optimized travel markets for each mode—between the transit line and freeway.

Market-segmentation between transit and freeway is achieved using the following guiding principles and techniques:

- **Market-Segmented Transit and Freeway Designs (Multimodal Coordination):** Station spacings and interchange spacings along each facility are designed to give each mode an advantage either in long-haul or short-haul corridor trips. The new paradigm multimodal corridor offers the opportunity for each mode to thrive and potentially increases the total carrying capacity of the corridor.
- **Market-Segmented Urban Form Patterns:** The new paradigm multimodal corridor encourages the development of separated, distinct land use and urban design environments for each mode within the same corridor. Transit station areas should have high-density, mixed-use, pedestrian-oriented land uses and urban design characteristics. Freeway interchange locations should have lower density, separated uses with street designs conducive to smooth traffic operations and freeway access.
- **Market-Specific Station Access:** Automobile-oriented (called here, park-and-ride access) multimodal corridors focus on providing freeway-competitive transit speeds and prioritize auto and bus access to their stations. Transit-oriented multimodal corridors focus on maximizing transit line access to corridor land uses via nonautomobile modes while discouraging automobile access.
- **Market Segmentation through Constrained Freeway Capacity:** Although often politically unpalatable, some multimodal corridors have developed divided travel markets by constraining the capacity of the freeway. Putting a low ceiling on the carrying capacity of the freeway gives the transit line an operational advantage, particularly for long-haul corridor trips.
- **Coordinated and Distinct Intermodal Operations:** The new paradigm incorporates two approaches to maximize interoperability among the transit line, the freeway facility, feeder bus lines, and pedestrian and bicycle facilities.
- **Intermodal Connections Limited to Key Locations:** The new paradigm corridor encourages intermodal transfer stations—where park-and-ride lots, bus transfer facilities, nearby freeway interchange ramps, and cross-corridor pedestrian and bicycle route facilities encourage intermodal transfers—to be built at end-of-the-line (terminal) locations and key midline locations.
- **Intermodal Intelligent Transportation Systems:** Intermodal transfers between freeway and transit can be facilitated and encouraged by real-time traveler information systems that provide information on corridor traffic conditions (congestion and incidents), transit schedule and schedule adherence, comparative corridor travel times (freeway versus transit), and station and destination parking availability and costs.

The Old and New Paradigms Compared

The key difference between the old and the new paradigms involves the role of the freeway in corridor travel. The interstate was originally designed to serve the type of trips that its name implies: long-haul, interstate trips. However, as the interstate model evolved, interstate freeways became the infrastructure of choice for intraurban travel as well, often displacing transit services into playing a supplementary, congestion-reliever role to their freeway counterparts.

The new paradigm seeks to restore freeways to their originally intended role as long-distance, intercity, and interstate facilities and so provide opportunities for transit to again be the preferred intraurban mode.

There are important differences between the old and new paradigms. Both in terms of their inherent goals and tangible benefits, the new paradigm offers improved performance

and efficiencies when compared with the old paradigm. Key distinctions include the multi-modal goals inherent in each paradigm, their environmental effects, and the technological, institutional, and planning techniques and models they employ. These differences are summarized in Table S-1.

The New Paradigm Typology and Corridor Evolution

The new paradigm offers several paths to develop multimodal corridors. First, a transit-oriented corridor can be built where the transit line is given the design, operating characteristics, and surrounding land use patterns that will effectively carve out a near-exclusive corridor travel market.

Table S-1. Comparison of the benefits and goals of the old and new paradigms.

Characteristics	Goals and Benefits	
	Old Paradigm	New Paradigm
<i>Multimodal Goals</i>		
Corridor Modal Focus	Automobile Dominated	Multimodal
Coordination	Supplementary	Complementary
Freeway Travel Markets Served	Short- and Long-Haul Trips	Long-Haul/Interurban Trips
Transit Travel Markets Served	Either Short- or Long-Haul Trips	Short-Haul/Intraurban Trips
Design Focus	Vehicle Throughput	Person Throughput
Congestion	Congestion Relief	Reduced Automobile Use
Travel Benefits	Enhanced Mobility	Enhanced Accessibility
Freight	Increased Capacity	Long-Haul/Interurban Focus
<i>Environment</i>		
Environmental Benefits	Reduced Congestion-Caused Emissions	Reduced Emissions through Mode Shift to Transit
Land Use	Automobile-Oriented	Transit-Oriented Near Stations through Coordinated Corridor Land Use Controls and Policies
Station Access	Automobile Access	Pedestrian/Transit Access
<i>Institutions and Planning</i>		
Institutional Coordination	Highway Department Lead	Multimodal Agency Partnerships
Planning Focus	Responds to Forecasted Travel Demands	Shapes Future Pop. & Travel Growth
Planning Approach	Ad Hoc Design of Transit in Corridor	“Intentional” Multimodal Design
<i>Implementation</i>		
Transit Right-of-Way (ROW)	“Leftover” ROW in Freeway Corridor	<ul style="list-style-type: none"> • Possible Freeway Lane Conversion for Transit • “Intentional” Multimodal Design
<i>New Technologies</i>		
Goal	Freeway Capacity Maximization	<ul style="list-style-type: none"> • Modal Coordination • Maximize Person Capacity
Tools	<ul style="list-style-type: none"> • Vehicle Detection • Ramp Metering • Traffic Management Center 	<ul style="list-style-type: none"> • Electronic Fare Payment • Multimodal Traveler Information • Parking
Applications	<ul style="list-style-type: none"> • Freeway Demand Management • Incident Management • Congestion Pricing 	<ul style="list-style-type: none"> • Coordinated Multimodal Pricing • Coordinated Multimodal Incident Management • Corridor-Level Parking Management

The second path involves a two-step process of multimodal corridor planning, design, and construction. In the first step, transit facilities are designed and built in freeway corridors with performance characteristics that enable them to compete with the freeway facility on a travel time basis. Then as the corridor evolves, infill stations can be built that provide greater coverage and accessibility for the transit riders to corridor land uses and activities, which can further encourage the corridor to develop additional transit-oriented design (TOD). It is conceivable that, over time, this process can lead to the conversion from a purely automobile-oriented, freeway-dominated corridor to a park-and-ride-access multimodal corridor to a transit-oriented corridor. As discussed in the research report, a new paradigm multimodal corridor would take one of three forms:

- **Transit-oriented multimodal corridors** are designed to give transit a performance advantage in serving short- and medium-length trips, while the freeway is given a performance advantage for serving long-haul corridor trips.
- **Park-and-ride access multimodal corridors** are designed to provide high levels of automobile access within, and high transit speeds through, the corridor.
- **Transit-optimized/freeway-constrained multimodal corridors** are designed to give transit a performance advantage in the corridor by constraining the capacity and performance of the freeway.

Corridor Evolution

The travel patterns and built environments of corridors can change dramatically over time. Although the new paradigm offers three different types of multimodal corridor (as described above), each of these is not seen as a necessary end state. The new paradigm encourages the evolution from freeway-only, automobile-oriented, and old paradigm corridors into transit-oriented corridors. Park-and-ride-access and transit-optimized/freeway-constrained corridors are not end states, but steps along the path to livable, sustainable, efficient transit-oriented corridors. Figure S-1 illustrates this progression.

The Key Factors for Successful New Paradigm Corridors

The degree to which transit competes directly or works cooperatively with its freeway neighbor is the critical determinant of transit success in a multimodal corridor. Multimodal corridor transit and freeway systems often are built to compete directly with each other for the same travel markets. When this happens, one mode can dominate, and the freeway typically attracts the most patrons. As a result, the surrounding land uses and activities will be shaped to serve the freeway, leaving transit underpatronized.

The new paradigm for multimodal corridors offers insights into the competition between freeways and transit and how this competition can be structured, effectively carving out travel market niches where each mode can thrive.

Multimodal Corridor Design and Operational Tradeoffs

The critical choices made for a multimodal corridor's design revolve around the advantages and disadvantages given to each mode, both as stand-alone facilities and in relation to one another. Sometimes, an advantage given to transit comes at the expense of the performance of the freeway and vice versa. Several tradeoffs between performance and design characteristics have been identified in this research to frame the discussion of the new paradigm. Each of the tradeoffs represents the aggregation of many individual corridor choices and

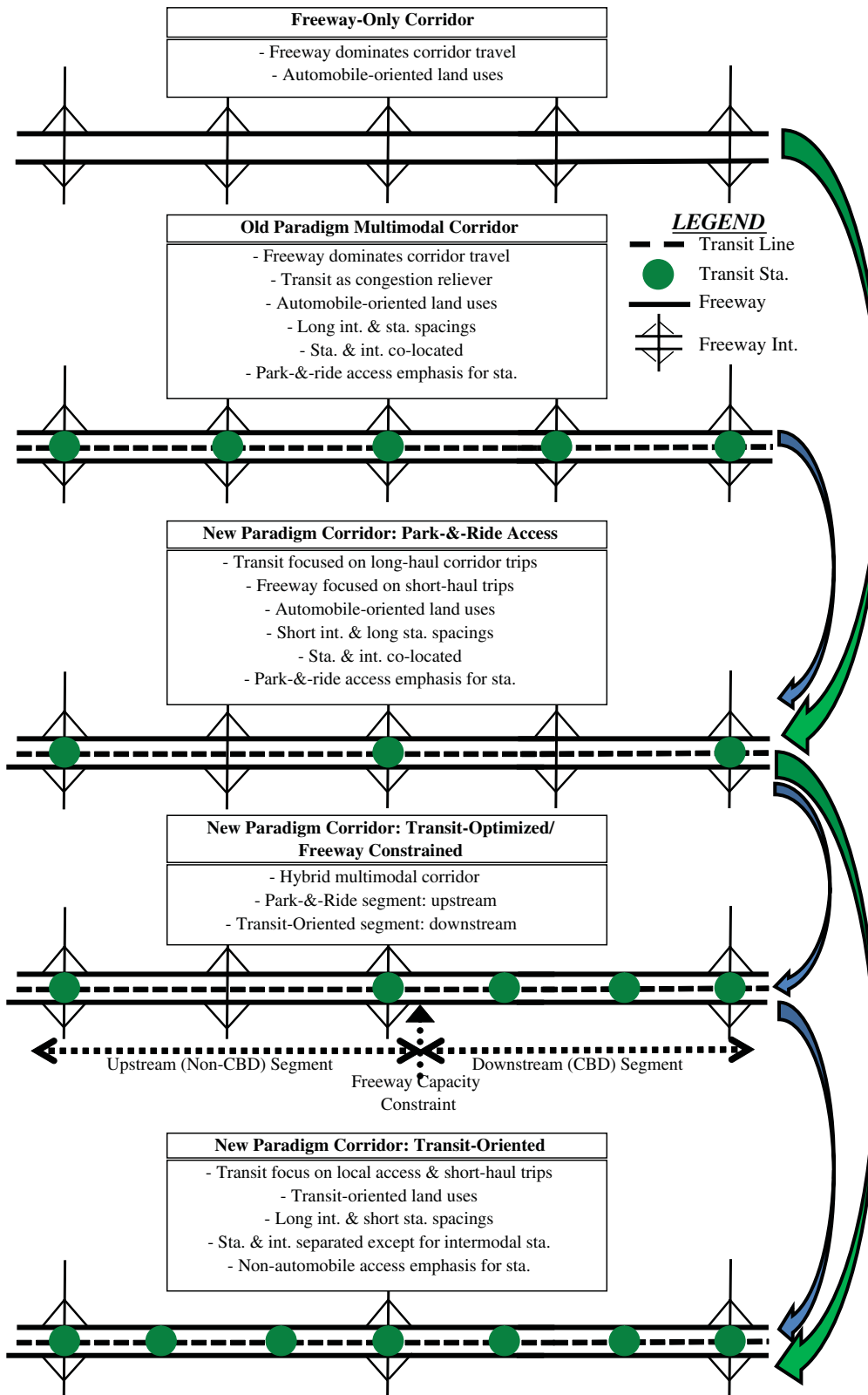


Figure S-1. Possible paths to developing transit-oriented new paradigm corridors.

characteristics. The successful development of a new paradigm multimodal corridor depends on selecting and combining them and in doing so to achieving the desired tradeoff and performance ends.

The following is a list of critical tradeoffs that describe and determine the relative success of a multimodal corridor:

- **Transit corridor accessibility** versus **operating speed**
- **Freeway accessibility** versus **operating speed**
- **Freeway capacity** versus **transit ridership**
- **Transit-oriented** versus **automobile-oriented urban form**
- **Local access** versus **intermodal transfer oriented stations**
- **In-median** and **adjacent** versus **offset freeway alignment**
- **Supplementary** versus **complementary** transit and freeway service
- **Fixed** versus **flexible transit routing**
- **Incremental** versus **concurrent corridor planning approaches**

Evidence on the Patronage Impacts of Multimodal Corridors

When transit and freeways compete with each other, the old paradigm resigned transit to take second place, serving as the overflow service to the freeway during peak congestion periods and suffering from low ridership. But analysis of existing multimodal corridors suggests transit does not need to play this role. There are transit lines that thrive in the same corridors as freeways. This study found the following characteristics correlated with multimodal corridor success:

- **Multimodal corridor coordination:** Total corridor patronage (transit and freeway) tends to be higher in corridors with complementary coordination. Complementary coordination describes the conditions where the transit and freeway facilities are designed and operated to serve different travel markets, primarily by providing either wide station spacings paired with short interchange spacings (automobile-oriented) or short station spacings and long interchange spacings (transit-oriented complementarity).
- **Transit-oriented corridor urban form:** Transit patronage is higher in corridors with transit-oriented land uses and urban design characteristics. Corridor urban form is divided into four components: density, diversity, design, and clustered destinations.
- **Transit-oriented station access:** Transit ridership is lower in corridors where freeway ramps touch down near transit stations. Corridor station access reflects the design and operational elements within and near stations that encourage either auto access (automobile-oriented) or pedestrian and other nonautomobile access (transit-oriented) modes. A high number of freeway ramps that touch down near transit stations coupled with park-and-ride lots that surround transit stations impede pedestrian station access.

Based on a combination of quantitative and qualitative analysis of the multimodal corridor case studies, the research team identified the following desirable attributes for multimodal corridors:

Transit-oriented corridors:

- High-capacity/fixed-capital-asset transit modes such as heavy rail, light rail and BRT
- Transit-dependent-rich market
- Concentrated station-area land uses

- Distributed nodes maximize activities served along entire route
- Clustered mixed-use destination(s) at many locations along corridor
- Balanced jobs and housing in corridor (jobs clustered in station areas but dispersed along corridor)
- Limited parking supply and high cost of available parking within destination CBD
- Radial metropolitan alignment with transit line serving more than one activity center along route
- Transit-oriented land uses and urban design around stations
- Stations located either adjacent or offset from freeway
- Short station spacings
- Long interchange spacings
- Ramp touchdowns located far from stations
- Station access:
 - Intermodal stations only at terminal corridor locations and major freeway-to-freeway interchanges
 - Community-oriented station access modes
 - “Green connector” paths leading to stations

Park-and-ride access corridors:

- At least one large activity center or anchor, usually a CBD with high levels of employment
- Direct access to the city center and other major “anchors” (This likely involves leaving the freeway to penetrate these areas)
- Limited and costly parking in the CBD
- Effective transit distribution in the CBD, preferably off-street
- Constrained freeway capacity such as lane drops, route convergence, and travel barriers
- Wide station spacing that permits high transit speeds
- Good access to stations on foot, by car, and/or by public transport; a limited number of freeway interchange ramps within walking distance of transit stations
- A multimodal corridor that extends at least 10 miles and has at least eight residential “catchment” stations
- Transit-supportive development in the environs of key stations
- An interagency multimodal corridor overlay zone that can specify uses and densities and form guidelines and requirements

Transit-optimized/freeway constrained corridors:

- Freeway bottleneck (lane drop or other capacity constraint) roughly mid-point in the corridor that gives transit a travel time advantage in CBD side of corridor.
- Transit-oriented corridor qualities downstream of freeway bottleneck
- Park-and-ride access corridor qualities upstream of freeway bottleneck

The Institutional Landscape for Multimodal Corridors

Getting a multimodal corridor built is one thing, but building a successful, balanced, and coordinated new paradigm corridor requires a unique combination of collaboration, flexibility, and single-minded tenacity on the part of the project’s stakeholders. Multimodal transportation systems require cooperation and collaboration between different levels of government (for example, federal, state, regional, and local), different agencies with mode-specific missions (for example, state freeway departments, transit agencies, and

city streets and roads departments), and different public agencies with divergent missions (for example, city land use planning departments and transit agencies).

During the past 50 years these organizations have evolved from being somewhat limited, mode-specific organizations into more multimodal agencies. As such, they are now better poised to plan, design and implement new paradigm multimodal corridors. In particular, the Intermodal Surface Transportation Efficiency Act (ISTEA) legislation brought key innovations into practice, including policies specifically directed at breaking down the barriers between institutions that have prevented multimodal projects from being developed.

New Paradigm Barriers and Opportunities

The complexities of multimodal corridor projects result from a combination of institutional, political, technical, and planning barriers. While some issues arise routinely in transit and highway projects, multimodal corridor projects must address the larger union of these two sets of issues.

Types of Barriers

This research has explored how various spatial, institutional, and financial barriers can inhibit successful new paradigm multimodal corridor development, and the development of a mix of activities and land uses along a corridor that can justify and support these infrastructure investments.

Physical or spatial constraints pose tangible limitations to the successful placement and operations of multimodal corridors. These include

- Regional urban structure
- Right-of-way and footprint constraints

Institutional barriers hinder the development of multimodal facilities that may otherwise meet spatial and financial requirements for success. Institutional barriers include the formal goals and objectives pursued by stakeholders, the effects of widely held perceptions and biases, and the institutionalized habits and inertia that affect established organizations, partnerships, and relationships with the public. These include

- NIMBYism (“Not in my Backyard”)
- Mode bias
- Political barriers
- Policy barriers
- Land use/zoning barriers
- Administrative barriers

Overcoming Barriers

Despite the barriers to planning, building, and operating successful new paradigm multimodal corridors, there are many tools and approaches to overcome barriers. These include practical approaches and strategic measures such as

- Viewing every corridor for its multimodal potential
- Building constituencies around multimodal alternatives
- Identifying potential linkages, sharing, and trades

Table S-2. Approaches to planning, design, and operations for old and new paradigm corridors.

Characteristics	Old Paradigm	New Paradigm
<i>Motivations for Planning</i>	Reacting to economic growth and community and environmental impacts	Proactive planning for economic, community, and environmental goals
<i>Setting Priorities</i>	Moving vehicles	Moving people and freight
<i>Assessing Needs</i>	<ul style="list-style-type: none"> ◆ Capacity ◆ Throughput ◆ Travel time costs 	<ul style="list-style-type: none"> ◆ Reliability ◆ Reduced delay times ◆ Accessibility ◆ Business logistics ◆ Economic competitiveness
<i>Analysis Approaches</i>	Individual modes and facilities	End-to-end trips focusing on multiple modes and the connections between them
<i>Planning Processes</i>	Emphasis on individual jurisdictions	Balanced approach to meeting local, regional, state, and national transportation needs

- Building the organization(s) around the project
- Reducing administrative barriers
- Focusing on quality design and service
- Prioritizing access area (around stations and interchanges) land uses
- Developing access points as coordinated and mode-segmented travel markets

Table S-2 provides an overview of the differences in planning, design, and operational approaches between the old and new paradigms.

CHAPTER 1

Multimodal Corridors—An Overview

Transportation agencies throughout the United States are faced with myriad challenges. People are stuck in traffic—consuming oil, polluting the air, and wasting time. Our transportation infrastructure is aging and inadequate under the weight of increasing travel demand. Our automobile-dominant transportation system becomes inefficient and ineffective during peak hours and emergencies—the times when it is most needed. Public transit is often too slow and limited in coverage to win over automobile users. Transit needs to be a truly competitive travel alternative, but building effective, high-capacity transit lines in developed, automobile-oriented urban areas is expensive and difficult.

In response, many U.S. cities have built multimodal freeway corridors (hereafter referred to as multimodal corridors)—freeways and high-capacity transit lines (either fixed rail or bus rapid transit [BRT]) running parallel in proximity to each other. These corridors were developed to take advantage of existing right-of-way (ROW) and minimize land acquisition costs.

Over time, multimodal corridor configurations have yielded mixed results. All things being equal, transit and freeways tend to flourish within their own, distinct land use and urban design environments. With a few notable exceptions high-capacity transit lines built in freeway corridors are generally designed with transit stations that optimize automobile access and circulation, often leaving transit, pedestrian, and bicycle access to stations as an afterthought. Although ROW costs may be lower for transit lines built in freeway corridors, it has proven difficult to attract transit riders to these automobile-dominated environments.

Research Goals and Objectives

The objectives of this research were to (1) evaluate the potential for rehabilitating and reconstructing portions of interstate freeways and other similar facilities in the urbanized areas in the United States as new paradigm multimodal transportation facilities and (2) develop strategies to plan and

implement these facilities. These facilities might be better used by people, if the facilities offer passenger mobility by multiple modes and are better integrated into communities.

A New Paradigm for Building and Operating Multimodal Corridors

This report presents a new paradigm for planning, designing, building, and operating multimodal corridors. This new paradigm emphasizes building transit lines and supporting pedestrian and bicycle facilities in existing freeway corridors. New paradigm transit facilities are built with the following goals:

- **Enhancing corridor transportation capacity and performance** without adding freeway capacity, by building and operating transit lines (including bus rapid transit, light rail, heavy rail, and commuter rail) in existing freeway corridors
- Building and operating successful transit systems in freeway corridors that attract **high transit ridership** levels and encourage **corridor livability and environmental sustainability**
- Transforming a corridor's land uses and activities to a more **transit-oriented pattern**.

Our Deteriorating Interstates—The Opportunity

In 2006, the Eisenhower Interstate Highway System celebrated its 50th anniversary. This system, along with the increasing availability of automobiles, provided this country with the mobility it needed to fuel the post-World War II economic expansion. Today, its importance cannot be overstated: it accounts for only 1 percent of U.S. highway miles but carries 24 percent of all highway traffic.¹ Much of the urban

¹AASHTO (2007) "Transportation Invest In Our Future: Future Needs Of The U.S. Surface Transportation System," February, Available at: <http://www.transportation1.org/tif1report/TIF1-1.pdf>

landscape of the nation was shaped by the interstates as well, creating the double-edged sword of economic growth and low-density, suburban sprawling development.

Now that the Interstate Highway System is exceeding its design life and with the limited availability of rights-of-way in congested urban corridors, we can coordinate freeway rehabilitation and reconstruction with high-capacity public transportation investments, changing our travel patterns and the character of our urban areas in the process.

These high-capacity multimodal transportation facilities could represent a new paradigm for corridor transportation planning. Rebuilding portions of our freeways² as multimodal facilities could increase transit mode share, reduce automobile dependence, ensure long-term mobility, refashion portions of our suburban areas to be more transit-supportive, and reduce the environmental impacts of automobile travel.

However, our understandings of how to select, redesign, and retrofit freeway corridors with transit systems that will generate sufficient ridership are in their infancy. The focus of this report is on identifying the key concepts that can guide the location of high-capacity transit facilities in or near freeway rights-of-way.

Freeways and Transit— Inherent Conflicts and Potential Solutions

The degree to which transit competes directly or works cooperatively with its freeway neighbor is the critical determinant of transit success in a multimodal corridor. Multimodal corridor transit and freeway systems often are built to compete directly with each other. When this happens, one mode can dominate, and the freeway typically attracts the most patrons. As a result, the surrounding land uses and activities will be shaped to serve the freeway, leaving transit underpatronized.

In the past, the inherent conflicts between transit and freeways were not addressed systematically. Multimodal configurations have focused on maximizing the cost-effectiveness of transit investments by minimizing construction costs. The emphasis has been on alignment of the right-of-way, while the implications of coordinated access across modes have not played a large role in planning decisions. Future investments in multimodal corridors need to address these cross-modal conflicts directly and consistently.

Although multimodal corridors with coordinated access will never compete with the best-performing transit-only corridors in terms of transit ridership or land use benefits, they may

offer an important tool to address the diminishing returns of single-mode freeway corridors—a condition that describes most suburban travel corridors in the United States today. In this sense, coordinated, high-capacity, multimodal transportation systems would represent a new paradigm in corridor planning.

Previous research has given us a solid understanding of the factors that lead to successful freeway facilities—factors such as geometric design, access ramp configurations, and surrounding land uses.^{3,4} Similarly, the post-World War II struggles of the transit industry to stem the tide of losses in ridership have led to a wealth of research and professional experiences on what makes transit systems succeed or fail.^{5–15} This literature is explored and evaluated in Chapters 3 and 4 of this report.

Unfortunately, past research gives little information about how to weave freeways, transit, pedestrians, and bicyclists together into truly multimodal corridor facilities. Frequently transit and freeway systems are built and operate separately and independently within the same physical corridor. There are benefits to be found not only from colocating transit and freeway facilities, but from the coordinated planning, design, and operation of these facilities and their surrounding built environments in a complementary fashion.

This study focuses on developing a new understanding of and approach to planning and implementing multimodal corridor

³AASHTO (2004) *AASHTO Green Book: A Policy on Geometric Design of Freeways and Streets*, 5th Edition.

⁴Skabardonis, A., et al. *Low-Cost Improvements for Recurring Freeway Bottlenecks*. NCHRP Project 03-83, anticipated publication in 2010.

⁵Cervero, R. (1998) *The Transit Metropolis: A Global Inquiry*. Washington, DC: Island Press.

⁶Vuchic, V. (2005) *Urban Transit: Operation, Planning and Economics*. Hoboken, NJ: Wiley.

⁷Vuchic, V. (2007) *Urban Transit: Systems and Technology*. Hoboken, NJ: Wiley.

⁸Deakin, E., et al. (2002) *Policies and Practices for Cost-Effective Transit Investments: Recent Experiences in the United States*. Transportation Research Record: Journal of the Transportation Research Board 1799 (–1): pp. 1–9.

⁹Cervero, R., et al. (2004) *TCRP Report 102: Transit Oriented Development in the United States: Experiences, Challenges, and Prospects*.

¹⁰Ewing, R., and Cervero, R. (2001) *Transportation Research Record 1780: Travel and the Built Environment: A Synthesis*. pp. 87–114.

¹¹Pushkarev, B. & J. Zupan (1971) *Public Transportation and Land Use Policy*. Don Mills, Ontario: Indiana University Press.

¹²Moore, T., P. Throsnes, and B. Appleyard (2007) *The Transportation/Land Use Connection*, American Planning Association., Planning Advisory Service, Report 546 (Chicago; www.planning.org), 2007.

¹³*TCRP Report 27: Building Transit Ridership* (1997) Transportation Research Board, Washington DC.

¹⁴*TCRP Report 28: Transit Markets of the Future* (1998) Transportation Research Board, Washington DC.

¹⁵Levinson, H. (1973) “Modal Choice and Public Policy in Transportation,” *Engineering Issues: Journal of Professional Activities*, Vol. 99, No. 1, January, pp. 65–75.

²Out of necessity and based on direction from TRB, the scope of this investigation is limited to corridors with freeway facilities (as opposed to other highway types).

projects. The remainder of this chapter defines the universe of multimodal facilities and corridors—both successful and less than successful—and in doing so, it identifies the parameters of the new paradigm definition.

What Is a Multimodal Corridor?

The basic components of a multimodal corridor are as follows:

- **Transportation facilities:** Discrete physical facilities for freeways, public transit, pedestrians, and bicycles.
- **Multimodal transportation facilities:** The combination of the above physical transportation facilities (multimodal facilities incorporate freeways, transit, pedestrian facilities, and bicycle facilities). The most prominent and often capital-intensive of these transportation facilities are those that provide line-haul service through the length of the corridor—the freeway and the high-capacity transit line.
- **Physical context:** The characteristics of the land use, urban design (street and block characteristics), and social, economic, demographic, and other corridor context factors.
- **Institutional context:** The institutional arrangements for physical design, freeway operations, other modal operations, and land development decisions along and near the corridor. This includes not only institutional arrangements for providing access to the corridor from the area served by the corridor but also the policies, regulations, and other transportation management actions that help determine corridor operations.

How these components are combined characterize the corridor:

- **Corridor:** The combination of multimodal facilities and the land uses surrounding them (corridor consisting of transportation facilities and the physical context—that is, the surrounding land uses and surface street network).
- **Multimodal corridor:** The combination of multimodal facilities, land uses, and institutional arrangements to facilitate multimodal uses. For this report, multimodal corridors have combinations of transit and freeways with the following characteristics:
 - **Parallel transit and freeway facilities:** A corridor is considered multimodal if it contains a parallel freeway and a high capacity transit line (rail or bus rapid transit) separated by no more than a half-mile for the length of two or more stations on the transit line. Transit facilities can be built as an elevated, at-grade, underground, or otherwise below-grade facility with any of the following alignments in relation to the freeway:

- **In-median:** transit line runs down the median of an existing freeway
- **Adjacent:** transit line runs to the side of, and immediately adjacent to, the freeway
- **Offset:** transit line runs parallel to, but up to a half-mile distant from, the freeway
- **High-capacity transit facilities:** Heavy rail, light rail, commuter rail, or bus rapid transit.
- **Transit built in available right-of-way** (if possible): Transit line built in available right-of-way (in-freeway, freeway-adjacent, or separated from the freeway by up to a half-mile).

Multimodal case study examples were investigated to determine the common factors that lead to the success of each system element. Once identified, these factors were analyzed to identify how they work together so as to develop a new understanding of how multimodal corridors and their facilities can be successfully planned, built, and operated—a new multimodal corridor paradigm.

Why Build a Multimodal Corridor?

Multimodal corridors can and should be built for several reasons. These reasons will be discussed and evaluated in the following chapters, but in brief, they are

- **Limited right-of-way availability:** Sometimes, topographic restraints such as hills or water crossings (such as in San Francisco) require facilities to be placed together; in other cases, the freeway right-of-way is superimposed on an existing rapid transit line that is to be retained (as in Chicago and Philadelphia).
- **Lower-cost right-of-way acquisition:** Combined transit and freeway facilities simplify land acquisition, bringing economies of scale to right-of-way assembly and using available rights-of-way more efficiently.
- **Additional and redundant transportation capacity:** This provides reserve capacity for long-term travel growth in the corridor, as well as redundant capacity to handle peak period (recurrent) and incident-related (nonrecurrent) congestion on all modes.
- **Fewer land “takings”:** Given that a single right-of-way can be used for both transit and freeway facilities, there is potentially less need for “takings” to acquire right-of-way, fewer residential displacements, and less disruption of existing neighborhoods and communities. This can increase the political palatability of a transit project.
- **Reduced environmental and safety impacts:** Combining transit and freeway facilities in the same alignment can effectively attenuate noise impacts and other externalities. Putting high-speed, and thus high-decibel, investments on similar

alignments keeps the noise impact zone (as well as the impact zone of fumes, vibration, visual intrusion, and headlight glare at night) within a more limited geographic area. Cost savings are also possible from building one set of sound walls and other environmental mitigations for both freeways and high-speed transit versus two separate investments. Co-alignments can also reduce the safety hazards (and the costs of mitigating them) of electric third-rails for transit lines, which must be fenced off if transit runs in its own alignment. In a freeway co-alignment, the freeway is the barrier that prevents people and animals from straying onto a rail right-of-way.

- **Coordinated environmental review:** By combining transit and freeway facilities, the negative impacts of both facilities together—particularly when sharing the same right-of-way—can be analyzed together, yielding potential environmental review cost-savings.
- **Transit-oriented development potential:** Adding a transit line to a freeway corridor can help create a corridor of high accessibility that can channel development to a more compact, transit-oriented form while offering users a choice of travel modes. Although it is unlikely that multimodal corridors can consistently and evenly achieve transit-oriented urban form patterns seen in transit-only (non-freeway) corridors across the United States, a more modest (but still effective) level of density, land use diversity, and pedestrian-oriented design is possible, particularly around select stations that are insulated from the negative externalities of their freeway neighbor.
- **Increased nonautomobile mode share:** Increased transit services in a freeway corridor can attract former automobile patrons to ride transit, thereby reducing fuel consumption, dependence on foreign oil, greenhouse gas emissions, and the air, noise, and water pollution associated with automobile travel. Increased transit use can also encourage pedestrian and bicycle activities in station areas, further reducing the attractiveness of automobile use and creating pedestrian-friendly environments.

The Old Paradigm for Multimodal Corridors

The history of multimodal corridors is discussed in detail in Chapter 2. Analysis suggests that there is a paradigm that has been governing the theory and practice of multimodal corridor development and operations to date—a system of ideas and actions that we will refer to as the old paradigm. This old paradigm has governed the choices (largely in the United States) made for designing parallel transit and freeway facilities.

The basic assumptions of the old paradigm are

- **Design for speed:** few stations with long spacings between them make for faster transit travel times. This way, transit

can compete head-to-head for the long-haul travel market in its corridor.

- **Minimize transit construction and operations costs:** low-cost transit options are emphasized.
- **Build automobile-oriented station areas**
 - Stations are close to freeway on- and off-ramps.
 - Generous park-and-ride lots surround suburban stations.
- **Build to serve a large central business district (CBD):** Transit line should directly serve a large CBD, the larger the better.
- **Use transit as congestion relief:** transit line mainly provides supplementary capacity to the adjacent freeway—it is a reliever or overflow service.

A New Paradigm for Multimodal Corridors—Segmented Travel Markets

The new paradigm offers an optimized combination of theory, policies, practical applications, and planning processes that can help ensure the construction of a thriving, low-cost transit line operating in concert with its freeway corridor neighbor. The old paradigm was based on theoretical assumptions that favored the transit line competing directly with its freeway neighbor for long-haul corridor trips and as a reliever service during peak congestion periods. In the new paradigm, however, the planning, design, and engineering efforts of multimodal corridors focus on providing distinct, separated, and optimized travel markets for each mode—transit line and freeway—while broadening the perspective of planners and politicians to use these facilities to fuel the development of transit-supportive land uses in the corridor.

Market-segmentation between transit and freeway is achieved using the following guiding principles and techniques.

Market-Segmented Transit and Freeway Designs (Multimodal Coordination)

The concepts and benefits of multimodal coordination are described in greater detail in Chapters 3 and 4. In brief, station spacings and interchange spacings along each facility are designed to give each mode an advantage either in long-haul or short-haul corridor trips. By dividing the travel market within the corridor, the new paradigm offers each mode the opportunity to thrive and potentially increases the total carrying capacity of the corridor.

Market-Segmented Urban Form Patterns

Transit and freeway facilities thrive within, and encourage their own, distinct land uses. The new paradigm encourages the development of separated, distinct land use and urban design environments for each mode within the same corridor.

The planned orientation of urban form should be guided by the location of each mode's access points—freeway interchange ramp touch-down locations and transit stations. Ideally, transit station areas should have high-density, mixed-use, pedestrian-oriented land uses and urban design characteristics, with select station areas designated as freeway- and bus-to-transit intermodal station areas. Freeway interchange locations should have lower-density, separated uses with street designs conducive to smooth traffic operations and freeway access.

Market-Specific Station Access

Transit stations and stops should be designed to encourage desired modes of access that are conducive to the surrounding land uses and designs of the corridor's multimodal transportation facilities. Corridors that focus on providing freeway-competitive transit speeds should prioritize automobile and bus access to their stations with a generous supply of park-and-ride spaces around them, bus bays for quick bus-to-line-haul transit transfers, and "kiss-and-ride" areas near station entrances to allow smooth and quick drop-off and pick-up activities. Automobile-oriented stations should be placed near freeway interchange ramps to encourage freeway-to-transit transfers.

Corridors that focus on maximizing transit line access to corridor land uses should encourage bicycle, pedestrian, and bus access to stations and discourage automobile access. Transit-oriented stations should be placed as far from freeway interchange ramps as possible to reduce automobile/nonautomobile conflicts.

Market Segmentation through Constrained Freeway Capacity

Although sometimes controversial, some multimodal corridors have developed divided travel markets by constraining the capacity of the freeway. Washington DC's Orange Line/I-66 corridor is a prime example of this, where the transit line is given a speed/travel time advantage by limiting the capacity of the freeway to between two and three lanes in each direction. The low ceiling on the carrying capacity of the freeway gives the transit line an operational advantage, particularly for long-haul corridor trips.

Coordinated and Distinct Intermodal Operations

The new paradigm incorporates two approaches to ensuring the maximum amount of interoperability among the transit line, the freeway facility, and feeder services such as bus lines, and pedestrian and bicycle facilities. These are the sparing use of intermodal connections and the use of key intelligent trans-

portation systems (ITS) designed to enhance intermodal transfers and operations.

Intermodal Connections Limited to Key Locations

Intermodal transit stations—where park-and-ride lots, bus transfer facilities, nearby freeway interchange ramps, and cross-corridor pedestrian and bicycle route facilities encourage intermodal transfers—are a critical element of any multimodal corridor. However, since land requirements for intermodal transfer operations are often high, these stations tend to discourage transit-oriented development (TOD). As a result, the new paradigm encourages limited use of intermodal stations.

These stations should be built at end-of-the-line (terminal) locations and key midline locations where existing bus lines, freeway facilities, and/or bicycle and pedestrian routes converge. In this way, a multimodal corridor should be divided into separated submarkets, with a few station areas dedicated to intermodal transfers and the rest dedicated to taking advantage of and/or encouraging transit-oriented urban form.

Intermodal Intelligent Transportation Systems

Information and communications technology systems offer a wealth of potential for improving and optimizing intermodal operations in a multimodal corridor. Intermodal transfers between freeway and transit can be facilitated and encouraged by employing real-time traveler information systems that provide information on corridor traffic conditions (congestion and incidents), transit schedule and schedule adherence, comparative corridor travel times (freeway versus transit), and station and destination parking availability and costs.

The New Paradigm as a Process

Although this offers a new perspective on multimodal corridor design and operations, it does not discard the old paradigm methods. Rather, the new paradigm uses the old paradigm's approach as a potential first step in building a corridor where transit not only survives, but thrives.

The new paradigm proposed here is based on the intersection of three multimodal corridor types, one of which includes the crucial elements of the old paradigm. The new paradigm multimodal corridor could take one of three basic forms:

- **Transit-Oriented Multimodal Corridors:** an operating environment conducive to transit, bicycle, and pedestrian access to the transit facility
- **Park-and-Ride Access Multimodal Corridors:** an operating environment conducive to automobile access to the transit facility (and the form most similar to the old paradigm)

- **Transit Optimized/Freeway Constrained Multimodal Corridors:** an environment where transit is given an operational advantage over the freeway by constraining the capacity of the freeway

Transit-Oriented Multimodal Corridors

Transit-oriented multimodal corridors are designed to give (1) transit a performance advantage in serving short- and medium-length trips and (2) the freeway a performance advantage for serving long-haul corridor trips. This travel market segmentation is achieved through several means:

- **Transit-Oriented Complementary Multimodal Coordination:** Provide a high density of transit stations with close spacings (between 0.50 and 0.75 mile) and a low density of freeway interchanges with long spacings (more than 1 mile). This configuration encourages two performance outcomes:
 - High transit and low freeway accessibility to corridor land uses
 - High freeway automobile speeds and (relatively) slower transit speeds
- **Transit-Oriented Urban Form:** encourage transit-supportive land uses and urban design qualities in the corridor, particularly near stations, while allowing automobile-oriented land uses and urban design qualities near freeway interchange ramps.
 - *Station-area urban form:* high residential and employment densities in the corridor and a grid-type street network that encourages nonautomobile travel in station areas. Station area land uses are transit-oriented, with higher density, mixed-use, and pedestrian-friendly development.
 - *Interchange area urban form:* lower residential densities and employment land uses; high-capacity, high-speed street designs.
- **Transit-Oriented Station Access:** Transit stations are designed to favor nonautomobile access. Trip origin stations are placed as far as possible from the freeway and its off-ramps to reduce the amount of automobile traffic in the station-area neighborhoods as well as the negative externalities of the freeway facility itself. Stations should be placed as far from freeway interchanges as possible to avoid automobile/nonautomobile conflicts and encourage non-automobile access to stations.
- **Corridor-Wide Jobs-Housing Balance:** Ideally, travel flows through the corridor are relatively balanced, so the capacities of the freeway and transit line are maximized. Balanced travel flows can be achieved by a corridorwide jobs-housing balance, where no station or group of stations is only a destination (such as a CBD) or a residential trip generator.

- **Limited Intermodal Stations:** With the possible exception of end-of-the-line or terminal stations, stations have few if any park-and-ride spaces, bus bays or other bus connection facilities that can disrupt pedestrian and bicycle access to stations.

Park-and-Ride Access Multimodal Corridors

Park-and-ride-access multimodal corridors are designed to provide high levels of automobile access within, and high transit speeds through, the corridor. This is achieved through several, mutually supporting design and operational elements:

- **Automobile-Oriented Complementary Multimodal Coordination:** Transit provides a long-haul travel alternative to the freeway. The corridor is designed to have a low density of transit stations with long spacings (more than 0.75 mile) and a low density of freeway interchanges with long spacings (between 0.25 and 0.50 mile). This configuration encourages the following two performance outcomes:
 - Low transit and high freeway accessibility to corridor land uses
 - Low freeway automobile speeds and (relatively) high transit speeds
- **Automobile-Oriented Urban Form:** Allow automobile-oriented land uses and urban design qualities in the corridor, particularly near interchanges and non-CBD stations, but put in place transit-oriented land use controls and plans that will enable the corridor to evolve into a more transit-friendly environment in the future.
 - **Station area urban form:** low residential and employment densities in most of the corridor, with the exception of a few destination station areas with high employment densities. The primarily low-density form is punctuated by high-density employment station areas (like those found in a CBD) where transit riders who accessed the transit line by car can walk to their destinations. Implement a hierarchical, high-capacity street network that encourages high-speed automobile travel throughout the corridor.
 - **Interchange area urban form:** low-density residential and employment land uses; high-capacity, high-speed street designs.
- **Automobile-Oriented Station Access:** The transit line's non-CBD stations are designed to favor automobile access. Trip origin stations are placed close to the freeway interchange ramps to facilitate quick, easy transfer from the freeway to the transit line; trip destination stations (such as those serving a CBD) are placed far away to promote pedestrian movements within employment centers. Origin stations have ample park-and-ride capacity and a high-capacity street network nearby to handle the peak-period demand at stations from park-and-riders and pick-up/drop-off activities.

- **Corridor Serves Large Central Business District:** Commuter travel will be encouraged on the transit line by providing direct service to a large CBD. Non-CBD corridor stations will maximize automobile-access and will serve largely suburban, automobile-oriented residential areas.

Transit-Optimized/Freeway-Constrained Multimodal Corridors

A transit-optimized/freeway-constrained multimodal corridor is designed to give transit a performance advantage in the corridor by constraining the capacity and performance of the freeway.

- **Capacity-Constrained Freeway:** These corridors constrain the capacity of the freeway facility, giving transit a performance advantage over its freeway neighbor.
- **Hybrid Corridor Configuration:** Ideally these corridors will combine the constrained freeway facility with either transit-oriented or park-and-ride access features to take full advantage of transit's performance advantage. The location of the freeway capacity constraint (bottleneck) is often a transition point for the corridor, splitting it into two sections, one of which (typically the side leading into a downtown/CBD) is transit-oriented while the other section ("upstream" from the bottleneck) provides park-and-ride access.

Conclusions: The Evolution of Multimodal Corridors Over Time

Transit thrives (in terms of ridership) when it operates in a pedestrian-oriented, high-density, mixed-use environment. It would be best for transit to build all multimodal facilities

in corridors with transit-oriented urban form characteristics, but most freeway corridors in the United States—where the lion's share of multimodal corridor opportunity sites exist—have decidedly automobile-oriented land uses and urban design qualities.

Therefore, the new paradigm offers several paths to develop multimodal corridors. First, a transit-oriented corridor can be built where the transit line is given the design, operating characteristics, and surrounding land use patterns that will effectively carve out a near-exclusive corridor travel market.

The second path involves a two-step process of multimodal corridor planning, design, and construction. In the first step, transit facilities are designed and built in freeway corridors with performance characteristics that enable them to compete with the freeway facility on a travel time basis. If done well, this park-and-ride access model aims to design the transit line to attract sufficient riders, encourage transit-oriented design (TOD) around its stations, and encourage the evolution of its surrounding corridor toward a more transit-oriented urban form.

The second step is to build infill stations (where economically and operationally feasible) that provide greater coverage and accessibility for the transit riders to corridor land uses and activities, which can further encourage the corridor to develop additional TOD. Over time, the new paradigm process can lead to the conversion from a purely automobile-oriented, freeway-dominated corridor to a park-and-ride access multimodal corridor to a transit-oriented corridor.

Therefore, our conception of the new paradigm does not discriminate against corridors with automobile-oriented urban form, but sees them as opportunities to build cost-effective, park-and-ride access transit lines that can be slowly transformed into transit-oriented corridors, if and when real estate market and political conditions support it.

CHAPTER 2

The History of Multimodal Corridors

As the interstate highway system nears completion, demand for transportation services is increasingly outstripping supply. The costs of new construction in already-built corridors have been prohibitive. Ripping out established neighborhoods to build a new transportation facility has become increasingly objectionable over the years for numerous reasons, including environmental, aesthetic, social equity, and economic disruptions.¹ Meanwhile, congestion continues to grow and the environmental consequences of automobile travel have steadily eroded public support for new freeway construction.

The motivation for developing multimodal corridors originally arose from a simple need: to assemble land for a transit (or freeway) right-of-way at a reasonable cost.¹ More recently, multimodal corridors have been seen as offering qualities beyond low-cost construction, with performance benefits over and above those possible from stand-alone freeway or transit facilities. The history of how multimodal corridors have evolved provides insights into the changing perspectives on transit, freeways, and multimodal corridors. Multimodal corridors can serve another function: providing an integrated, multimodal system where each mode complements the other, yielding a total corridor level of service greater than the sum of its parts.

Although the history of multimodal corridors offers many techniques and tools that can help achieve cost savings and avoid land acquisition headaches, building an integrated, complementary multimodal system within a travel corridor has remained an elusive goal. The new paradigm we discuss offers tools and techniques for achieving these elusive ends, but it does not throw away the lessons and insights of the old paradigm—the new paradigm builds on the methods and ideas

of previous multimodal corridor efforts. To take full advantage of both these methods, it is important to understand the history of multimodal corridors.

The Historical Evolution of Multimodal Corridors

The complexity of multimodal corridors makes it difficult to realize the goals that originally inspired their planning, design, and implementation. Several early examples of multimodal corridors combined transit and highways. Perhaps the first is New York City's Brooklyn Bridge—a structure built across the East River in the late nineteenth century—and the Manhattan, Williamsburg and Queensborough Bridges built in the early twentieth century. In the 1930s, rail transit was incorporated into the Delaware River Bridge between Philadelphia and Camden, and into the San Francisco-Oakland Bay Bridges. The Shaker Heights “rapid” (in the Cleveland, Ohio, suburbs) was built in the wide median of Shaker Boulevard in the early 1920s. On or around 1941 a section of the San Fernando Valley interurban line of the Pacific Electric Railway was relocated into the Hollywood Freeway median near Mulholland Drive in Cahuenga Pass in Los Angeles.¹

One common theme motivating all of these early examples was the desire for construction cost savings. This original purpose—to reduce land acquisition and construction costs—may have seemed like a sensible, straightforward idea, but challenges arose almost immediately that made it difficult to realize these cost-reduction benefits.

Successfully retrofitting transit facilities into an existing freeway corridor was one of the first and most intractable challenges encountered because of the potential for dislocating businesses and disrupting economic activities. This challenge was evident in the first era of multimodal corridor planning, the Street Railway Era (see Figure 2-1).

¹Krambles, G. “Expressway Rapid Transit,” A paper prepared for the 1971 ASCE-ASME National Transportation Engineering Meeting, Seattle, July 26, 1971.



Source: Public domain, United States Library of Congress's Prints and Photographs division.

Figure 2-1. Traffic and commerce disruptions from street railway lines in Washington, DC.

1890–1950: The Street Railway Era

From the earliest days of modern cities, as the industrial revolution was transforming and increasing the size of cities at a rapid pace, transportation planners and engineers gravitated toward combining transit and road facilities into street railways—the earliest version of a modern, multimodal corridor facility. By combining fixed-rail transit and urban surface streets into a single facility, social, economic, and political disruptions were minimized and a more efficient use of the existing street right-of-way and its neighboring land uses resulted.¹

But street railway systems had their drawbacks, the most serious of which were the conflicts between streetcars and other modes sharing a mixed-flow right-of-way. Before the introduction of the automobile, transit vehicles could dominate this environment, setting the pace of flow and demanding priority through a combination of the bulk and speed of their vehicles along with a liberal use of bell-clanging. As the automobile gained in popularity, streetcars began to take second priority in mixed-flow traffic and increasingly had to wait for automobile traffic congestion to clear or caused congestion themselves (see Figure 2-2).

As the automobile became the preferred mode of urban travel in U.S. cities, streetcar lines were increasingly abandoned, their tracks torn up, and their rights-of-way turned over completely to the automobile. Some cities, such as Boston and New Orleans, avoided this problem by giving streetcars their own, exclusive rights-of-way in the center median of large streets—which we might call semi-grade separated. This solution gave streetcars an advantage in terms of speed and



Source: Historic photo courtesy of San Francisco History Center, San Francisco Public Library.

Figure 2-2. Streetcar-caused congestion on San Francisco's Market Street circa 1947.

reliability, removing their operations from the congestion delays and conflicts of automobile traffic. Although this solution might have seemed ideal to transit advocates, the growth of automobile use and the demands placed on the urban street networks proved insatiable, and streetcar rights-of-way were increasingly turned over to automobile traffic.

After World War II, metropolitan areas in the United States expanded rapidly, sprawling outward with freeway- and automobile-led development, and access to and from these new suburbs to the traditional urban core areas—the neighborhoods that had been developed in a transit-oriented fashion—remained difficult and expensive. Wherever possible, underutilized transit and freight rail rights-of-way were converted into multimodal facilities, carrying both modes, or converted completely to freeways. Los Angeles's famed Pacific Electric Railway interurban rapid rail system was torn up and largely replaced with freeways. Many other cities followed suit. In Chicago, however, a hint of things to come could be seen: efforts to make transit and freeways co-exist and thrive in the same rights-of-way, were beginning.

1955–1965: The Chicago Era

Ironically, the first truly multimodal corridor—Chicago's Eisenhower Expressway/Blue Line facility—was built not as a

means to add more transit capacity but to add more freeway capacity. The planned freeway needed roughly 550 feet of right-of-way width, extending the full length of the city from east (at the central business district) to the developing suburbs in the west. Running along this alignment was the Metropolitan West Side Elevated Railway, occupying its own 75-foot-wide right-of-way. Instead of wholesale removal of the transit line as had been done in Los Angeles, Chicago acquired additional land around the existing right-of-way and rebuilt the transit line in the median of the new freeway facility.

Once completed in 1960, cost studies found that it was substantially less expensive to build rail in a multimodal corridor than the freeway facility—the division of costs was estimated at roughly 80 percent of total costs to freeway and 20 percent to rail. Passenger-loading surveys showed that the number of patrons served during peak hours exceeded those of the freeway.¹

It quickly became clear that the Eisenhower/Blue Line offered a new model for providing grade-separated transit service into the heart of an established urban area using existing or proposed freeway rights-of-way. Although this corridor was built as a multimodal facility essentially by adding a freeway to an existing transit line, its success in operational terms was sufficient proof of concept to encourage other areas to consider their own combined freeway and transit line facilities.

Chicago quickly followed this success with the Eisenhower corridor in the Kennedy (opening in 1961) and Dan Ryan Expressway (opening in 1962) corridors. Although federal monies for constructing freeways were readily available from the Federal Aid Freeway Act of 1956, the federal government had no such financing program for transit capital projects. As a result, the rail components of these corridors were not built when the expressways opened, and the Chicago Transit Agency temporarily ran buses in the mixed-flow lanes of the Dan Ryan and Kennedy facilities until rail construction funds could be found. In 1964, Congress passed legislation offering funding assistance for transit capital and construction costs. In 1966, Chicago's mayor, Richard J. Daley, put a bond initiative before the voters to fund the construction costs for the Kennedy and Dan Ryan rail lines. It passed by a 2-to-1 margin, and construction began on both projects after approval of the grant assistance from the federal government. The rail component of the Dan Ryan Expressway/Red Line was opened and operational in 1969 and in the Kennedy corridor 4 months later.¹

The design of Chicago's first three multimodal corridors was similar in many respects. However, while the case can be made that the transit facilities in the Eisenhower/Blue Line and Kennedy Expressway/Blue Line corridors were built to compete directly with their adjacent freeways for the same travel market, the Dan Ryan/Red Line corridor was built to give the rail line a competitive advantage in terms of travel speed for one segment of the corridor travel market—the long-haul



Source: Photo courtesy of Van den Bossche Peter.

Figure 2-3. Chicago's Dan Ryan Expressway/Red Line.

commute passenger (see Figure 2-3). Station spacing is a primary determinant of rail transit speeds—the fewer the number of stations, the faster the train can travel to its CBD destination. Similarly (though with less certainty) freeway interchanges play a role in determining automobile speeds because vehicles entering and exiting the freeway cause disruptions in traffic flows that can cause congestion and reduced speeds. Thus, the fewer the number of interchanges, the higher the average freeway travel speeds.

A simple comparison of the median spacings between interchanges and stations along each of Chicago's three multimodal corridors suggests planners took a different approach with the Dan Ryan Expressway/Red Line. Although the median station spacings are roughly equal to the median interchange spacings for the Kennedy and Eisenhower corridors, the median station spacings are almost double the median interchange spacings in the Dan Ryan corridor. This suggests that the Dan Ryan's planners wanted to give the rail line a competitive travel time advantage over its adjacent freeway. In this respect, the Dan Ryan line represented a shift in multimodal corridor design towards a model more similar to a commuter rail line—offering less access to neighborhoods along the spine of its corridor and emphasizing speed for long-distance commuters. This approach was enthusiastically adopted by the next wave of multimodal corridors designed for the BART system in the San Francisco Bay Area.

1965–1980: The Park-and-Ride Access Era

Taking cues from the successes in Chicago, the San Francisco region designed its heavy/rapid rail system to take advantage of available freeway rights-of-way wherever possible. Unlike Chicago's expressways, which were often planned and built in tandem with their rapid rail components, San Francisco's Bay

Area Rapid Transit (BART) system was planned, designed, and built as an afterthought to the freeway network. BART's planners knew their system would often be at a competitive disadvantage vis-à-vis the freeway system in terms of travel times, speed, the surrounding land configurations, and public perception.

BART's planners decided to try to give the system's trains a fighting chance against the freeways wherever possible. By planning multimodal corridors—where the new trains would run in the medians or directly adjacent to a freeway—BART planners designed the system to function more like a high-capacity commuter rail train than a heavy rail system. Station spacings that are much wider than in Chicago's Dan Ryan corridor are the most obvious result of this decision, giving BART trains on the Concord Line (now known as the Pittsburg/Bay Point Line) corridor very high average speeds. Similarly, large, commuter-rail-style park-and-ride lots surround most suburban stations on the BART system (see Figure 2-4). BART's suburban stations often were placed directly adjacent to freeway interchange ramps, minimizing the difficulties of intermodal transfers from freeway to BART by drivers.

Park-and-ride access station designs also encouraged and perpetuated the automobile-orientation of their surrounding corridor land uses. Long station spacings mean fewer stations within the corridor, which reduced the opportunities for BART to influence surrounding land uses and the travel patterns of corridor residents. Park-and-ride lots surrounding stations took up valuable land for car access that could have been used for transit-oriented developments. Placing BART stations close to freeway interchange ramps cemented the automobile-orientation of the areas surrounding stations,

with high automobile traffic volumes from the freeway making the street environment decidedly unfriendly for pedestrians and bicycles.

Public perception of transit as an old and slow technology was addressed as well. BART intentionally designed its trains with a sleek, futuristic appearance,² even at the expense of operational convenience and performance. A noticeable example of this public perception-driven design emphasis is the sloped front of the train design. BART's engineers intentionally designed the front and end cars to project a futuristic image; this over protests from within BART itself that the design was impractical from an operations standpoint since it would not allow front and end cars to be placed between cars in a connected train, as other heavy rail systems can.

The BART system focused on luring freeway drivers out of their cars and on to trains, by making transit attractive in terms of comparative travel times to downtown San Francisco and Oakland, by offering ease of transfer between freeways and BART, and through a futuristic design aesthetic. Although this automobile-access priority for suburban stations is sensible from the perspective of planners trying to address the competitive advantage of nearby freeways, it also limited the long-term influence of the system on corridor land use development patterns.

BART was one of the first post-World War II heavy rail system built in the United States and became a model for systems to come. BART's design priorities were adopted by planners in other cities for their multimodal corridors. The Washington Metropolitan Area Transit Authority (WMATA) and Metropolitan Atlanta Regional Transit Authority (MARTA) systems designed similar lines in freeway corridors with large station spacings and park-and-ride-oriented station access designs.

1980–Today: The Low(er)-Cost Era

Although there were cost savings to be had by sharing rail and freeway rights-of-way, most multimodal corridors planned and built since Chicago's Eisenhower Expressway/Blue Line were expensive heavy rail systems. In Chicago, the pre-existing heavy rail system made this mode the obvious choice. In San Francisco, BART planners hoped to halt and even reverse the ever-growing dominance of the automobile and its freeway system as the preferred mode of regional travel and the driving force behind suburban sprawl. Heavy rail's high passenger capacities, fast operating speeds, and image made it the transit mode of choice for large and prosperous cities. But costs of \$100 million per mile or more for heavy rail construction caused many cities



Source: GoogleEarth.

Figure 2-4. BART's Lafayette Station in the median of State Route 24.

²Webber, M., *The BART Experience—What Have We Learned?*, October 1976, No. 26, Institute of Urban and Regional Development and the Institute of Transportation Studies, University of California, Berkeley.

considering new transit lines to balk, despite any cost savings that might be had from colocating them with freeways.

Seeking lower cost solutions, many cities developed multimodal corridors in the 1980s, 1990s, and into the new millennium using less expensive transit modes. The model for this trend was the El Monte Busway in Los Angeles. Hailed as a success virtually from its opening, the busway originally consisted of a single, exclusive, reversible bus lane along the I-10 (San Bernardino) Freeway corridor—somewhat ironically, a freeway that occupies the former Pacific Electric Interurban Rail right-of-way between El Monte and downtown Los Angeles. The busway has one-way bus lanes built in the median strip or alongside the freeway, which are separated from the general-purpose traffic lanes by concrete barriers or a buffer lane with traffic posts. Downtown distribution is provided by city streets.

These attributes dramatically cut costs of construction and operations compared to its heavy rail predecessors. Buses are substantially cheaper to purchase, maintain, and operate than rail cars. A single, reversible lane needs much less right-of-way to operate than double- or triple-tracked heavy rail rights-of-way. Using city streets to distribute buses instead of acquiring dedicated rights-of-way means substantially lower land acquisition costs and fewer disruptions of established land uses.

Unfortunately, these cost-cutting measures also reduce the capacity and performance of the corridor's transit component. A single-direction, reversible lane means the line is only serving peak-period commuters in the corridor. Buses may be cheaper than rail, but they carry fewer passengers and can cost more per rider compared to a high-ridership rail line. Although using city streets to distribute buses at the destination end of a corridor substantially reduces right-of-way costs and enables more flexible and direct routing opportunities, buses must fight downtown traffic and are subject to delays and unreliability.

Despite these challenges (and the subsequent opening of the exclusive bus lane to carpools), the El Monte Busway garnered upwards of 25,000 daily bus riders in the 1980s, elevating it to a preeminent status as the “granddaddy”³ of U.S. bus rapid transit systems. It has been held up as a model for the potential of low-cost multimodal corridor transit systems.

Other cities took their cues from the El Monte, seeking to drive down the costs of transit in freeway corridors while maintaining service and performance as much as possible—for both the freeway and the transit components. Houston was next, with a BRT demonstration project that opened in 1979 on the I-94 freeway north of downtown. Houston picked up where Los Angeles left off, finding even more inventive ways to effectively cut costs and woo skeptical voters to support a

transit project. Although this proposal planned to take away a freeway lane of travel, the contraflow lane was created by taking the inside lane from the off-peak direction of travel. By taking away a lane during the peak period from the excess capacity in the nonpeak direction, the demonstration project avoided public outcry and resistance. So while this project only attracted about 6,400 bus riders, the low cost of implementation plus the introduction of a carpool lane to this congested freeway corridor were enough of a success that Houston went on to plan, build, and operate a total of six high-occupancy vehicle (HOV)/BRT lines on its region's freeways.

San Jose was next, and as in Chicago's Eisenhower corridor, this Silicon Valley hub decided to build its light rail line at the same time that they built the adjacent freeway. San Jose was quickly followed by Denver's Central/I-25 Corridor in 1994; Los Angeles' light rail Green Line/Century Freeway Corridor in 1995 and Harbor Transitway BRT line in 1996; BART's Dublin Heavy Rail line in San Francisco's east bay suburbs in 1997; Portland's MAX Airport/I-84 Red Line extension in 2001; Los Angeles' Gold LRT Line in the I-210 corridor in 2003; and Denver's LRT T-REX extension in 2006. Of these 10 multimodal corridors built since 1980, all but one (BART's Dublin Line extension) used either some variant of bus rapid transit or light rail for the transit component.

A Brief History of Multimodal Project Funding

Funding multimodal projects in the United States has always been a challenge. Since World War II, transit systems have suffered both from declining ridership and insecure financing, while highways and the automobile have become the primary means of surface transportation and have benefited from steady and relatively generous funding. This modal imbalance has made it difficult to plan, design, and build balanced, multimodal systems. Meanwhile, changing social attitudes toward these two modes have brought political and institutional changes to multimodal project funding as well. In response to these economic, political, and institutional changes, approaches to planning, designing, and building multimodal corridors have changed over time as well.

The Federal Aid Highway Act and Transit's Increasing Government Dependence

While the automobile had become the favored mode of surface transportation in the United States prior to World War II, this dominant position was cemented by the passage of the Federal Aid Highway Act in 1956. This legislation set the blueprint for building and operating the nation's interstate highway system. Its success was due in no small part

³Trombley, W., “El Monte Busway Is Rousing but Solitary Success in L.A.,” *Los Angeles Times*, September 26, 1985, http://articles.latimes.com/1985-09-26/news/mn-1357_1_el-monte

to a dependable revenue stream based largely on user fees collected through gasoline taxes and tolls. With this act, the federal government created a strong institutional link between themselves, the states, and the voters. Despite the fact that the interstate system was and still is subsidized by taxpayer receipts (currently roughly 30 percent),⁴ the general perception has been that it is self-supported by user fees. This funding stream and the projects it built became increasingly important, bringing economic development and political benefits to all levels of government.

Meanwhile, transit systems around the country, many of which had been privately owned and operated, suffered from declining ridership, revenues, and physical infrastructure. To maintain viable multimodal alternatives in their communities, many local governments acquired their local transit systems and subsidized their operations. Unfortunately, the strong and effective use of user fees to fund large portions of the interstate system has not been a successful model for transit funding due to declining ridership and farebox revenues.

As a result, multimodal projects in the United States were decidedly highway-focused throughout the 1950s and 1960s. The multimodal corridor projects built during this period, largely in Chicago (see description above), were typically freeway construction or widening projects, with transit included either because it was already there (as in the case of the Eisenhower Blue Line) or as a freeway congestion reliever service.

Reaching for Parity: Freeway Revolts and the Urban Mass Transit Administration

Almost at the same time as the passage of the Federal Aid Highway Act in 1956, freeway construction projects began to encounter local resistance. Starting in the mid-1950s in San Francisco, local residents turned activists began to oppose freeways planned to cut through existing urban neighborhoods. Often, public transit was seen as a viable and necessary alternative to urban freeway projects and antifreeway activists often found themselves in political alliances with protransit advocates and their allies in government. This local resistance to specific freeway projects also found friendly support from the nascent environmental movement, which increasingly saw freeways and the automobile as prime culprits in threatening the environment. So-called “freeway revolts” spread across the country and put pressure on the federal government to narrow the funding gap between highways and transit.

At the same time, concerns in urban municipal governments about the deterioration of their transit systems and their

⁴“Highway Statistics 2007, Funding For Highways and Disposition of Highway-User Revenues, All Units of Government, 2007.” <http://www.fhwa.dot.gov/policy/information/statistics/2007/hf10.cfm>. Retrieved 2009-06-19.

inability to find reliable funding sources for transit projects found a sympathetic ear in the Democratic administration of John F. Kennedy and his successor, Lyndon B. Johnson. In 1964, the Johnson administration championed the formation of a federal transit aid program, at that time under the administrator of the Housing and Home Financing Agency. In 1968, Congress transferred the transit program to the United States Department of Transportation (USDOT) and created the Urban Mass Transit Administration (UMTA).⁵

These programs and new institutions were intended to help bring funding and political parity for transit with freeways. But in the case of Chicago’s Kennedy/Blue Line and Dan Ryan/Red Line corridor projects, these developments were almost too late. For the first time, federal assistance for transit capital expenditures was available, but the freeways for these corridors had already been funded, built, and opened before the transit components had begun construction. Local voters had been asked to pay for these transit improvements, but it was not until 1966 that they approved a bond measure based on the promise of UMTA funds to follow.¹

The delay in transit funding for these projects effectively solidified their freeway components as the top priority for their respective corridors. Before the transit lines could be completed, the freeways had a head start in attracting patronage and influencing corridor land uses. Nevertheless, the multimodal corridor projects that followed were more balanced in their designs and funding between freeway and transit components.

Attracting Scarce Federal Funds through Marquee Transit Projects

Even after the establishment of UMTA and a dedicated transit capital funding source, multimodal corridor projects faced a severe disadvantage vis-à-vis freeways. Until 1983, the federal government funded UMTA using general revenues—as opposed to Highway Trust Fund (HTF) monies. Transit had no dedicated federal funding source. To help rectify this imbalance, Congress passed the Surface Transportation Assistance Act of 1982 (STAA) that created the Mass Transit Account (MTA) and funded it using a portion of revenues from the federal motor fuel tax for public transportation uses. STAA also increased the federal gas tax from 4 cents per gallon to 9 cents per gallon and specified that 1 cent of the 5 cents per gallon increase (20 percent) would fund the newly created MTA. Since then, for each increase in the federal gas tax, 20 percent has been deposited in the MTA.⁶

⁵APTA, “APTA Primer on Transit Funding,” August 2009, http://www.apta.com/gap/policyresearch/Documents/Primer_SAFETEA_LU_August_2009_Update.pdf

⁶APTA, “APTA Recommendations on Federal Public Transportation Authorizing Law,” Adopted October 5, 2008, Revised November 1, 2009, http://www.apta.com/gap/legissues/authorization/Documents/apta_authorization_recommendations.pdf

Despite these improvements in funding parity, transit remained a second-tier priority in most multimodal planning efforts, particularly prior to the passage of STAA. To overcome these hurdles, transit projects needed to take the center stage. San Francisco's BART system was the first heavy rail transit system built in the United States in the post-World War II era, much of it within already built or planned freeway corridors. With backing from a Department of Defense-led study that recommended a rapid rail system for the Bay Area and strong local political support, its initial system was planned, designed, and built using no federal funds. However, its high-profile status as the forerunner of a new generation of heavy rail transit systems helped win federal funding for future extensions. Therefore, and somewhat ironically, the sheer scale and expense of this heavy rail investment may have helped elevate its profile and have given it an edge in winning federal funding support.

Soon after, WMATA and MARTA won federal funding support for constructing BART-like heavy rail systems, again, often within existing freeway corridors. Multimodal corridor alignments took on new importance during this period, where the efficiencies of lower costs of right-of-way acquisition and construction could be a useful selling point to UMTA and Congress. Multimodal corridor alignments also represented the realization of political compromises between highway and transit interests. WMATA was funded and built explicitly as a compromise between these factions, who often fought vigorously, corridor by corridor, for whether a freeway or a heavy rail transit line would be built.

Approaching Parity: Flexible Funding and the Intermodal Surface Transportation Efficiency Act

One of the most important changes in the transportation legislative landscape was the Intermodal Surface Transportation Efficiency Act (ISTEA), signed into law in 1991. Prior to ISTEA's passage, multimodal corridor projects were difficult to undertake successfully. ISTEA provided the incentives and the impetus for agencies to undertake multimodal corridor projects.

The ISTEA legislation brought a number of key innovations into practice, including policies specifically directed at breaking down the barriers that have impeded multimodal projects. Among these were

- **Flexible funding of transportation projects**, providing new funds that Metropolitan Planning Organizations (MPOs) can use to fund various projects: highways, streets, transit, pedestrian, bicycle, and others
- **A direct link between transportation and environmental planning**, specifically giving transportation planners

the responsibility to meet air quality mandates (reinforcing earlier highway and air quality legislation making such calls)

- **The elevation of MPOs to a prominent role in urban transportation planning**, decision-making, and financing
- **A mandate that state DOTs adopt an intermodal approach** to transportation planning⁷
- A mandated **link between transportation and land use planning**

Whereas the federal government had traditionally provided highway funds directly to state departments of transportation (DOTs), ISTEA elevated the status of metropolitan transportation organizations (MPOs), essentially bypassing the states and putting substantial highway funds directly into local hands. At the same time, federal mode-specific funding requirements were loosened, allowing MPOs to use these funds more flexibly. As a result, highway funds need not be used for building or maintaining highways, but can be used for transit and nonmotorized projects.

This shift in the transportation finance landscape has elevated the profile and viability of multimodal corridor projects. The name ISTEA begins with the word "intermodal," indicating its authors' interest in encouraging multimodal projects. During this period, multimodal corridor projects have been growing in number and changing in design and approach. Increasingly, project sponsors sought lower costs through light rail (Portland's Blue and Red Line MAX, San Jose's Guadalupe line, and Los Angeles's Green Line) and bus rapid transit (such as Los Angeles' El Monte and Harbor BRT projects and Houston's BRT network) while the marquee and expensive heavy rail projects became more of a rarity. This low-cost priority can appear somewhat ironic, since it came during the same period that local interests gained more control over federal funding, which would suggest that cost would be less of a concern. However, the requirements for federal funding—as specified in the "Full Funding Grant Agreement" which places the risk of cost overruns squarely on the local sponsor—have also given them a new perspective on the risks of expensive megaprojects, fulfilling the promise of ISTEA's other implicit priority, efficiency.

Current Financial and Process Barriers to Multimodal Projects

Financial barriers to multimodal corridor development arise because there are separate regulations for funding highway and transit projects. First, any multimodal project that includes

⁷Goetz, A. R., et al., "Assessing Intermodal Transportation Planning at State Departments of Transportation," *World Review of Intermodal Transportation Research* 2007; Vol. 1, No.2 pp. 119–145.

significant capital investment in both highway and transit infrastructure must navigate two distinct regulatory processes, increasing the administrative burden on multimodal corridor planners. Second, although there is some flexibility in using highway funds to fund transit planning and vice versa, and some highway trust fund programs have an explicit transit focus, taking advantage of this flexibility requires considerable time and expertise and risks a loss of transparency. Third, aspects of the review process affect transit and highway projects differently; these may tend to stall transit project funding, risking that the highway project may proceed on a more advanced track, which is in itself potentially detrimental.

Added to this are considerations that take effect at the state and local level. States tend to delegate transit planning to the local and regional level and, because capital investments in transit are fewer and farther between, the base of experience in working through the federal process is potentially thinner.

Nevertheless, thus far, requests for New Starts funds have outstripped supply, and while FTA is authorized to fund up to 80 percent of the capital costs of a transit project, most projects receive less than half. This is compared to the HTF, which has traditionally provided 90 percent of construction costs for the interstate system.⁸

Coordinating a transit funding process and a highway funding process places a premium on flexible funding, but because the flexible sources of funding are more limited, this poses a constraint on the magnitude of any request that depends on flexible funding. The precise limitations on flexible use of funds are another constraint. Figure 2-5 illustrates the sources and patterns of available funding.

Historically, differences in the review process for New Starts transit projects compared to highway projects have led to unfavorable comparisons between the two, which undermine a multimodal approach. The lower ridership base for transit has rendered aggregate time savings a less substantial factor in the benefit calculations as compared to highways, but the externalities related to highway travel, such as congestion and air quality effects, are not counted as costs for highway projects.

In addition to these considerations, a long-term downward trend in the highway trust fund has been noted over most of the last decade. This is exacerbated by a decline in the real value of the gas tax over time because of inflation and threats to the absolute revenue generated as the vehicle fleet achieves higher fuel economy.

At the state and local level, trends in finance pose some constraints as well. The hypothecation (or fixed-purpose designation) of funds raised through bond measures and

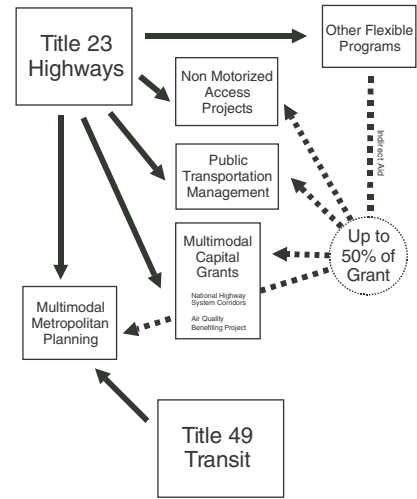


Figure 2-5. Flexible federal transportation funding.

sales taxes undermines flexibility. Many of these taxation powers are invested with municipal and county governments, often bypassing MPOs altogether, even though MPOs are charged under federal legislation with the primary planning responsibility.⁹

Somewhat ironically, the Clean Air Act is a financial barrier to building transit in new paradigm corridors. Areas in nonattainment (those regions that exceed federal air quality standards) are denied federal transportation funds, including transit capital projects funding unless it is possible to demonstrate no increase in emissions. Although withholding highway funds from nonattainment areas makes sense because highway expansions would be counterproductive to efforts to reach attainment, withholding funds dedicated to building air quality enhancing projects like transit, and specifically Congestion Mitigation and Air Quality (CMAQ) program funds, prevents transit and new paradigm multimodal projects in general from offering potential solutions.

Conclusions: History as Context— History in Context

The history of multimodal corridor planning and financing is instructive in two respects: as a lens to understand the accomplishments and shortcomings of the old paradigm multimodal corridors and as a guide to understanding the potential for the new paradigm. The history of multimodal corridor planning has been driven by the desire to add multimodal capacity (typically high-capacity transit) to urban travel corridors that can effectively compete with freeways in terms of speed and cost.

⁸Gifford, J., "The Exceptional Interstate Highway System: Will a Compelling New Vision Emerge?," *TR News*, May-June 2006, 244, p. 10.

⁹Goldman, T., and M. Wachs, "A Quiet Revolution in Transportation Finance: The Rise of Local Option Transportation Tax" *Transportation Quarterly*, 2003

This old paradigm approach has been problematic in terms of its implementation and its outcomes. Funding for transit and multimodal projects in general has been difficult to acquire. The plethora of stakeholders and partners involved in multimodal projects must be coordinated to act in concert. Difficulties in coordination were magnified by the mode-specific planning and financing institutional structures in the United States that became more balanced and collaborative only with the passage and implementation of ISTEA and its successors.

These improvements in multimodal financing and institutional collaboration have set the stage for a reassessment of multimodal corridor planning ideas, priorities, and techniques—a new paradigm. The new paradigm is intended to take full advantage of these multimodal shifts in planning and financing and seeks to redefine the priorities of these fa-

cilities from a focus on direct competition between modes, to a focus on providing segregated travel markets tailored to the natural advantages of each mode of travel in a corridor. The new paradigm also incorporates and offers a new set of tools and perspectives that can help achieve USDOT's strategic emphasis on livability initiatives. These initiatives include

- **Better integration of transportation and land use planning**
 - **Fostering of multimodal transportation systems** and effective multimodal connections
 - **Provision of more transportation options** to improve access to housing, jobs, businesses, services, and social activities
 - **Increased public participation** and enhanced coordination of transportation and housing and healthy communities
 - **Reduced emissions**
-

CHAPTER 3

Existing Multimodal Corridors— What Can We Learn From Them?

This chapter presents three types of new paradigm multimodal corridors, discusses the evolution of corridors from one type to another, and compares the old and new paradigms for multimodal corridors.

Types of New Paradigm Multimodal Corridors

The new paradigm focuses on helping transit to compete effectively with and complement a neighboring freeway facility by establishing one of the following types of multimodal corridors:

- **Transit-oriented:** an operating environment conducive to transit, bicycle, and pedestrian access to the transit facility
- **Park-and-ride access:** an operating environment conducive to automobile access to the transit facility
- **Transit-optimized/freeway constrained:** an environment where transit is given an operational advantage over the freeway by constraining the capacity of the freeway

Transit-Oriented Multimodal Corridors

Transit-oriented new paradigm corridors are designed to provide high levels of transit access within the corridor and high automobile speeds with low local (i.e., infrequent) access on the freeway. High levels of transit access are achieved by providing relatively short station spacings (between 0.50 and 0.75 mile); high automobile speeds and low local freeway access comes from relatively long interchange spacings (more than 1 mile) on the freeway. This allows the transit line to serve short- and medium-length trips, while the freeway facility is oriented toward long-haul and through trips.

Urban form in these corridors typically has high levels of residential and employment densities and a grid street network that encourages nonautomobile travel in station areas. Ideally, travel flows through the corridor will be relatively balanced,

so that both the capacities of the freeway and transit line are maximized.

The transit line's stations are designed to favor nonautomobile access. Trip origin stations are placed as far as possible from the freeway and its off-ramps to reduce both the amount of automobile traffic in the station-area neighborhoods and the negative externalities of the freeway facility. With the possible exception of end-of-the-line (terminal) stations, stations have few, if any, park-and-ride spaces, and bus bay or other bus connection facilities are sited to maximize bus access to the stations without disrupting pedestrian and bicycle access. Corridor land uses and station area access are transit-oriented, with higher density, mixed-use, and pedestrian-friendly development.

Where it Works

There are no multimodal corridors that are consistently transit-oriented over their entire lengths. However, there are cases where segments of multimodal corridors meet the transit-oriented criteria. Examples include

- Washington D.C. Orange Line/I-66: from Ballston MU Station to Rosslyn Station
- Chicago Blue Line/Kennedy Expressway (I-90): from Belmont-Blue Station to Clinton Green Station
- San Francisco East Bay (BART) Pittsburg/Bay Point Line/S.R. 24: Rockridge Station to 19th Street Station

Since these corridors are also transit-optimized/freeway constrained cases, further discussion is provided in the Transit-Optimized/Freeway Constrained Corridors section below.

Park-and-Ride-Access Multimodal Corridors

Park-and-ride-access new paradigm corridors are designed to provide high levels of automobile access and high transit

speeds. This is achieved by designing the corridor's transportation facilities in an automobile-oriented complementary fashion, taking advantage of the already-existing freeway's relatively short interchange spacings (between 0.25 and 0.50 mile) and designing the transit line to have relatively long station spacings (more than 0.75 mile). Urban form in these corridors is distinguished by

- One (or more) highly **concentrated employment centers** (i.e., single or multiple business districts)
- Relatively **low residential densities** (at least, within a mile or so of the transit line)
- A **high-capacity street network** that favors automobile access to the transit stations

Transit trip origin stations (i.e., the non-business district stations) are close to the freeway off-ramps, have ample park-and-ride capacity, and have a high-capacity street network nearby to handle the peak-period demand at stations from park-and-riders and pick-up/drop-off activities. By contrast, transit trip destination stations (i.e., the business district stations) are placed far from the freeway to promote pedestrian activities within employment centers. In these multimodal corridors, transit provides a long-haul travel alternative to the freeway.

Where it Works

- Chicago Red Line/Dan Ryan Expressway (a transitional case—see discussion below)
- Los Angeles Green Line/Century Freeway
- Denver T-REX/I-25 Corridor

Chicago Red Line/Dan Ryan Expressway. The Chicago Red Line/Dan Ryan Expressway is an excellent example of a multimodal facility. It serves various residential uses within the city. This includes a number of neighborhoods with duplexes and single-family homes. Although the freeway was built first, the Red Line was an important complement to the original south side elevated line. The Red Line extends to the north side of the city and connects with other Chicago Transit Authority (CTA) rapid transit lines in downtown Chicago. All stations are served by bus lines on intersecting streets. Sections of the freeway consist of 14 lanes of through traffic. Many of the freeway sections have continuous service roads.

The corridor shares one important element with other Chicago multimodal corridors—the size of Chicago's central business district (CBD). As discussed earlier, the CBD provides a regional concentration of destinations, which encourages people to use transit.

In terms of multimodal coordination, the average station spacing for the Red Line (1.11 miles) is more than a half-mile

longer than the average interchange spacing for the Dan Ryan Expressway (0.50 mile) suggesting an automobile-oriented complementary corridor. This difference divides the travel market within the corridor into roughly two segments—long-haul, high-speed transit riders and freeway-accessible, more dispersed travel locations. It seems likely that this design helps the Red Line compete with and complement the freeway to attract transit riders despite the corridor's station access characteristics and its lack of clear automobile-versus transit-orientation in terms of urban form.

Perhaps the most notable transit-oriented characteristic for the Red Line is the lack of park-and-ride spaces at its stations. In general, the Red Line relies on bus-to-rail transfers and pedestrian access. There are several bus transfer stations located within the freeway right-of-way, and the 95th Street Terminal station is one of the busiest in the system. Therefore, while its surrounding corridor land uses and its multimodal coordination represents an auto-orientation, its lack of park-and-ride facilities suggests that the Red Line should be considered as a transitional example from its transit-oriented cross-town neighbors (the Eastern Kennedy and Eisenhower Blue Lines) to the more automobile-oriented, park-and-ride access examples that followed it.

Los Angeles Green Line/Century Freeway. Los Angeles's Green Line/Century Freeway is a more recent example of a park-and-ride access corridor. While light rail generally has lower operating speeds and carrying capacities than commuter or heavy rail, the Green Line attracts roughly 42,000 average weekday boardings, making it one of the top performers in this study.

Furthermore, and perhaps most striking, the Green Line does not directly serve a concentrated activity center or central business district. All the other case study corridors have a radial alignment, running like a spoke on a wheel from a central business district, but the Green Line is circumferential and runs from east to west, well south of downtown Los Angeles.

Adding further challenges to the success of the Green Line, the Los Angeles region is the prototypical automobile-oriented metropolitan area. Although downtown Los Angeles is large enough to support a light rail line, with roughly 40 million square feet of office space, most of Los Angeles's trip attractors are dispersed throughout the region in a polycentric fashion.

Finally, like all multimodal corridors, the Green Line competes for ridership with its freeway neighbor. The more capacity the freeway has, the more difficult it is for transit to compete. The Century Freeway is a ten-lane facility, the largest freeway in our study. Nevertheless, the Green Line is relatively successful when compared to other multimodal corridor transit lines.

Part of the Green Line's success may be its role as a transfer facility, feeding the Blue Line, a radial alignment light rail line

that serves downtown Los Angeles. Ridership data supports this interpretation, since a substantial number of Green Line riders transfer at the Imperial/Wilmington station on to the Blue Line.

The Green Line also serves non-CBD employment and activity centers, such as the nearby Los Angeles International Airport (LAX). This would appear at first glance to be a substantial trip attractor that would mitigate the lack of direct service to a CBD, but the Green Line's nearest station to LAX (Aviation/LAX) is roughly a mile from the airport and riders have to transfer to a shuttle to reach the airport. Nevertheless, there is a fair amount of employment in the Green Line corridor, if dispersed. It has an employment density of roughly 10 employees per acre, just below the average of 11.5 for all study corridors. This is particularly impressive since some of the study corridors have downtown stations, raising the study average substantially.

Residential corridor densities are low in this corridor, with an average (gross) housing density of 3.4 dwelling units per acre (compared to an average of 5 dwelling units per acre for all study corridors). This pattern is ideal for maximizing automobile mobility, but is difficult to serve effectively with high-capacity transit.

In terms of multimodal coordination, the average station spacing for the Green Line (1.68 miles) is more than a mile longer than the average interchange spacing (0.65 mile) suggesting an automobile-oriented complementary corridor. This substantial difference divides the travel market within the corridor into two segments: long-haul, high-speed transit riders and freeway-accessible local travelers. This complementary coordination works synergistically with the predominantly automobile-oriented land uses and stations to overcome the Green Line's challenges in this corridor.

Denver T-REX/I-25. Denver's Southeast Transportation Expansion Project (T-REX) line extends along the west side of reconstructed Interstate 25 to Lincoln. LRT lines to Union Station and to 16th Street in the eastern part of the CBD link both trunk lines with the City Center (see Figure 3-1). The T-REX/I-25 corridor, which was built and opened in 2006 has been very successful at attracting transit riders. That this corridor has attracted a substantial transit ridership, despite the increased capacity brought by the T-REX project's freeway widening, suggests there is a great deal to be learned from this case.

Urban form in the corridor before the project's opening suggests an extremely automobile-oriented pattern. Housing densities were among the lowest found in the study group, with less than 1 unit per acre (gross), substantially less than the study average of roughly 5. Employment is also low, with an average density of roughly 5 employees per acre (gross), less than half the study average of nearly 12. In terms of urban design, this corridor is decidedly automobile-oriented, as well.

This study employed a proxy indicator of urban design that measured the average density of four-legged intersections in the travel corridor (see the discussion of Land Use and Urban Design characteristics in Chapter 5). With an average density of 0.4 four-legged intersections per acre compared to the study average of 0.9, this corridor has a street grid pattern that is decidedly suburban and automobile-oriented.

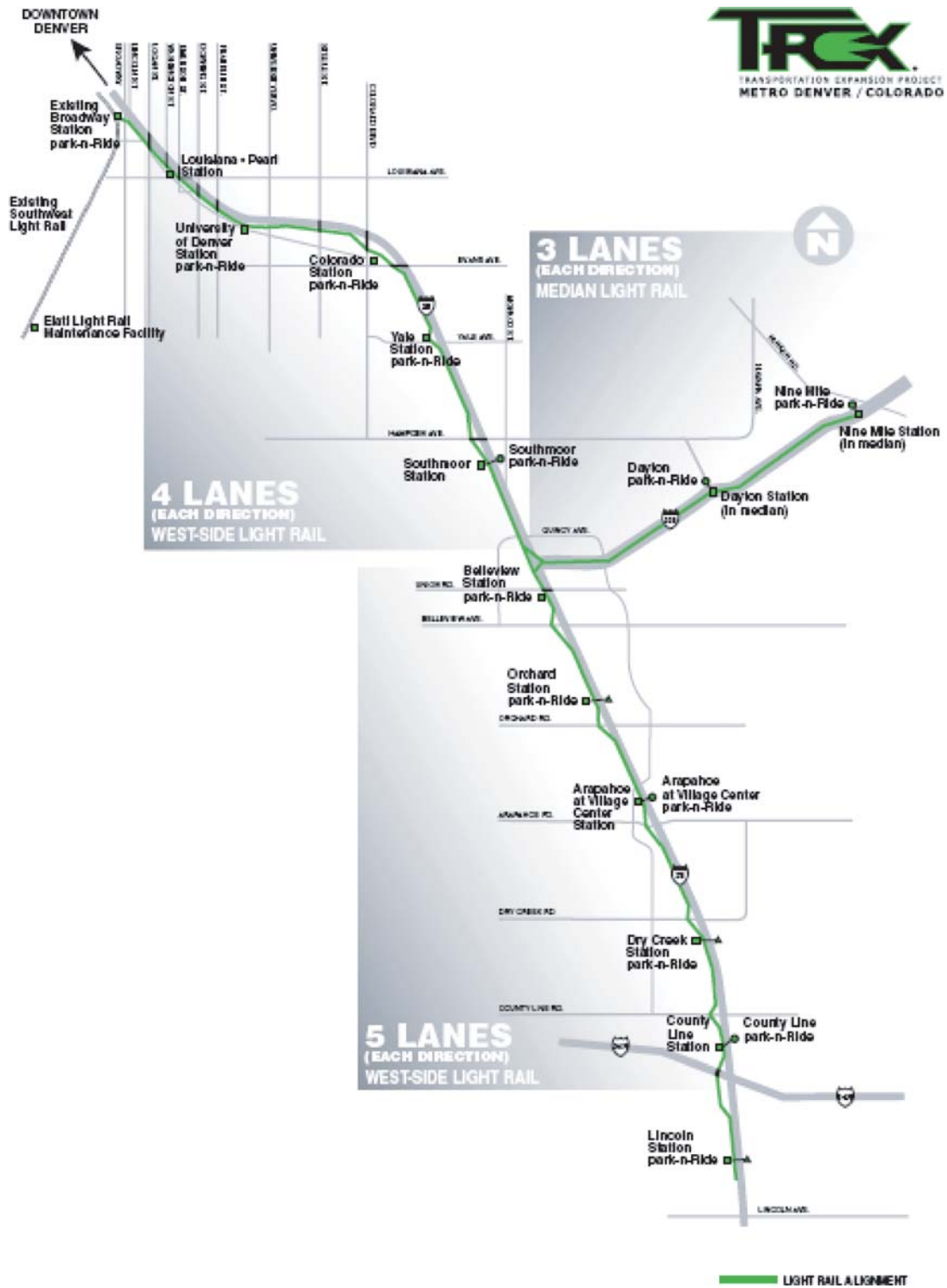
However, the size of Denver's CBD (roughly 23 million square feet) and the fact that the line also serves the Denver Tech Center—an office park concentration south of the CBD—seems to help overcome these automobile-oriented corridor challenges, providing a relatively strong anchor on which to build the transit line's ridership.

Station access indices used in this study also suggest a corridor that has been designed to maximize automobile-to-station transfers. On average, there are roughly three freeway ramps touching down within a quarter-mile of each station (higher than the 2.75 study average), suggesting that the T-REX light rail line was designed to offload traffic from the freeway onto transit. The average distance between stations and the freeway is roughly 0.05 mile, well below the study average of 0.13. While the number of park-and-ride spaces per station in this corridor (513) is below average compared to the study group (620), it is well above the average for study corridors that have light rail transit (324), suggesting that for a light rail line, this corridor's stations are highly automobile-oriented.

Transit-Optimized/Freeway Constrained Multimodal Corridors

The distinguishing feature of these corridors is the restricted capacity of the freeway facility. Constraining freeway capacity gives the corridor's transit line a performance advantage over its freeway neighbor. Ideally, these corridors will combine the constrained freeway facility with either transit-oriented or park-and-ride access features to take full advantage of transit's performance advantage. More specifically,

- **In the “upstream” (non-CBD) section** of the corridor before the freeway capacity constraint, the corridor is typically designed in a park-and-ride-access fashion where transit services are oriented toward long-haul commuter travel. Land uses and station access characteristics are generally automobile-oriented. Interchange spacings on the freeway are shorter than the transit station spacings, providing access to local corridor land uses by automobile.
- **In the “downstream” or CBD segment**, the corridor is designed in a transit-oriented fashion, with the transit line oriented toward short-haul travel. Land uses and station access in this downstream segment are generally transit-oriented as is the multimodal coordination, with long interchange spacings and short station spacings.



Source: Colorado Department of Transportation, T-REX Fact Book.

Figure 3-1. Denver's I-25/T-REX corridor alignment.

Where it Works

- Washington DC Orange Line/I-66
- Chicago Blue Line/Kennedy Expressway (I-90)
- San Francisco East Bay (BART) Pittsburgh/Bay Point Line/S.R. 24

Washington DC Orange Line/I-66. Washington DC's Orange Line runs into the District of Columbia from the Virginia suburbs to the west along Interstate 66. The rapid growth seen in this area over the past 30 years is an important part of the story behind this corridor's success. Interstate 66 is a unique case in that it was purposely built as a capacity-restricted facility. Its four to six lanes could have easily been built as eight or more to handle the rapid growth in the corridor. However, as a part of the financing package from Congress to fund the construction of the Orange Line, the Interstate was restricted to six lanes.¹ While the section between Washington DC and the Theodore Roosevelt Bridge is designated as an HOV-2-only facility during peak periods, the capacity restriction still serves to effectively discourage automobile traffic on the inner section of this corridor. As such, this case sets an example of how freeway capacity restrictions can substantially boost parallel transit line ridership and may also restrict total corridor throughput. The Orange Line's separation from the freeway as it travels through the Rosslyn neighborhood of Arlington, Virginia, helps to make this one of America's best example of off-lining an HRT alignment to leverage TOD.

Since the corridor has developed from largely rural countryside to low-density suburban with large "edge city" concentrations, urban form is decidedly automobile-oriented in its non-CBD, upstream, segment and largely transit oriented in its downstream segment. Housing densities in the corridor—about 2.4 units per acre—are well below the study average of roughly 5 units per acre. In suburban fashion, the street network in this corridor is largely automobile-oriented (largely curvilinear as opposed to a grid design) as suggested by the relatively low density of four-legged intersections (0.7 for the corridor compared to 0.9 for the study cases).

However, this corridor is rich with transit-oriented employment in its downstream segment. The Orange Line runs through several suburban "edge cities." As a result, the employment density for this corridor is estimated to be roughly 39 employees per acre, more than triple the study average of 12. Washington DC's central business district is large as well, with over 95 million square feet of office space, providing a strong set of anchors to the corridor's travel patterns and encouraging use of the transit line. These segmented land use patterns—with automobile-oriented forms upstream and transit-oriented

downstream—create an effective hybrid corridor that matches the design of the freeway and transit line to local urban form patterns. The result is a highly successful transit line—the only case in this study where the transit line's average daily boardings (139,000) exceed the estimated person trips of the freeway (127,000).

Chicago Blue Line/Kennedy Expressway (I-90). The Kennedy Corridor is unique in several respects. Built in 1962, its southern section was placed adjacent to the already existing Union Pacific Northwest Line; as a result, the neighborhood impacts of this portion of the Blue Line and the Expressway were minimized. Land uses in this corner of Chicago were established early and are distinctly transit-oriented in its downstream segment and automobile-oriented in its upstream segment.

There are several reasons for this corridor's success. First, it has a heavy rail line that provides fast, high-capacity transit service directly to downtown Chicago. This transit advantage is complemented by the freeway's design, which has a relatively modest six lanes in its western portion, giving the rail line an advantage during peak congestion hours on the freeway. However, once I-90 merges with I-94 in the southern section, the freeway facility widens to include eight general-purpose lanes and two center-median reversible lanes, providing higher freeway capacity to handle the added traffic from I-94. This freeway merge (and the reduction in total lanes from the two upstream feeder freeways) helps make the transit share of total person-trips in the corridor 16 percent and placing its ranking at fifth-highest among the study corridors.

This corridor's success is also due in part to the way the transit line and the freeway were designed to match the variations in the corridor's land uses and urban designs. Overall, housing densities in the corridor are a respectable 10 units per acre (gross) but with significant variations within it. The upstream segment generally has lower densities and the downstream segment higher. Employment densities show a similar variation, with the downstream segment providing direct access to the CBD. Downtown Chicago has one of the largest concentrations of non-commercial floorspace in the United States and is the second-largest of the study corridors. This provides a large anchor at the end of the corridor that attracts commuters to use the transit and highway facilities. The corridor's street network is also designed in a pedestrian/transit-friendly form, with a larger-than-average density of four-legged intersections per square mile, but again, the upstream street patterns are slightly more suburban than the downstream street patterns.

Access to the Blue Line's stations along this corridor is decidedly transit-oriented in design as well, but with similar differences upstream and downstream. Its stations have the lowest number of park-and-ride spaces of any study case.

¹http://en.wikipedia.org/wiki/Interstate_66

Since park-and-ride spaces encourage automobile access to stations and discourage pedestrian, bicycle, and bus access, this implies that the transit line is designed to primarily serve corridor trips for people living within the corridor, as opposed to casting a wider net and attracting automobile-to-transit transfers that often originate farther away.

The placement of the Blue Line's stations in relation to the highway facility encourages non-automobile access as well. On average, the distance from the corridor's stations to the highway is roughly 0.20 mile—higher than the average distance for the rest of the study corridors of 0.15 mile. However, most of this high average distance is due to the separation of stations from freeway in the downstream segment, where the gap is up to a half-mile, while the upstream segment has stations placed largely in the median of the freeway. This relatively large distance in the downstream segment mitigates some of the negative impacts of the highway on the transit line and has allowed the station areas there to maintain a transit-oriented urban form. Overall, these factors combine to make this corridor one of the most transit-friendly, in terms of urban form, of the study cases, largely due to its transit orientation of the downstream segment.

San Francisco East Bay (BART) Pittsburg/Bay Point Line/S.R. 24

The San Francisco BART's Pittsburg/Bay Point line runs from the East Bay suburbs of Pittsburg, Bay Point, Concord, and Walnut Creek to downtown Oakland and San Francisco. Here, as in the cases discussed above, restricting the freeway's capacity has been important to the adjacent transit line's success. But in the Pittsburg/Bay Point corridor, there are actually two freeway capacity constraints. The first occurs where Highway 24 and the BART line bore through the Oakland/Berkeley hills to reach the core Bay Area; the Caldecott Tunnel shrinks the freeway's capacity from eight to six lanes. The center bore of the tunnel is reversible, so during commuting hours, the peak direction of flow always has four lanes of travel. However, the nonpeak direction is reduced to two lanes, and as a result, there is almost always congestion and delay in both directions of travel during the A.M. and P.M. peak commute hours at the tunnel. While this nonpeak-direction capacity constriction does not directly encourage peak direction use of the BART line, it does restrict nonpeak direction flow, thereby providing direct incentive for nonpeak direction BART ridership and indirectly promoting the general perception that BART is the more hassle-free corridor alternative.

The second constraint occurs at the San Francisco Bay crossing itself, where BART runs in a submerged tube beneath the water and mud of the bay floor, while automobiles run in a parallel alignment across the San Francisco-Oakland Bay

Bridge. Since four freeways converge at the toll area at the east bay approach to the bridge, the six lanes (for each direction) of the bridge serve as a bottleneck to the ten lanes that feed it.

Both employment and housing densities (9.3 and 3.5 per acre, respectively) are below the study averages (12 and 5 per acre, respectively). The density of four-legged intersections in the corridor is similarly below average and together with the other urban form indices, suggests a moderately automobile-oriented corridor. However, there are meaningful variations in the corridor's urban form that help explain its success. Downstream of the Caldecott Tunnel, the corridor runs through the inner-ring suburbs and increasingly urban areas of Berkeley and Oakland. This segment has higher residential densities than the upstream segment, where more recent, low-density suburban development patterns have dominated.

Similarly, the corridor's stations are best described as automobile-oriented in design and function, but the upstream stations more so than the downstream stations. Overall, the average number of park-and-ride spaces per station in this corridor is roughly 1,600—more than double the study average of 620. The corridor's stations are also very close to the highway (roughly 0.05 mile on average, compared to the study average of roughly 0.13), providing an attractive option to highway drivers to exit, quickly park, and complete their trips via BART. However, the most automobile-oriented stations are generally in the upstream segment, while the downstream segment's stations tend to have fewer park-and-ride spaces and are designed to be friendlier to pedestrian access.

In terms of multimodal coordination, the average station spacing for the Pittsburg/Bay Point Line (6.42 miles) is dramatically longer than the average interchange spacing for State Route 24 (0.93 mile), resulting in a highly complementary corridor with a Coordination score of 5.5 miles. However, station spacing gets shorter in the downstream segment, providing better access from the BART line to the local land uses than in the upstream segment. Clearly, this configuration provides a speed advantage to the BART line in the upstream segment compared to other heavy rail systems with shorter station spacings and, functionally, means the line in the upstream segment operates almost more as a commuter rail line than heavy rail. This higher operating speed, plus the near-constant congestion at the Caldecott Tunnel and the Bay Bridge, gives the BART line a chance to capture a respectable share of corridor travel.

Corridor Evolution

Corridor travel patterns and built environments can change dramatically over time. Often, changes in land uses and transportation facilities affect each other. The new paradigm offers

ideas and tools to harness, guide, and shape these changes, with the goal of creating a corridor where all modes can flourish within a sustainable and livable environment.

Although the new paradigm typology offers three scenarios, as described above, each of these should not be seen as a necessary end-state. The new paradigm is designed to encourage

the evolution of freeway-only, automobile-oriented, and old paradigm corridors into transit-oriented corridors. Park-and-ride-access and transit-optimized/freeway-constrained corridors need not be seen as end-states, but steps along the evolutionary path toward livable, sustainable, efficient transit-oriented corridors (see Figure 3-2).

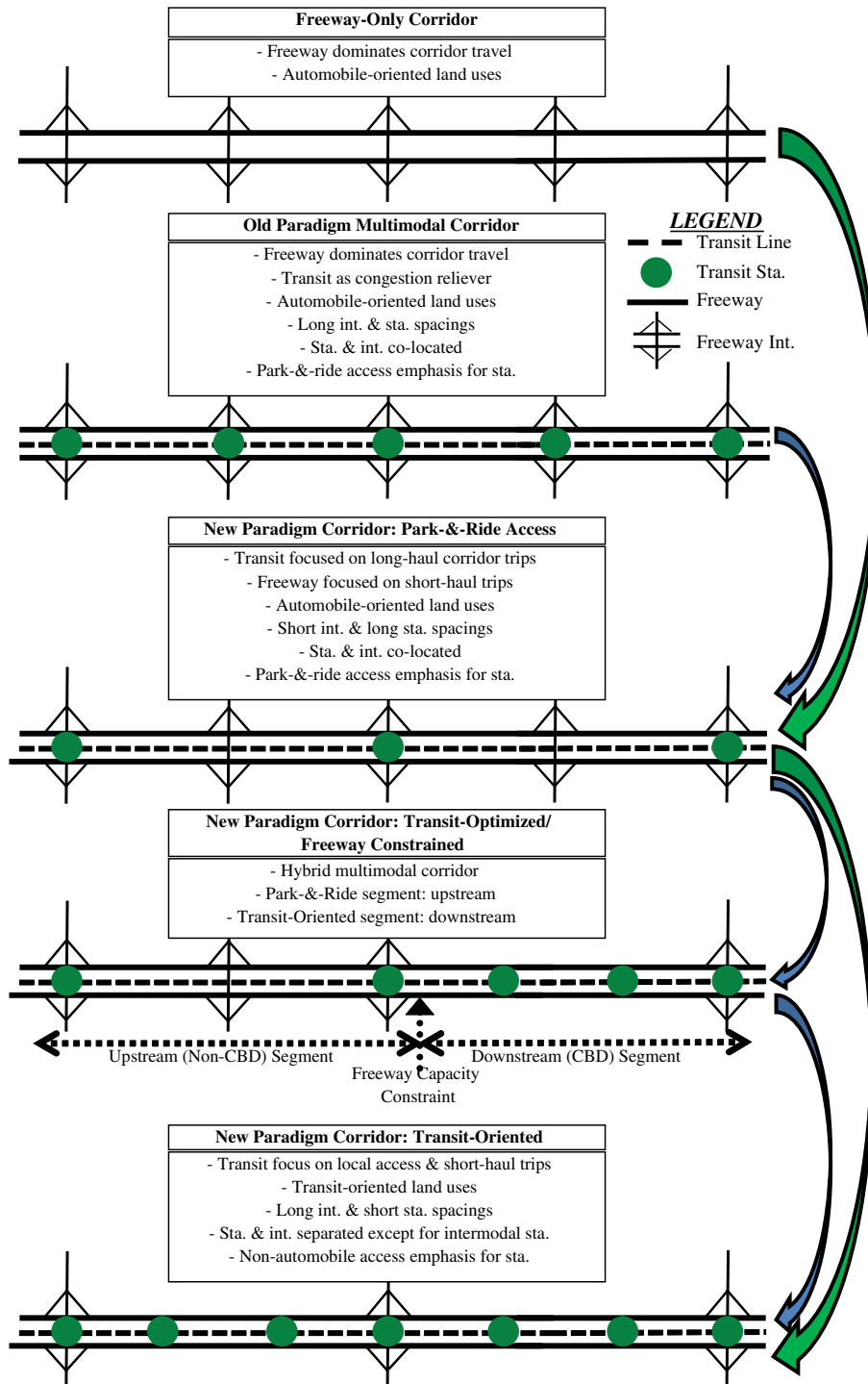


Figure 3-2. Possible paths to developing transit-oriented new paradigm corridors.

Therefore, although the success of the new paradigm requires the identification of a clear, consistent and widely supported vision for what the multimodal corridor will look like and how it will function in the long term, it does not require these changes to all take place at once. Rather, a long-term vision can be realized through a series of incremental improvements over time, with each step building on the last to create gradual and sustainable changes.

Introducing a new transit line to a corridor is particularly challenging, for all the reasons discussed in this report. Therefore, it is often unrealistic to assume that even the most radical and well-financed changes to an existing automobile-oriented, freeway-only corridor can yield a successful transit-oriented new paradigm corridor immediately. However, if transit is introduced using the principles of the new paradigm's park-and-ride access model, it can establish its own share of the corridor's travel market. Once successful as a park-and-ride access corridor, incremental changes can be introduced that can help it transition to becoming more transit-oriented over time.

Bus rapid transit can be a cost-effective park-and-ride access mode to start this evolutionary process. The following sections describe how BRT and other incremental improvements can be introduced as stepping stones leading to a more transit-oriented new paradigm corridor.

Incremental Transit Improvements: Steps Toward Full BRT and the New Paradigm

Off-freeway BRT alignments in multimodal corridors can be problematic. When BRT does not run on a grade-separated alignment and must travel in mixed-flow, on-street traffic,

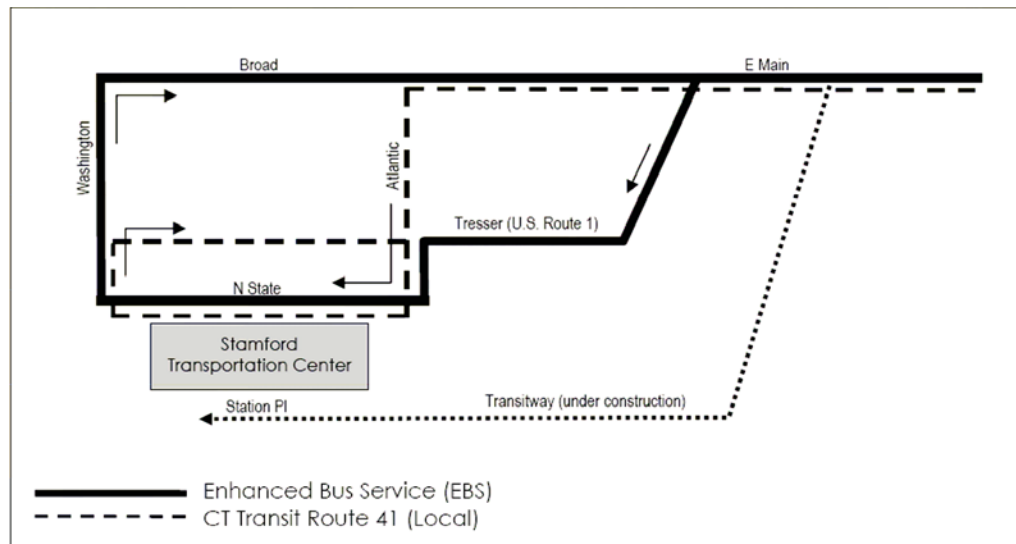
planners often must give up on the idea of competing with the freeway on the basis of comparative travel times or offer a higher level of accessibility to corridor land uses. In the planned Greenwich/Norwalk BRT line, system planners are focusing on incremental improvements to existing corridor transit services that provide improved transit travel times between the relatively dense urban centers of Greenwich and Norwalk, Connecticut.

While a full BRT alternative was considered, corridor planners opted for a more incremental approach. Planned improvements include an on-street signal preemption system to reduce intersection delays, a "priority lane," which will be shared between transit vehicles and mixed traffic, queue-jump lanes, and a suite of intelligent transportation systems to provide real-time bus arrival and departure information at bus stops, travel times, schedule adherence, and automatic announcement information.

In addition, incremental improvements will be made to intermodal terminal stops to improve quality of service and reduce dwell times. Figure 3-3 illustrates the improvements to routing that the "enhanced bus service" will provide and also shows the alignment of a dedicated transitway that will give dedicated right-of-way access into the Stamford Transportation Center.

Hybrid Multimodal Corridors: Taking Advantage of Changing Corridor Urban Form

No two corridors are the same. Each metropolitan area, and each corridor, has different travel patterns and built envi-



* All bus services will pick up and discharge passengers within the Stamford Transportation Center bus lanes

Source: Courtesy of South Western Regional Planning Agency and AECOM, Greenwich/Norwalk Bus Rapid Transit Study.

Figure 3-3. Planned incremental improvements to the Greenwich/Norwalk Bus Rapid Transit Line over time include the construction of a bus-exclusive transitway.

ronment qualities. The same goes for corridors themselves. The characteristics and travel patterns within each corridor can vary considerably. To succeed and thrive in a freeway corridor, transit must adapt to these variations.

Two of the best-performing transit lines running in multimodal corridors do just that—they are designed to change their alignments and station access characteristics depending on their surroundings. Chicago’s Kennedy/Blue Line corridor carries nearly 60,000 daily boardings, while Washington DC’s Orange Line/I-66 corridor carries roughly 139,000 daily boardings. Both owe their success in no small part to the hybrid approach system planners took to designing the alignment of these transit lines. Both corridors are split into two halves: an upstream segment (from the line terminus to roughly the midpoint of the corridor) with the transit line and its stations placed in the median or adjacent to the freeway, and a downstream segment (roughly from the midpoint of the corridor to the CBD) with the line and its stations offset from the freeway.

For each of these multimodal corridors, their transit lines and nearby freeways are designed in tune with their surrounding contexts. In more suburban environments, further from the regional CBD, park-and-ride access designs are more appropriate, as are transit-oriented designs for more urban environments closer in. Designing a successful new paradigm corridor requires that the transportation facilities match the surrounding land uses and travel patterns—either existing or planned. Once a successful new paradigm corridor is established, then incremental changes can build on these

successes, transforming both land uses and transportation facilities into the desired end-state over time.

The Old and New Paradigms Compared

The key difference between the old and the new paradigms involves the role of the freeway in corridor travel. The interstate was originally designed to serve long-haul, interstate trips. However, as the interstate model evolved over time, interstate freeways became the infrastructure of choice for intraurban travel as well, often displacing transit services into playing a supplementary, congestion-reliever role to their freeway counterparts.

There are important differences between the old and new paradigms. Both in terms of their inherent goals and tangible benefits, the new paradigm offers improved performance and efficiencies when compared to the old paradigm. The new paradigm seeks to restore freeways to their originally intended role as long-distance, intercity, and interstate facilities, and provide opportunities for transit to again be the preferred intraurban mode. Other key distinctions include the multimodal goals inherent in each paradigm, their environmental effects, and the technological, institutional, and planning techniques and models they employ. Table 3-1 summarizes these differences.

Table 3-2 provides an overview of the differences in planning, design, and operational approaches between the old and new paradigms.

Table 3-1. Comparison of the benefits and goals of the “old” and “new” paradigms.

Characteristics	Goals and Benefits	
	Old Paradigm	New Paradigm
<i>Multimodal Goals</i>		
Corridor Modal Focus	Automobile Dominated	Multimodal
Coordination	Supplementary	Complementary
Freeway Travel Markets Served	Short- and Long-Haul Trips	Long-Haul/Interurban Trips
Transit Travel Markets Served	Either Short- or Long-Haul Trips	Short-Haul/Intraurban Trips
Design Focus	Vehicle Throughput	Person Throughput
Congestion	Congestion Relief	Reduced Automobile Use
Travel Benefits	Enhanced Mobility	Enhanced Accessibility
Freight	Increased Capacity	Long-Haul/Interurban Focus
<i>Environment</i>		
Environmental Benefits	Reduced Congestion-Caused Emissions	Reduced Emissions through Mode Shift to Transit
Land Use	Automobile-Oriented	Transit-Oriented Near Stations through Coordinated Corridor Land Use Controls and Policies
Station Access	Automobile Access	Pedestrian/Transit Access

Table 3-1. (Continued).

<i>Institutions and Planning</i>		
Institutional Coordination	Highway Department Lead	Multimodal Agency Partnerships
Planning Focus	Responds to Forecasted Travel Demands	Shapes Future Pop. & Travel Growth
Planning Approach	Ad Hoc Design of Transit in Corridor	“Intentional” Multimodal Design
<i>Implementation</i>		
Transit Right-of-Way (ROW)	“Leftover” ROW in Freeway Corridor	<ul style="list-style-type: none"> • Possible Freeway Lane Conversion for Transit • “Intentional” Multimodal Design
<i>New Technologies</i>		
Goal	Freeway Capacity Maximization	<ul style="list-style-type: none"> • Modal Coordination • Maximize Person Capacity
Tools	<ul style="list-style-type: none"> • Vehicle Detection • Ramp Metering • Traffic Management Center 	<ul style="list-style-type: none"> • Electronic Fare Payment • Multimodal Traveler Information • Parking
Applications	<ul style="list-style-type: none"> • Freeway Demand Management • Incident Management • Congestion Pricing 	<ul style="list-style-type: none"> • Coordinated Multimodal Pricing • Coordinated Multimodal Incident Management • Corridor-Level Parking Management

Table 3-2. Approaches to planning, design and operations for old and new paradigm corridors.

Characteristics	Old Paradigm	New Paradigm
<i>Motivations for Planning</i>	Reacting to economic growth and community and environmental impacts	Proactive planning for economic, community, and environmental goals
<i>Setting Priorities</i>	Moving vehicles	Moving people and freight
<i>Assessing Needs</i>	<ul style="list-style-type: none"> ◆ Capacity ◆ Throughput ◆ Travel time costs 	<ul style="list-style-type: none"> ◆ Reliability ◆ Reduced delay times ◆ Accessibility ◆ Business logistics ◆ Economic competitiveness
<i>Analysis Approaches</i>	Individual modes and facilities	End-to-end trips focusing on multiple modes and the connections between them
<i>Planning Processes</i>	Emphasis on individual jurisdictions	Balanced approach to meeting local, regional, state, and national transportation needs

CHAPTER 4

Managing Multimodal Tradeoffs— Structuring Corridor Competition and Integration

This chapter offers insights into the key tradeoffs that need to be made when planning, designing, building, and operating a new paradigm corridor. Close scrutiny of existing multimodal corridors suggests that the effectiveness of a transit line within a multimodal corridor depends on its design and the design of its adjacent freeway. The new paradigm offers insights into the competition between freeways and transit and how this competition can be structured to effectively carve out travel market niches in which each mode can thrive. This chapter investigates the alternatives that should be considered when planning a new paradigm corridor project.

Multimodal Corridor Design and Operational Tradeoffs

A new paradigm corridor is planned, designed, and operated to ensure an even playing field for competition between transit and freeway by segmenting the corridor's travel markets. Segmented corridor markets—where transit and freeway are each given a distinct travel market segment—can be encouraged by the deliberate selection of combinations of planning, design, and operational corridor components. These components are discussed here as tradeoffs between performance and design characteristics that help frame the discussion of the new paradigm.

Although these tradeoffs should be considered when planning a multimodal corridor, a successful new paradigm corridor uses the sum total of these tradeoff choices as building blocks to yield a corridor that segments its travel market, giving both transit and freeway an advantage in serving a submarket. Segmented multimodal corridor markets can generally be classified as having either a transit or automobile orientation. The following section begins by describing transit and automobile corridor orientation, followed by a discussion of the building block tradeoffs that contribute to them and ensure segmented travel markets.

Transit Versus Automobile Corridor Orientation

The tradeoffs between freeways and transit lines involve the facilities themselves as well as the corridors they inhabit. The orientation of a corridor's urban form (including land uses and urban design) and the design of the transit and freeway facilities are important elements determining the relative success of the corridor's transportation facilities (see Figure 4-1).

Transit-oriented corridors are designed to maximize non-automobile access to land uses and transit stations. Land uses are generally high density with minimal parking. Walking is encouraged through the provision of dense, grid street networks with wide sidewalks and streets designed for pedestrian friendliness and moderate traffic speeds. The transit system and its surrounding circulation systems are all designed to maximize access to transit stations by all modes of travel, especially pedestrians.

Automobile-oriented corridors favor automobile mobility over nonautomobile station access. This typically leads to a corridor with low-density, dispersed land uses that are difficult for pedestrians, bicycles, and transit to traverse while automobiles can effectively, safely, and comfortably access these destinations. The freeway and its surrounding circulation systems are designed to maximize automobile throughput (capacity), automobile travel speeds, and/or automobile access to corridor land uses. If transit service exists at all in automobile-oriented corridors it generally supports automobile circulation. Transit stations or stops are designed to maximize automobile access and parking. Park-and-ride lots dominate the immediate station environments, and high-capacity road connections between station areas and the freeway encourage peak-period commuters to reduce freeway congestion by parking their cars and transferring to transit.

Few corridors are purely transit- or automobile-oriented; most have a mixture of automobile- and transit-oriented elements. These hybrid types can be placed somewhere along

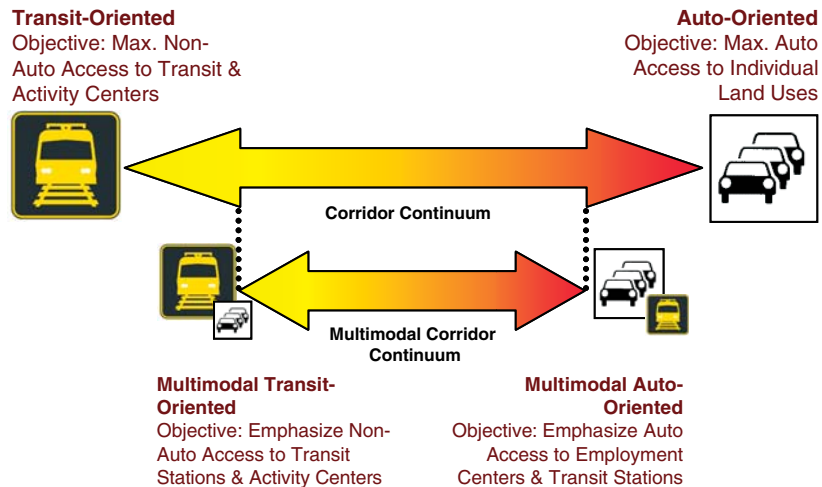


Figure 4-1. *The corridor and multimodal corridor continuums.*

the multimodal corridor continuum shown in Figure 4-1—a subset of the corridor continuum. Under this framework, we can envision a range of multimodal corridor types. At one extreme, multimodal transit-oriented corridors generally emphasize nonautomobile access to land uses and transit stations, but still provide sufficient parking and freeway-to-transit intermodal transfer capabilities to allow and encourage transfers between modes. At the other end of the spectrum, multimodal automobile-oriented corridors emphasize automobile access to relatively dispersed land uses and to the freeway.

New paradigm corridors require deliberate mixtures of these components to create segmented travel markets favoring each mode. The critical choices made for a multimodal corridor’s design revolve around the advantages and disadvantages given to each mode. Often, tradeoffs must be made between modes. An advantage given to transit may come at the expense of the performance of the freeway and vice versa. The degree to which a corridor has optimized combinations of transportation services and land uses will depend on the degree to which it was intentionally and effectively planned and managed that way. Therefore, the multimodal corridor continuum is best understood in relation to what we refer to later in this chapter as the “multimodal planning continuum” (see Figure 4-7).

Key New Paradigm Corridor Tradeoffs

The selection of new paradigm corridor design and operating characteristics should be done within the context of how these choices will affect the tradeoffs in performance among corridor modes. These tradeoff choices will, in turn, determine corridor orientation and market segmentation. The following is a list of critical tradeoffs that describe and determine the relative success of a new paradigm corridor:

- **Transit corridor accessibility** versus **operating speed**
- **Freeway accessibility** versus **operating speed**
- **Freeway capacity** versus **transit ridership**
- **Transit-oriented** versus **automobile-oriented urban form**
- **Local access** versus **intermodal transfer stations**
- **In-median and adjacent** versus **offset freeway alignment**
- **Supplementary** versus **complementary transit and freeway service**
- **Fixed** versus **flexible transit routing**
- **Incremental** versus **concurrent corridor planning approaches**

Transit Corridor Accessibility Versus Operating Speed

To a large extent, both transit coverage and operating speeds are a function of the number of stations provided on the transit line. The more stations per mile of transit line (that is, the higher the density of stations) the more area the transit line will serve and the more accessibility transit riders will have to corridor land uses. However, the more stations a transit line has, the slower the speed of the transit vehicles will be and the more difficult it will be for transit to compete with the adjacent freeway in terms of travel times.

The illustrations in Figure 4-2 show how a high frequency of stations and a circuitous alignment can increase transit accessibility to local, corridor land uses at the expense of operating speeds, while low station frequencies and straight alignments can offer higher operating speeds at the expense of transit accessibility to corridor land uses.

Transit lines generally are designed to either attract local, short-haul riders or long-haul, “through” riders. Transit generally attracts local riders when the line and its surrounding land uses are coordinated to provide high accessibility, while it attracts through passengers when it emphasizes fast operating

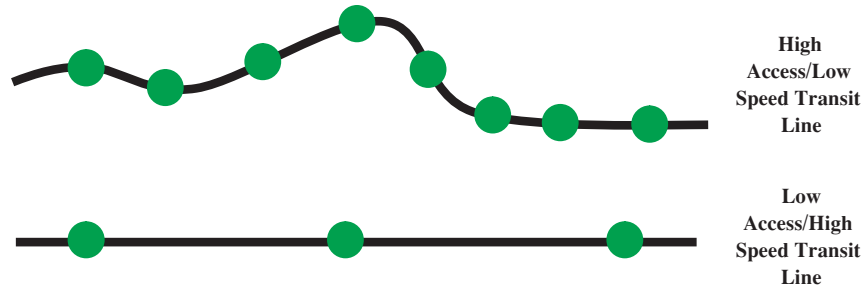


Figure 4-2. Transit corridor accessibility versus operating speed designs.

Table 4-1. Transit corridor accessibility versus operating speed tradeoff outcomes.

	Transit Corridor Accessibility	Transit Operating Speed
Market Segmentation	Local/Short-haul trips	Regional/Long-haul trips
Corridor Orientation	Transit-oriented	Automobile-oriented

speeds. Table 4-1 suggests how this tradeoff can serve the purposes of developing a new paradigm corridor to have market segmentation and an optimized corridor orientation.

Freeway Corridor Accessibility Versus Operating Speed

Freeway systems with high interchange frequencies (that is, a large number of interchanges per mile) and circuitous right-of-way alignments generally provide high levels of accessibility to local, corridor land uses at the expense of operating speeds. These facilities are often more congested because more access points and curves along a freeway tend to slow traffic.

Figure 4-3 shows how a high frequency of interchanges and a circuitous alignment can increase freeway accessibility to local, corridor land uses at the expense of operating speeds, while a low frequency of interchanges and straight alignments offer higher operating speeds at the expense of freeway accessibility to corridor land uses.^{1,2}

Similar to transit lines, freeways are generally designed to attract either local short-haul patrons or long-haul “through” patrons. Freeways tend to attract local trips when the freeway and its surrounding land uses are coordinated to provide high area coverage, while it attracts through (long-haul) passengers when the facility and its corridor alignment emphasize high

operating speeds. Table 4-2 suggests how this tradeoff can serve the purposes of developing a new paradigm corridor to have market segmentation and an optimized corridor orientation.

Freeway Capacity Versus Transit Ridership Performance

On transit lines that directly compete with freeways, ridership can suffer when freeway capacity is maximized. If ample freeway capacity is available—for example, when a freeway has enough lanes to handle peak-period traffic demand—freeway travel times will be short because of lower congestion levels and transit will not be an attractive alternative to driving. Table 4-3 suggests how this tradeoff can serve the purposes of developing a new paradigm corridor to have market segmentation and an optimized corridor orientation.

Transit-Oriented Versus Automobile-Oriented Urban Form

Urban form describes both the land uses and urban design qualities of an urban environment. Transit-oriented urban form is typically defined as high-density, mixed-use, pedestrian-friendly land uses close to transit stations. Nonautomobile-motive circulation is encouraged using dense, grid street networks and other design measures to slow automobile speeds. Automobile-oriented urban form has lower density, separated land uses with street pattern and urban design qualities intended to give priority to automobile circulation. Table 4-4 suggests how this tradeoff can serve the purposes of developing

¹AASHTO (2004) *AASHTO Green Book: A Policy on Geometric Design of Freeways and Streets*, 5th Edition.

²Skabardonis, A., et al. *Low-Cost Improvements for Recurring Freeway Bottlenecks*. NCHRP Project 03-83, anticipated publication in 2010.

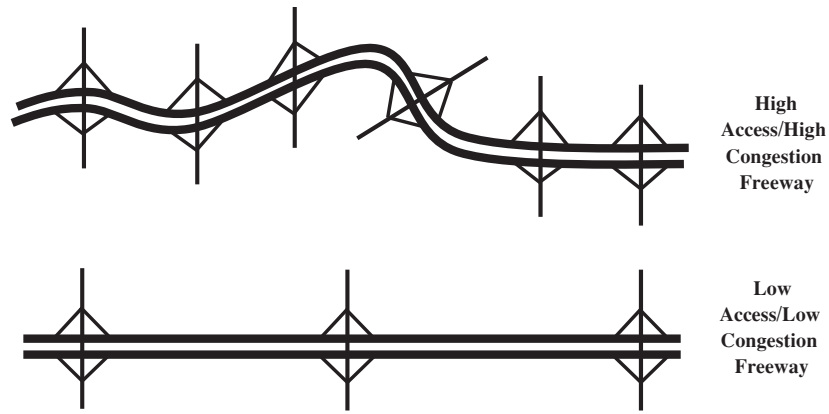


Figure 4-3. Freeway corridor accessibility versus operating speed designs.

a new paradigm corridor to have market segmentation and an optimized corridor orientation.

Local-Access- Versus Intermodal-Transfer-Oriented Stations

Local-access-oriented stations are designed to accommodate and attract patrons from nearby neighborhoods, while inter-

modal transfer stations are designed to attract patrons arriving by car or bus transit from beyond the station’s local neighborhood. Local-access stations provide excellent pedestrian, bicycle, and local circulator shuttle service access to station entrances, unencumbered by park-and-ride lots, kiss-and-ride drop-off areas, and bus terminal facilities.

Intermodal-transfer-oriented stations attract automobile- and bus-to-transit transfer patrons by providing ample

Table 4-2. Freeway corridor accessibility versus operating speed tradeoff outcomes.

	Freeway Corridor Accessibility	Freeway Operating Speed
Market Segmentation	Local/Short-haul trips	Regional/Long-haul trips
Corridor Orientation	Automobile-oriented	Transit-oriented

Table 4-3. Freeway capacity versus transit performance outcomes.

	Freeway Capacity	Transit Ridership Performance
Market Segmentation	Freeway dominates corridor travel	Transit has a potential to serve a secure travel market
Corridor Orientation	Automobile-oriented	Transit- or Automobile-oriented

Table 4-4. Transit- versus automobile-oriented urban form tradeoff outcomes.

	Transit-Oriented Urban Form	Automobile-Oriented Urban Form
Market Segmentation	Nonmotorized transit station access	Automobile transit station access
Corridor Orientation	Transit-oriented	Automobile-oriented

Table 4-5. Local access versus intermodal transfer tradeoff outcomes.

	Local Access	Intermodal Transfer
Market Segmentation	Nonmotorized transit station access	Automobile transit station access
Corridor Orientation	Transit-oriented	Automobile-oriented

park-and-ride lots, quick and effective kiss-and-ride drop-off facilities, and efficient, high-capacity bus terminal facilities to handle intermodal transfers. Intermodal stations are often located close to freeway ramp touchdown points, allowing quick freeway-to-transit intermodal transfers. Table 4-5 suggests how this tradeoff can serve the purposes of developing a new paradigm corridor to have market segmentation and an optimized corridor orientation.

In-Median and Adjacent Versus Offset Freeway Alignment

The alignment of the transit and freeway facilities has implications for the patronage of each mode as well as the costs of

constructing them. Figure 4-4 illustrates the range of horizontal multimodal corridor alignments.

In-median and adjacent alignments offer the greatest potential for cost-savings in land acquisition and construction for the transit line (assuming it is the second facility built in the corridor after the freeway) because they can take advantage of any surplus right-of-way land in or next to the freeway. Offset transit lines must often piece together vacant or otherwise available land to create a new right-of-way, potentially incurring significant costs.

The adjacent alignment/offset stations option is a hybrid variant with potential to take advantage of some of the cost savings possible from adjacent or in-median alignments while also avoiding the pedestrian and transit access impediments

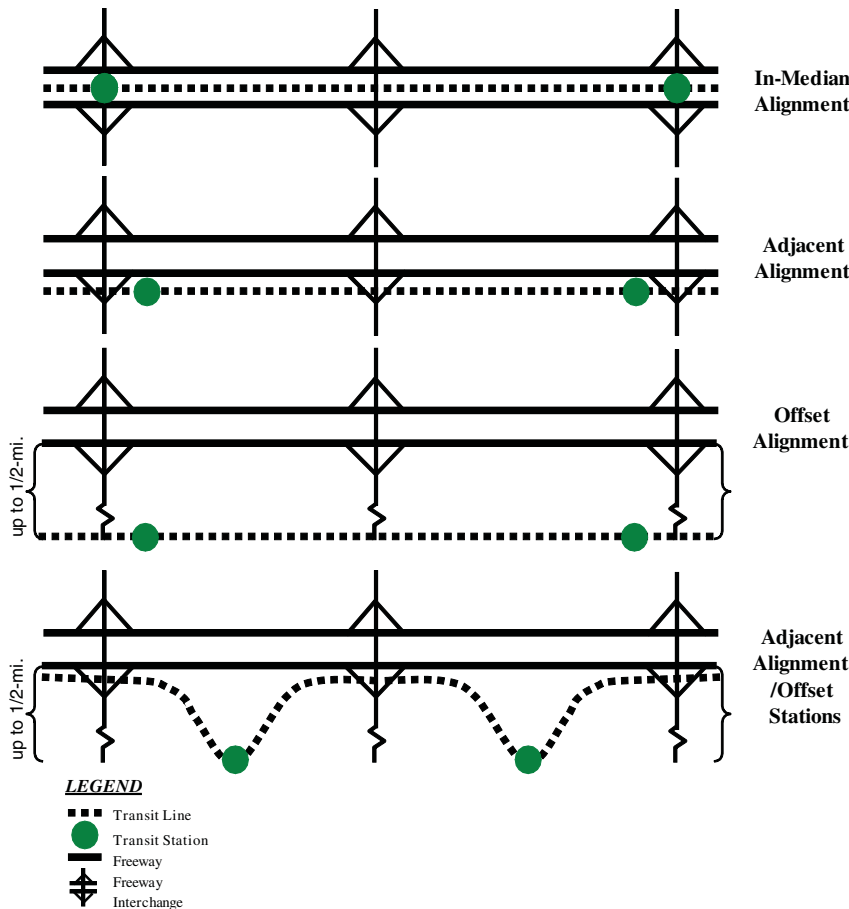


Figure 4-4. The range of horizontal multimodal corridor alignments.

of these approaches. By running the transit line primarily in the freeway ROW while locating the stations as far as possible from the freeway, benefits for pedestrian, bicycle, and feeder transit access to the stations can be realized, but often at the expense of transit operating speeds and travel times along the corridor due to the circuitous route the transit line must follow.

The range of possible corridor horizontal alignments also has significant performance implications. In-median alignments have the most potential for operational conflicts between the transit stations and the freeway and its interchange ramps. The freeway is a physical barrier to pedestrians and bicyclists accessing both adjacent and in-median stations. Traffic going to and from the freeway via its interchange ramps pose a safety hazard to pedestrians and bicycles attempting to access the stations and tend to make a transit-unfriendly environment.

Transit lines offset from their freeway neighbors can operate in greater isolation from the freeway and its automobile traffic, potentially taking advantage of a more pedestrian-friendly environment. As a result, adjacent or in-median transit lines must depend more on automobile and bus access to their stations, potentially limiting the ridership performance of their systems. In-median and adjacent transit alignments also have performance implications for freeways, since the traffic associated with station access can disrupt the smooth operation of freeway interchange ramps and reduce the carrying capacity of the freeway itself.

Table 4-6 suggests how this tradeoff can serve the purposes of developing a new paradigm corridor to have market segmentation and an optimized corridor orientation.

Multimodal Coordination: Supplementary Versus Complementary Transit and Freeway Services

A truly multimodal corridor is designed to maximize the intermodal relationships between the freeway and transit facilities in the corridor. Ideally, either automobile-to-transit or nonautomobile-to-automobile transfers will be seamless and as effortless as possible. In this way, transit and freeway systems complement each other, providing a combined level of service for corridor trips that exceeds the summed capacity and performance of its component parts.

However, the proximity of transit and freeways in multimodal corridors often cause operational conflicts for both modes. These conflicts can be minimized by effectively dividing the corridor's travel market into long- and short-haul trips and then designing the transit line and the freeway to cater exclusively to one or the other.

Although it is understood that traditionally the spacings of freeway interchanges are keyed to street patterns and design standards, while the spacings of rapid transit are keyed to bus routes, development densities, and street patterns, the effects of multimodal coordination can affect operations and patronage, without respect to the original intentions of the systems' designers.

Multimodal corridor transit and freeway facilities are generally either coordinated in a supplementary or complementary fashion.

- **Supplementary coordination** means that the additional infrastructure in terms of lanes, track, ramps, and stations will supplement the capacity of the corridor, increasing access and mobility. Supplemental effects improve the corridor capacity additively.
- **Complementary coordination** results from the fact that the transit and freeway components of the corridor may exhibit different though complementary characteristics, outcomes, and benefits. Complementary benefits would occur from the integration of modes within a multimodal corridor. Transit and freeway facilities can coexist in the same corridor, but may not work in a coordinated fashion. The various modes in a corridor might be coordinated through a common payment system, a traveler information system with comparative travel times by mode, or a coordinated, real-time congestion management system that adjusts the capacity and service deployments of one mode to compensate for the capacity constraints of another.

Corridors that have either a combination of long station spacings and short interchange spacings, or the opposite, offer complementary travel services in a multimodal corridor and tend to carry more total passengers. So-called supplementary corridors that have similarly spaced stations and interchanges will compete directly with each other for the same corridor trips, and performance of the entire corridor suffers as a result.

Table 4-6. In-median and adjacent versus offset alignment tradeoff outcomes.

	In-Median/Adjacent Alignment	Offset Alignment
Market Segmentation	Intermodal transfers/Transit as congestion relief to freeway	High level of segmentation possible
Corridor Orientation	Automobile-oriented	Transit-oriented

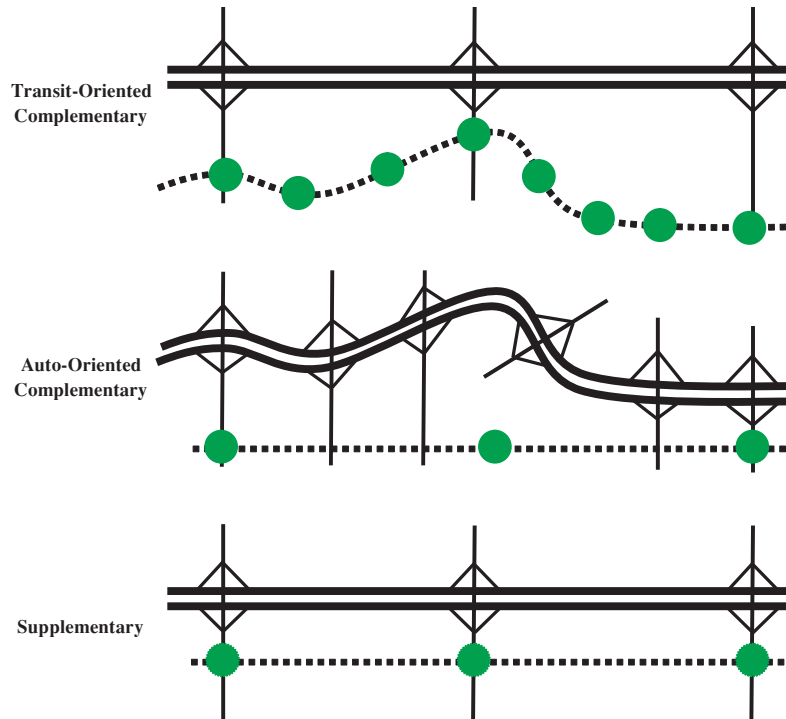


Figure 4-5. Multimodal coordination hypothetical complementary and supplementary corridors.

Analysis suggests that corridors will carry the most total passengers (transit riders and freeway passengers) if they are designed with complementary coordination, and a combination of either a transit-oriented urban form pattern and transit-oriented station access services, or automobile-oriented urban form and automobile-oriented station access.

Based on these findings, we further propose three multimodal coordination configurations (illustrated in Figure 4-5): transit-oriented complementary, automobile-oriented complementary, and supplementary.

A corridor with transit-oriented complementary coordination has long interchange spacings on its freeway component and relatively short station spacings on its transit line. This provides a high level of local accessibility and slower speeds for transit, and higher speeds and lower accessibility for automobiles via the freeway.

A corridor with automobile-oriented complementary coordination has long station spacings on its transit facility and relatively short interchange spacings on its freeway component. This provides a low level of local accessibility and higher speeds for transit, and lower speeds and higher accessibility for automobiles via the freeway.

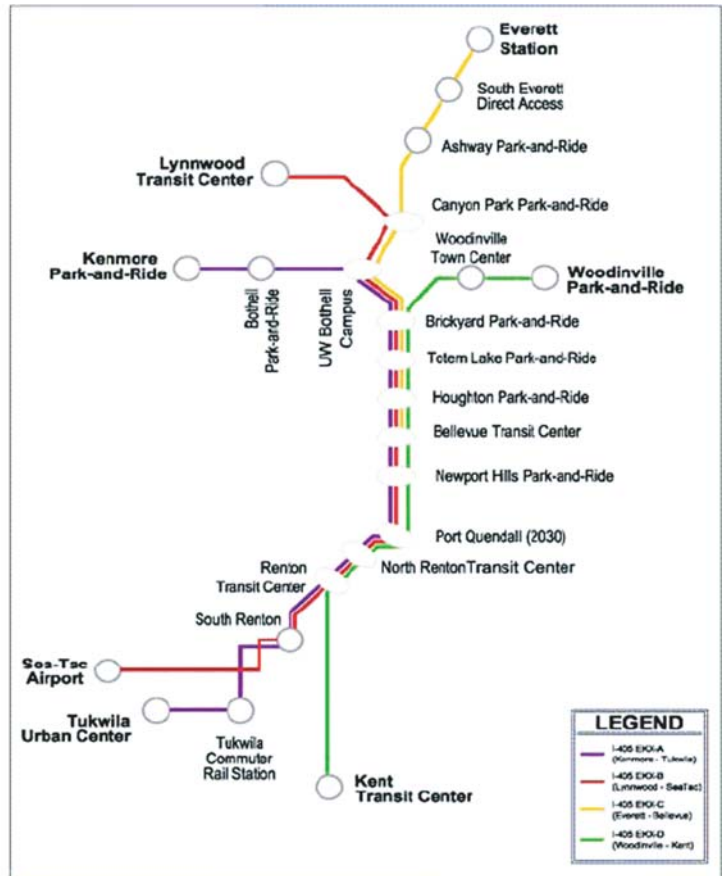
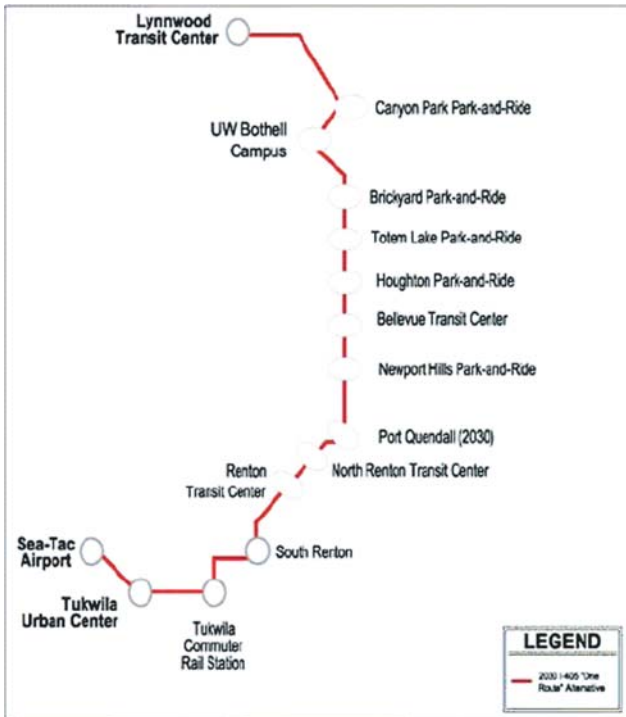
Table 4-7 suggests how this tradeoff can serve the purposes of developing a new paradigm corridor to have market segmentation and an optimized corridor orientation.

Fixed Versus Flexible Transit Routing

One of the most important advantages automobiles have over traditional transit services is their flexibility—wherever roads go, cars can go. Fixed-rail transit vehicles only go where tracks are installed. This means fixed-rail transit operates at a

Table 4-7. Multimodal coordination tradeoff outcomes.

	Supplementary	Automobile-Oriented Complementary	Transit-Oriented Complementary
Market Segmentation	Low levels of segmentation	Freeway: Local/Short-haul trips	Transit: Local/Short-haul trips
		Transit: Regional/Long-haul trips	Freeway: Regional/Long-haul trips
Corridor Orientation	Automobile-oriented	Automobile-oriented	Transit-oriented



Source: Courtesy Washington State Department of Transportation and IBI Group, I-405 South Corridor Bus Rapid Transit Pre-Design, Final Report.

Figure 4-6. Two routing alternatives for the proposed I-405 South Corridor Bus Rapid Transit System for the Puget Sound Region illustrates the flexible routing capabilities of bus rapid transit.

disadvantage vis-à-vis a freeway because automobiles can cover much more territory within the same corridor. However, BRT is not dependent on fixed right-of-way infrastructure and therefore offers flexible routing as well as the carrying capacity and speed advantages of fixed rail. BRT operating in separate facilities in or alongside a freeway median may enter and leave the freeway at selected locations, and distribute to other areas. With rail lines, this usually requires a transfer to buses. The flexible routing capabilities of BRT are illustrated in Figure 4-6.

However, just as BRT can offer some of the routing flexibility advantages similar to automobiles, it can also suffer from some of the same disadvantages that automobiles face. Automobiles can operate at a disadvantage to fixed rail and exclusive lane BRT transit services because they are slowed by sig-

nal systems and are subject to congestion. Therefore, while flexibility of routing can be an advantage for BRT, it can also lower transit’s quality of service due to signal and congestion delays when not running exclusively in a dedicated lane.

Table 4-8 suggests how this tradeoff can serve the purposes of developing a new paradigm corridor to have market segmentation and an optimized corridor orientation.

**Planning Multimodal Corridors:
Concurrent Versus Incremental Approaches**

To understand how a multimodal corridor functions and its relative success, it is necessary to understand something about its history and the process by which it was planned,

Table 4-8. Fixed versus flexible transit routing tradeoff outcomes.

	Fixed Transit Routing	Flexible Transit Routing
Market Segmentation	High level of segmentation possible	Intermodal transfers/Transit as congestion relief to freeway
Corridor Orientation	Transit-oriented	Automobile-oriented

designed, and constructed. Under this framework, an effort is made to account for how a corridor is given or has taken on multimodal features. Here, we propose a continuum that distinguishes between the degree to which a multimodal corridor has developed as a result of an explicit intention or is the incidental result of a series of planning and investment decisions over time.

To the degree that the multimodal features of facilities—transit and freeways—are designed by intention and at the same time, we refer to them as concurrently planned. To the degree that the multimodal features of corridors arise over time, organically or as a result of incremental measures, they are referred to as incrementally planned (see Figure 4-7).

At one end of this continuum is the concurrently planned multimodal corridor. A hypothetical, pure example of such a corridor is one where all transportation facilities were planned, designed, and built at the same time and in a coordinated fashion. In this way, the full performance potential of the multimodal system can be realized, with each mode both supplementing and complementing the others in a coordinated whole. The surrounding land use context within the corridor could also develop in response to this coordinated multimodal system, ideally providing an optimized transportation and land use interface.

At the other end of the continuum is the incrementally planned multimodal corridor. Here, each corridor component has been designed and built in an incremental fashion. In this extreme case, there will be few if any functional connections between the various modes running in the corridor—transit, freeway, pedestrian, and bicycle facilities will all operate relatively independently with few transfers between systems and in an uncoordinated fashion. Gradually, incremental (and often inexpensive) connections will be made between the modes to create a more cohesive and coordinated multimodal corridor system. Shuttles may be set up to run between freeway park-and-ride lots and transit stations to encourage intermodal transfers. Traffic information management systems may be installed along the freeway to provide motorists

with comparative travel times for freeway and transit to reach their corridor destinations, encouraging peak-period mode shifting. Sidewalks, paths, and bicycle routes might be added to the existing surface street network to encourage more non-automobile circulation along the corridor and non-automobile connections between modes.

Another important option along this continuum is the transit retrofit approach. Located near the incrementally planned side of the scale, a transit retrofit project involves the addition of a transit line to a pre-existing freeway facility (such as in the case of Denver's T-REX/I-25 corridor) and its surrounding corridor. This approach is distinguished by the high costs involved in redesigning and reconstructing the freeway facility (or its immediate environment) relative to the purely opportunistic/incremental approach described above, but its costs are relatively low compared to the intentionally planned system described above. Typically, the designs of capital-intensive transit systems (historically rail but increasingly bus rapid transit) are driven more by short-term cost-minimization through retrofitting than long-term ridership development-maximization principles.

Also falling in the midrange of the continuum are multimodal facilities where the plans for and the reality of their operations and constructions diverge over time. Planned facilities can become obsolete, or conflicting plans developed by different stakeholders (for example, transit agencies, freeway departments, or local land use authorities) can result in sub-optimal operations and outcomes.

Table 4-9 suggests how this tradeoff can serve the purposes of developing a new paradigm corridor to have market segmentation and an optimized corridor orientation.

Summary and Conclusions

The key to planning, designing, building, and operating a successful new paradigm multimodal corridor is to provide segmented, distinct travel markets within the corridor that each mode can serve. Segmented multimodal corridor markets can

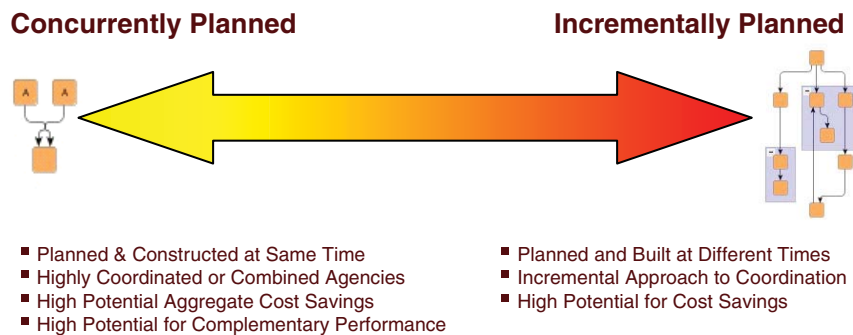


Figure 4-7. The multimodal planning continuum.

Table 4-9. Intentional versus incremental transit routing tradeoff outcomes.

	Concurrently Planned	Incrementally Planned
Market Segmentation	High level of segmentation possible	Intermodal transfers/Transit as congestion relief to freeway
Corridor Orientation	Transit-oriented	Automobile-oriented

generally be classified as having either a transit or automobile orientation. This chapter identifies the following tradeoffs that can be made when planning a new paradigm corridor:

- **Transit corridor accessibility** versus **operating speed**
 - **Freeway accessibility** versus **operating speed**
 - **Freeway capacity** versus **transit ridership**
 - **Transit-oriented** versus **automobile-oriented urban form**
 - **Local access** versus **intermodal transfer stations**
 - **In-median and adjacent** versus **offset freeway alignment**
 - **Supplementary** versus **complementary transit and freeway service**
 - **Fixed** versus **flexible transit routing**
 - **Incremental** versus **concurrent corridor planning approaches**
-

CHAPTER 5

The Design and Operational Characteristics of Success

This chapter details the key characteristics of successful new paradigm corridors. Characteristics include transportation facility type, corridor-level design and urban form, and station-level design and urban form. The selection of individual characteristics helps determine how the tradeoffs described in Chapter 4 will be managed and in turn, helps define how the corridor will function—either as a transit-oriented, a park-and-ride access, or a transit-optimized/freeway-constrained multimodal corridor.

Key Characteristics of New Paradigm Corridors

Planning, design, and operational measures can give transit a performance advantage over its freeway neighbor and help to secure a healthy level of transit patronage. The tradeoffs identified in Chapter 4 are intended as generalities—ideas and concepts that should be weighed and considered when planning, designing, and operating a new paradigm corridor. Each of these tradeoffs represents the aggregation of many individual corridor choices and characteristics. The successful development of a new paradigm corridor depends on the ability of politicians, planners, and engineers to identify the critical characteristics of the corridor being studied, determine how to combine them and, in doing so, which tradeoff options to select.

The key characteristics are listed below, followed by discussion of how they affect the tradeoffs discussed in Chapter 4, and ultimately, determine what type of new paradigm corridor will take shape:

- Transportation facility type
- Transit mode
- Transit line speed/time cost
- Freeway design
- Corridor-level characteristics
- A transit-receptive travel market
- Clustered destinations and employment

- Jobs/housing distribution
- Corridor parking management
- Metropolitan alignment
- Station-level characteristics
- Land use and urban design
- Station parking
- Freeway ramp touchdown locations
- Station design and access alternatives

Transportation Facility Type Characteristics

Transit Vehicle Type/Mode

The performance and success of transit in a multimodal corridor depends in part on the type or mode of transit system used. Each mode has its own attributes, and each will thrive or stagnate depending on the way these factors fit into the corridor's surroundings. There is no single, widely accepted system of classifying transit vehicle modes, but the following categories are useful within this discussion of the new paradigm (see Appendix B for more detailed descriptions):

1. **Local bus:** Single bus vehicles operating with a capacity of 35 to 50 seated passengers, operated along fixed routes, running in mixed-flow traffic along surface streets.
2. **Express/rapid bus:** Generally distinguished from local bus service by the limited number of stops made along a fixed route. The route can be in a surface street in mixed-flow traffic lanes either on a local surface street or a freeway. Express buses can be fitted with signal priority technology to increase running speeds
3. **Bus rapid transit (BRT):** The most important feature of BRT is that it runs on a dedicated, exclusive lane of travel, giving it a high level of service reliability (since it does not compete for right-of-way with other modes) and speed. Bus priority technologies (such as signal prioritization) are often used to improve travel times and provide a competitive edge to BRT vis-à-vis other modes. Off-bus

Table 5-1. Transit mode/type new paradigm characteristics.

Transit-Oriented Corridor Qualities	Park-and-Ride Access Corridor Qualities	Transit-Optimized/Freeway Constrained Corridor Qualities
High-capacity/fixed-capital-asset transit modes	Low-cost and automobile-access transit modes	High-speed/automobile-access transit modes
Heavy rail	Commuter rail	Commuter rail
Light rail	Bus rapid transit	Heavy rail

fare collections as well as platform boarding and alighting are frequently used to reduce dwell times at stops.¹

4. **Light-rail transit (LRT):** Light-rail vehicles run singly or in short trains on tracks in various right-of-way environments, including mixed-flow surface streets, dedicated lanes with grade crossings, and fully grade-separated dedicated facilities.¹
5. **Heavy-rail/rapid transit (HRT):** Heavy-rail transit provides intraurban service running on exclusive, dedicated, fully grade-separated rights-of-way. Called “heavy” because of its large passenger capacity, HRT can generally carry up to 50,000 passengers per hour at high speeds and excellent service reliability. Cars are generally designed to carry 90 to 150 people each in comfort, and up to double that in “crush load” conditions. The trains are typically very long compared to LRT, up to 8 to 11 cars depending on their size. To reduce dwell times and increase service speeds, HRT systems have fare collections in the stations, as well as high-level station platforms and more doors per car than other vehicles to speed boarding and alighting.¹
6. **Commuter rail:** Commuter rail provides service between a metropolitan area’s suburban areas and its main CBD. It usually shares tracks with other railroad traffic (freight and intercity passenger) and so can suffer from delays due to these competing uses. Typically, commuter trains run less frequently than other forms of rail transit, often only during peak periods. Commuter rail equipment and system design are comparable to HRT or LRT, but the route distances are often longer, ranging between 15 and 30 miles.

Table 5-1 suggests the most appropriate transit mode choices (based on their operating speeds) for each new paradigm corridor type.

Transit Line Speed/Time Cost

The higher the speed a transit line sustains, the better it will perform compared to automobile travel times and the more

riders it will attract. Maximum operating speeds depend on several factors including station spacing, vehicle design speed, vehicle design acceleration, vehicle braking rates, station dwell times, signal densities, and train densities. In general, the operating speeds for each mode can be summarized as shown in Table 5-2.

Table 5-3 suggests the most appropriate transit mode choices for each new paradigm corridor type.

Corridor-Level Characteristics

The old paradigm called for selecting a corridor where transit could effectively compete head-to-head with its freeway neighbor. The new paradigm calls for selecting a corridor where separate travel markets can be carved out for transit and the freeway—where each can have a competitive advantage. Corridor characteristics that support the establishment of these mode-segregated travel markets include the selection of a transit-receptive travel market, clustered destinations and employment centers, a favorable jobs/housing distribution, corridorwide parking pricing and supply management, and a corridor alignment within the region that serves a stable and reliable set of travel patterns.

Table 5-2. Transit average operating speeds by mode.

Mode	Average Speed (Miles per Hour)
Bus ¹	12.6
Bus Rapid Transit (Freeway) ²	20 - 30
Bus Rapid Transit (Arterial) ²	8 - 9
Commuter Rail ¹	31.5
Heavy Rail ¹	20.4
Light Rail ¹	15.5

Sources:

1 - American Public Transportation Association, <http://www.apta.com/research/stats/service/speed.cfm>

2 - TCRP 90: Bus Rapid Transit. Vol. 1, p. 23.

¹Pushkarev, B. and J. Zupan, 1971. Public Transportation and Land Use Policy. Don Mills, Ontario: Indiana University Press.

Table 5-3. Transit line speed new paradigm characteristics.

Transit-Oriented Corridor Qualities		Park-and-Ride Access Corridor Qualities	Transit-Optimized/Freeway Constrained Corridor Qualities
Local access-oriented lower-speed transit modes	or	Automobile-competitive/higher-speed transit modes	Automobile-competitive/higher-speed transit modes
Heavy rail		Heavy rail	Heavy rail
Light rail		Commuter rail	Commuter rail
Bus rapid transit		Bus rapid transit	
		Express bus (as transitional transit mode until BRT can be developed)	

Transit-Receptive Travel Market

Transit markets are often broken down into two groups: transit-dependent riders, who are forced by economic or travel necessities to use transit, and transit-choice riders, who can use transit and are receptive to doing so as long as the pricing, performance, and convenience of doing so are favorable. We refer to these two groups collectively as a transit-receptive market. For the most part, the more transit-receptive the travel market is within the corridor, the more successful the transit line will be at attracting riders.

Transit-receptive markets can be identified in demographic terms. The following demographic characteristics are generally associated with high-transit-usage markets:²

- Zero-vehicle households
- African American, non-Latino
- Asian, Pacific Islander
- Latino
- Renters
- One-vehicle households
- Females

In addition, the following demographic groups have been identified as holding promise for developing as a base for future transit use:³

- Zero-vehicle households with incomes greater than \$15,000 (1989)
- College- or graduate-school-educated

- High-school-educated aged 17–29
- Immigrants
- Aged 65+

Park-and-ride access new paradigm facilities are likely to thrive in corridors where there are an abundance of transit-choice riders. Because choice riders are more likely to switch modes when travel conditions favor it, they will provide the flexible travel market receptive to intermodal transfers. However, since park-and-ride access corridors are often unfriendly for pedestrians, such systems are not favorable for transit-dependents who usually cannot afford an automobile and therefore cannot flexibly switch modes when travel conditions favor it.

A successful transit-oriented multimodal corridor is more likely to favor transit-dependent riders while still offering adequate access and performance to the “choice” riders. These corridors offer pedestrian-friendly access to stations and, therefore, may flourish in transit-dependent-rich environments. Table 5-4 suggests the most appropriate travel markets for each new paradigm corridor type.

Clustered Destinations and Employment

Clustered destinations (particularly employment centers) that concentrate trip ends within easy walking distance of transit stations generally encourage non-automobile and transit use. Typically, the automobile congestion that occurs in concentrated CBDs discourages driving. Table 5-5 suggests the most appropriate destination and employment cluster choices for each new paradigm corridor type.

Jobs/Housing Distribution

This factor primarily describes the distribution and concentrations of land uses at the corridor level. Several researchers

²TCRP Report 27: *Building Transit Ridership*, 1997, Transportation Research Board, Washington DC, p. 22, Table 15.

³TCRP Report 28: *Transit Markets of the Future*, 1998, Transportation Research Board, Washington DC, p. 36, Table 16.

Table 5-4. Transit-receptive travel market new paradigm characteristics.

Transit-Oriented Corridor Qualities	Park-and-Ride Access Corridor Qualities	Transit-Optimized/Freeway Constrained Corridor Qualities
Transit-dependent-rich market	Transit choice-rich market	Transit receptive market

Table 5-5. Clustered destinations and employment new paradigm characteristics.

Transit-Oriented Corridor Qualities	Park-and-Ride Access Corridor Qualities	Transit-Optimized/Freeway Constrained Corridor Qualities
Distributed nodes maximize activities served along entire route	Clustered destinations at limited number of station areas	Hybrid corridors with clustered destinations on one side of freeway capacity constraint location (bottleneck) and clustered residential stations on the other
Clustered mixed-use destination(s) at many locations along corridor	Clear distinction between residential stations and destination stations	

Table 5-6. Jobs/housing distribution new paradigm characteristics.

Transit-Oriented Corridor Qualities	Park-and-Ride Access Corridor Qualities	Transit-Optimized/Freeway Constrained Corridor Qualities
Balanced jobs and housing in corridor (jobs clustered in station areas but dispersed along corridor)	Jobs clustered in destination station/CBD and low in other stations	Jobs clustered near stations on the CBD side of the freeway bottleneck and few jobs near stations on the other side

have developed accessibility measures^{4,5} and measures of corridor-level jobs-housing balance.⁶ Others have focused on the presence of a CBD along the transit corridor, setting minimum thresholds for heavy rail, light rail, commuter rail, and bus transit services according to CBD size.^{1,7}

Research suggests that a corridor with employment and residential destinations spread throughout the corridor will encourage more balanced, efficient travel flows on its transportation systems.⁸ Another important aspect is to keep

traffic contained within “travelsheds” (collections of trip origins and destinations) that minimize lateral and cross-corridor movements—the type of flows for which there tends to be the fewest available road facilities, often leading to suburban congestion, trip circuitry, and the forced funneling of traffic onto the few available cross-town connectors, such as ring roads. Travelsheds can be effectively contained using corridor-level land use controls that limit employment land uses (trip destinations) to locating in designated central business districts at the terminal ends of a new paradigm corridor.

The choice of an ideal jobs/housing distribution for a new paradigm corridor depends on the existing conditions of the corridor and which new paradigm typology category best describes it (see Table 5-6).

Corridor Parking Management

Parking availability and cost are important factors in determining transit market share, both at the station level and for the corridor as a whole. Transit ridership can be enhanced through a coordinated system of land use and parking controls

⁴Ferrell, C. “Home-Based Teleshoppers and Shopping Travel: Do Teleshoppers Travel Less?” *Transportation Research Record* 1894, 2004, pp. 241–248.

⁵Cervero, R. “Paradigm Shift: From Automobility to Accessibility Planning.” *Urban Futures* 22: 9–20, 1997.

⁶Cervero, R. & M. Duncan. “Which Reduces Travel More: Jobs-Housing Balance or Housing-Retail Mixing?” *Journal of the American Planning Association*, Vol. 72, No. 4, 2006, pp. 475–490.

⁷Levinson, H. “Modal Choice and Public Policy in Transportation,” *Engineering Issues: Journal of Professional Activities*, Vol. 99, No. 1, January 1973, pp. 65–75.

⁸Cervero R. & M. Duncan, 2006. “Which Reduces Vehicle Travel More: Jobs-Housing Balance or Retail-Housing Mixing?” *Journal of the American Planning Association*, Volume 72, Issue 4 December 2006, pages 475–490.

Table 5-7. Corridor parking management new paradigm characteristics.

Transit-Oriented Corridor Qualities	Park-and-Ride Access Corridor Qualities	Transit-Optimized/Freeway Constrained Corridor Qualities
Parking turnover optimized for dense land uses	Parking turnover optimized for access to transit facility at non-CBD stations	Parking turnover optimized for access to transit facility in upstream (non-CBD) side of freeway bottleneck
Parking supplied privately and/or through shared-use agreements	Ample parking supply in non-CBD station areas	Ample parking supply in non-CBD (upstream of freeway bottleneck) station areas
Parking supply management, variable pricing, and coordinated transit feeder service to the line-haul transit facility	Variable pricing for parking spaces	Variable pricing for parking spaces
Limited parking supply and high cost of available parking within destination CBD	Limited parking supply and high cost of available parking within destination CBD	Limited parking supply and high cost of available parking within destination CBD

throughout the corridor that encourage transit-oriented development and discourage inexpensive, plentiful parking.⁹

Parking poses a classic double-edged sword problem for new paradigm corridors: it reinforces the automobile orientation of station areas and access points, but in most low-density settings, parking is necessary to encourage transit riding and to ensure viable commercial activities. At the station level, park-and-ride lots surrounding stations can encourage commuter ridership on the transit line, but often do so at the expense of off-peak riders who might travel to a station that has dense, mixed-use land uses near the station. If the main destination/CBD served by the transit line also has ample and inexpensive parking, transit mode share tends to be low. There should be some flexibility in setting parking codes to acknowledge potential vehicle trip reductions from TOD and integrated, multimodal development. If parking is over-supplied, the die may be cast, setting the area on a course to becoming a full-fledged, park-and-ride access multimodal corridor.

Accordingly, it is important to view parking as malleable and even transitional, providing a form of “land banking” where park-and-ride lots can be developed later into high-density, transit-oriented uses. This places a premium on parking placement, design, controls, and management. Table 5-7 suggests the most appropriate parking management approaches for each new paradigm corridor type.

⁹Hess, D. (2001), “The Effects of Free Parking on Commuter Mode Choice: Evidence from Travel Diary Data,” Lewis Center for Public Policy Studies, UCLA (www.sppsr.ucla.edu/lewis/WorkingPapers.html).

Metropolitan Alignment

The position of the corridor and the travel markets it serves within the larger metropolitan context play an important role in determining new paradigm success. Often, capital-intensive transit systems (such as heavy and light rail systems) have been designed and built along radial corridors, serving a large central business district at one end and more dispersed, suburban origins and destinations radiating out from the center city. Radial alignments are intended to take advantage of peak-period commuting patterns.

In existing multimodal corridors, the best radial alignment designs have the transit line running down or near the freeway facility for most of the length of the corridor, but once it nears the CBD, the freeway circumvents the CBD while the transit line diverges from the freeway and enters via surface streets, or in a grade-separated right-of-way (see Figure 5-1).

Although this alignment makes sense from a ridership perspective, increasingly dispersed land use patterns in U.S. metropolitan areas suggest that the radial alignments will not be able to effectively serve the increasingly suburb-to-suburb travel patterns. Suburb-to-suburb transit system alignments are rare in the United States. One notable example is the Green Line in Los Angeles, California, which provides cross-town connections between the communities of Norwalk and Redondo Beach. The main activity center served by this line is the Los Angeles International Airport (LAX), but LAX is not directly served by the line: a shuttle must be taken from the Airport/LAX station to the airport.

Ridership on the Green Line is substantial (roughly 42,000 average weekday boardings), but low compared to the

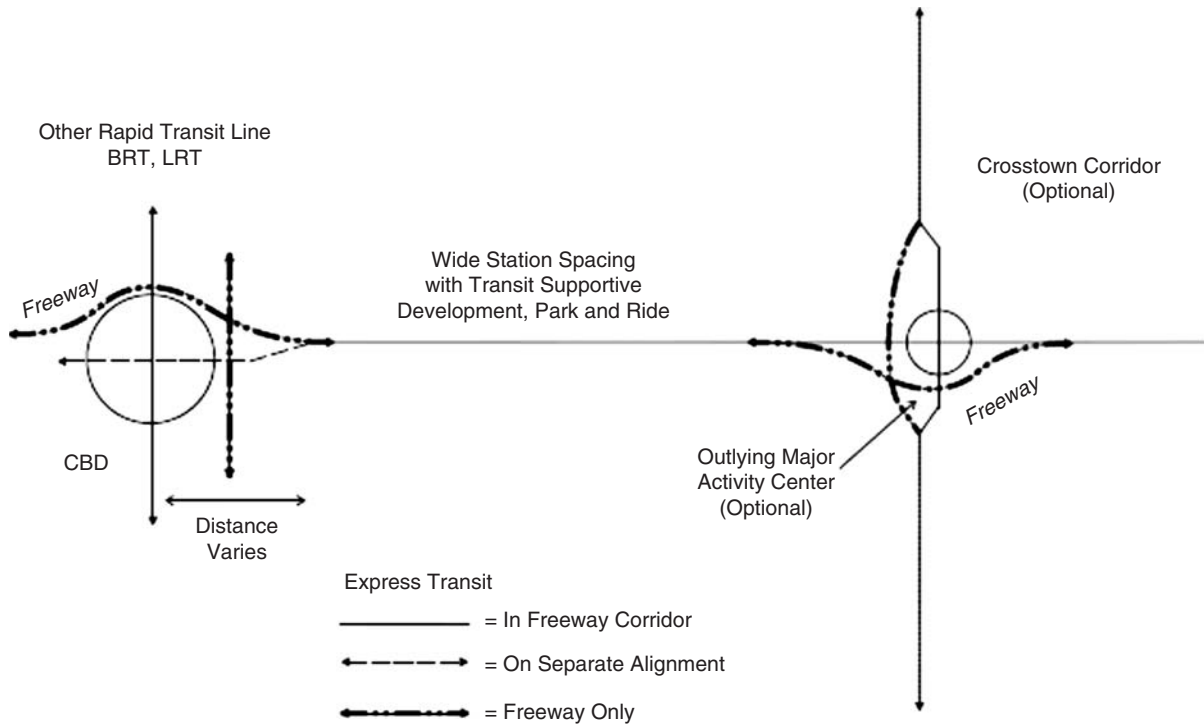


Figure 5-1. Metropolitan alignment concepts for new paradigm corridors.

Table 5-8. Metropolitan alignment new paradigm characteristics.

Transit-Oriented Corridor Qualities	Park-and-Ride Access Corridor Qualities	Transit-Optimized/Freeway Constrained Corridor Qualities
Radial alignment	Radial alignment	Radial alignment
Transit line serves more than one activity center along radial route (for example, each end of line serves a CBD).	Circumferential alignment serving major automobile-oriented activity centers (such as Edge City office clusters or airports).	Circumferential alignment serving major automobile-oriented activity centers (such as Edge City office clusters or airports).

nearby Blue Line that serves downtown Los Angeles (roughly 68,000 average weekday boardings).¹⁰ Thus, one of the challenges for the Green Line and for other suburb-to-suburb (circumferential) alignment transit lines is the lack of an anchor (clustered destination) served by the line.

Table 5-8 suggests the most appropriate metropolitan alignments for each new paradigm corridor type.

Transit Station-Level Characteristics

The old paradigm called for building automobile-oriented stations with large park-and-ride lots. The new paradigm starts with those station areas and retrofits them to promote transit and nonmotorized access modes. The new paradigm employs planning and design concepts such as transit-oriented

land use planning and urban design, coordinated transit and freeway access designs, and nonmotorized station access tools.

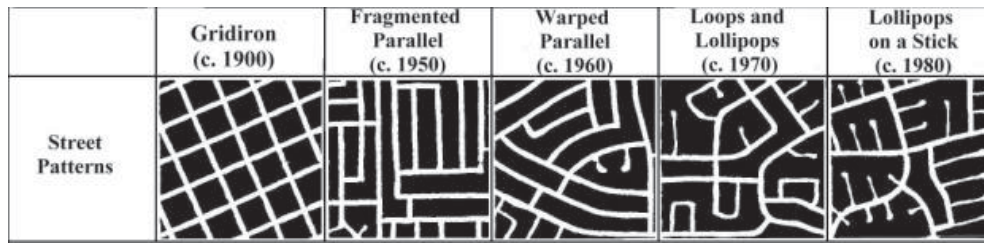
Land Use and Urban Design

Over the past 20 years or so, evidence has grown showing the influence of land use and urban design factors on travel behavior, and more specifically, mode choice. Cervero and Kockelman first defined and labeled three important characteristics of transit station areas as the 3-Ds—Density, Diversity, and Design.¹¹ These are defined as follows:

- **Density:** clustered trip origins (residential) and destinations (employment)¹ around stations

¹⁰http://www.metro.net/news_info/ridership_avg.htm

¹¹Cervero, R. & K. Kockelman. "Travel Demand and the 3 Ds: Density, Diversity, and Design," *Transportation Research D*, 2, 3: 199–219, 1997.



Source: Southworth, M. & E. Ben-Joseph, 2003. *Streets and the Shaping of Towns and Cities*. Washington, DC: Island Press. Courtesy of Michael Southworth and Peter Owens.

Figure 5-2. The evolution of street patterns since 1900 shows how street designs adapted to the needs of the automobile over time.

- **Diversity:** mixed land uses providing a range of clustered, mutually supportive trip destinations
- **Design:** transit- and pedestrian-friendly street networks and urban design (see Figure 5-2)

Subsequent researchers^{12, 13} have added the following factors:

- **Distance:** The shorter the walking distances between a transit station and surrounding land uses, the better. However, since a freeway facility's negative externalities (that is, noise, air, and sight pollution) tend to depress pedestrian activities, maximizing distances between a freeway and station areas or effectively mitigating the negative impacts of the freeway are desirable as well.
- **Destinations:** This factor was discussed in the Jobs/Housing Distribution section.

An important outcome of transit-supportive land uses and urban design is to improve pedestrian access to high-capacity stations. This is particularly important in multimodal corridor station areas where connections to interchanging transit lines, park-and-ride facilities, and adjacent developments should be convenient, weather protected, and compliant with the Americans with Disabilities Act (ADA). Table 5-9 suggests the most appropriate land use and urban design approaches for each new paradigm corridor type.

Station Location

Transit stations can be located within the freeway facility median; on the side of the freeway, separated by a barrier from the flow of traffic in the case of freeways; or off the freeway but close to it, requiring buses to travel onto nonfreeway surface

¹²Ewing, R., and Cervero, R. (2001). *Transportation Research Record 1780*, "Travel and the built environment: A synthesis" pp. 87–114.

¹³Moore, T., P. Throsnes, and B. Appleyard, *The Transportation/Land Use Connection*, American Planning Association. Planning Advisory Service, Report 546 (Chicago; www.planning.org), 2007.

streets or a dedicated road circulation system. (These options and how they may affect new paradigm corridor operations were discussed in Chapter 4.)

Construction costs and operations for offset/adjacent stations can differ for bus rapid transit (BRT) and rail facilities. For buses, offset/adjacent stations can be less costly than in-median or adjacent stations since they do not require as much expensive retrofitting of the freeway facility and do not require additional ROW width to accommodate the stations: stations can be placed where land is readily available.

However, offset stations require ROW acquisition from the freeway ROW to and from the station locations and, particularly in developed corridors with little vacant or inexpensive land, offset stations can cost more than retrofitting the freeway for in-median or adjacent placements. Offset stations typically increase service times because transit vehicles must exit and re-enter the mainline route. Offset stations can also be attractive for BRT as an incremental implementation step because they may incur fewer construction costs. More elaborate in-median or adjacent stations can be built later if ridership demand warrants.¹⁴

However, new paradigm corridor transit lines must penetrate major employment or activity centers, often leaving the freeway to do so. This penetration should be via off-street connections (grade-separated) but situations may require on-street stations and rights-of-way. Table 5-10 suggests the most appropriate station location choices for each new paradigm corridor type.

Station Spacings

As discussed in Chapter 4, station spacings are important in determining the speed of transit and the accessibility of transit riders to corridor land uses. Table 5-11 suggests the most appropriate station spacing approaches for each new paradigm corridor type.

¹⁴TCRP Report 90, Volume 2, page 5–9.

Table 5-9. Land use and urban design new paradigm characteristics.

Transit-Oriented Corridor Qualities	Park-and-Ride Access Corridor Qualities	Transit-Optimized/Freeway Constrained Corridor Qualities
High density	Low-density	Upstream (non-CBD) side of freeway bottleneck:
High diversity (mixed-use)	Low diversity (segregated uses)	Low-density
Pedestrian-scale urban design	Automobile-oriented urban design	Low diversity automobile-oriented urban design on upstream (non-CBD) side of freeway bottleneck
Short walking distances to station	Short driving distances (times) to station	Short driving distances (times) to station
		Downstream (CBD) side of freeway bottleneck:
		High density
		High diversity (mixed-use)
		Pedestrian-scale urban design
		Short walking distances to station

Interchange Spacings

As discussed in Chapter 4, interchange spacings are important in determining the amount of congestion on the freeway and, as a result, its vehicular operating speeds as well. Table 5-12 suggests the most appropriate interchange spacing approaches for each new paradigm corridor type.

Freeway Ramp Touchdown Locations

Vehicular traffic traveling to and from the freeway facility along surface streets through a transit-oriented neighborhood has a disruptive effect on nearby transit operations and station

access. This traffic can turn a transit- and pedestrian-oriented neighborhood into an automobile-oriented one. Proximity between freeway, transit, pedestrian, and bicycle facilities in a single corridor brings both advantages and disadvantages. Advantages result from the ease of transfer between modes. Disadvantages result from conflicts between each mode's access nodes (for example, stations and interchanges). The placement of freeway ramps in relation to transit station areas can help reduce these conflicts (see Figure 5-3).

Multimodal transit-oriented stations minimize the amount of freeway-related automobile traffic near stations by placing freeway ramps as far away as possible. Freeway ramps designed to disperse vehicular traffic and keep it at a distance from station

Table 5-10. Station location new paradigm characteristics.

Transit-Oriented Corridor Qualities	Park-and-Ride Access Corridor Qualities	Transit-Optimized/Freeway Constrained Corridor Qualities
Either adjacent or offset from freeway stations	Either in-median or adjacent stations	Upstream (non-CBD) side of freeway bottleneck: stations either adjacent or in median
		Downstream (CBD) side of freeway bottleneck: stations either adjacent or offset

Table 5-11. Station spacing new paradigm characteristics.

Transit-Oriented Corridor Qualities	Park-and-Ride Access Corridor Qualities	Transit-Optimized/Freeway Constrained Corridor Qualities
Short station spacings	Long station spacings	Upstream (non-CBD) side of freeway bottleneck:
High density of stations for maximum corridor area coverage	Low density of stations for maximum transit speeds	Long station spacings
Short station spacings combined with long interchange spacings (transit-oriented complementary coordination)	Long station spacings combined with short interchange spacings (automobile-oriented complementary coordination)	Low density of stations for maximum transit speeds Supplementary or complementary coordination
		Downstream (CBD) side of freeway bottleneck:
		Short station spacings
		High density of stations for maximum corridor area coverage
		Short station spacings combined with long interchange spacings (transit-oriented complementary coordination)

areas can effectively segment a multimodal corridor into transit-oriented nodes around stations and more automobile-oriented areas near ramps.

Alternatively, multimodal automobile-oriented nodes are designed to maximize automobile access to transit stations. As a result, freeway access points are often placed close to

the transit stations to facilitate and encourage the maximum amount of intermodal transfer between freeway and transit. Due in part to the added automobile traffic around them, these transit stations are often nearly devoid of pedestrian activities, except for the areas between park-and-ride lots and the transit station platforms.

Table 5-12. Interchange spacing new paradigm characteristics.

Transit-Oriented Corridor Qualities	Park-and-Ride Access Corridor Qualities	Transit-Optimized/Freeway Constrained Corridor Qualities
Long interchange spacings for low corridor accessibility	Short interchange spacings	Upstream (non-CBD) side of freeway bottleneck:
Low density of interchanges for maximum freeway speeds	High density of interchanges for maximum corridor area coverage	Short interchange spacings
		High density of interchanges for maximum corridor area coverage
		Downstream (CBD) side of freeway bottleneck:
		Long interchange spacings
		Low density of interchanges for maximum freeway speeds

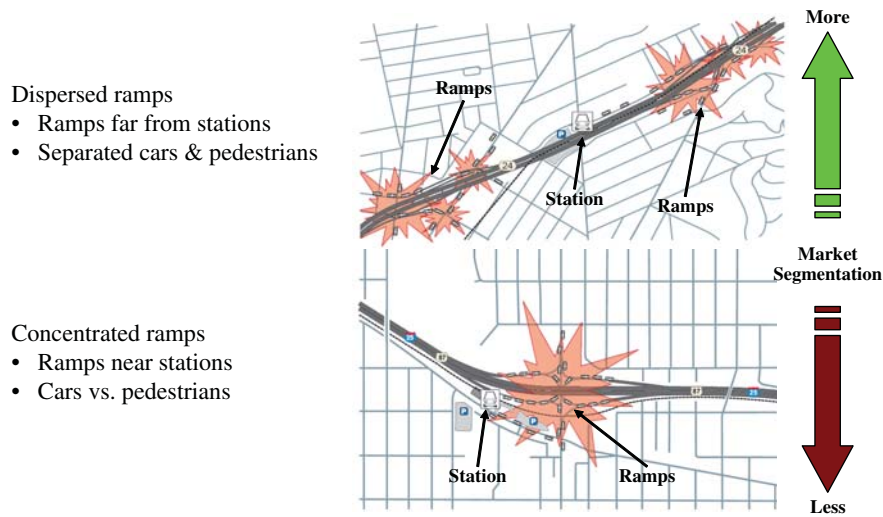


Figure 5-3. The placement of freeway ramps and its effects on station functions.

Table 5-13 suggests the most appropriate freeway ramp touchdown locations for each new paradigm corridor type.

Station Design and Access Alternatives

The design of stations and their surroundings play an important role in determining both the attractiveness of using the transit line as well as the modes travellers choose.

Intermodal Station Design

As discussed in the context of multimodal corridors, intermodal stations are designed to attract park-and-ride, kiss-and-ride, and bus feeder patrons. In new paradigm corridors, these stations are best placed at the terminal end of the transit line to attract automobile transfers from the freeway and at any freeway-to-freeway or large arterial-to-freeway interchanges along the spine of the corridor.

Intermodal stations are designed with large park-and-ride lots or parking structures, kiss-and-ride, and bus bays all close to the station entrances. It is generally best to place these

stations within (in-median) or immediately adjacent to the freeway to encourage freeway-to-transit transfers. For all intermodal and in-median stations, weather protection and climate controls are preferable to give pedestrians walking to and from the stations an extra incentive to use transit.

In-median intermodal bus station designs and operating plans sometimes require buses to cross over each other so doors can open onto a central platform. This crossover can present operational and safety issues and should be avoided if possible. A bus crossover can be eliminated where buses have doors on both sides, and where side platforms are used.

Figure 5-4 illustrates an in-median intermodal station design. However, the potentially unsafe design shown here with bus lane crossovers can be avoided with the use of buses with driver-side doors.

In some cases, circumstances may favor placement of an intermodal station at some distance from the freeway. In these cases, it is best to place the station adjacent to a major arterial street with easy access to the freeway interchange ramps. Figure 5-5 illustrates an intermodal station design for an offset/non-adjacent freeway location.

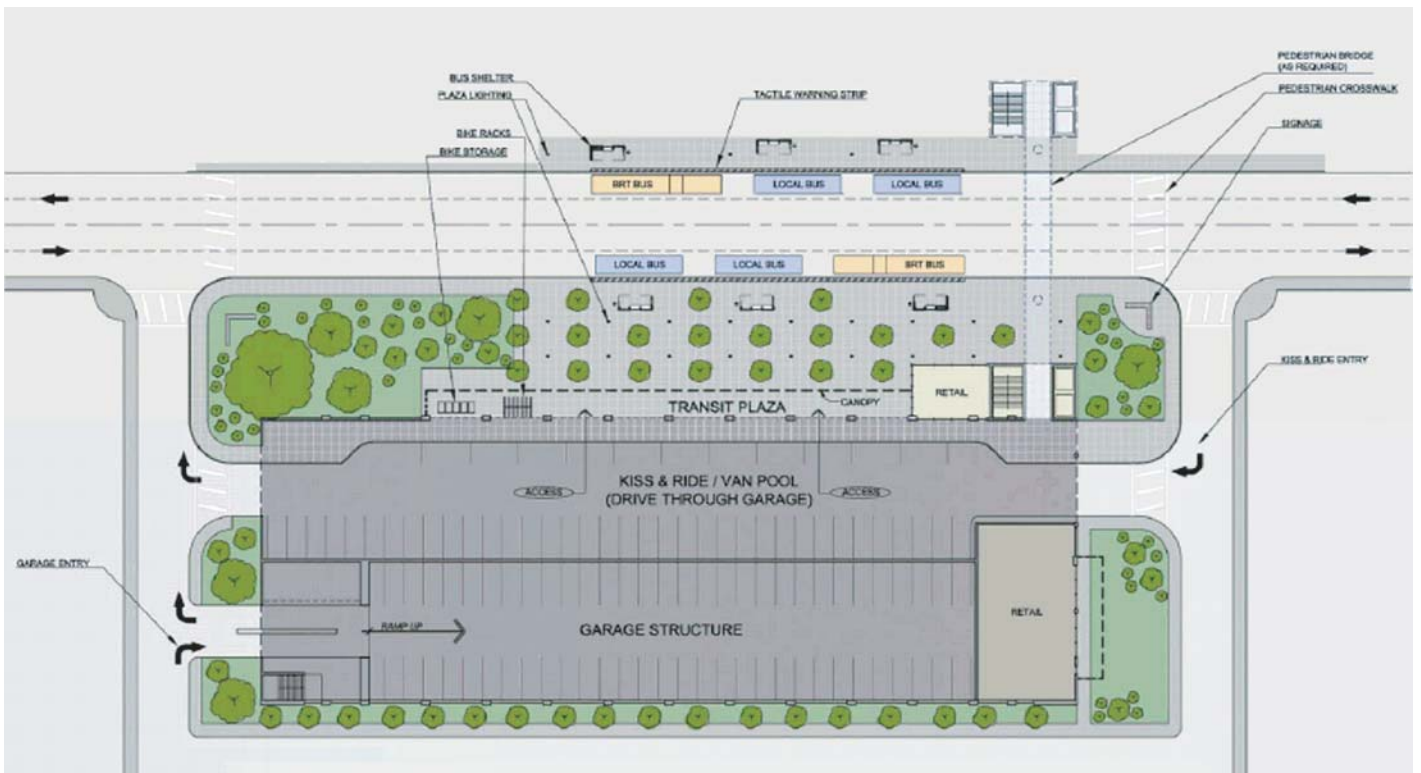
Table 5-13. Freeway ramp touchdown location new paradigm characteristics.

Transit-Oriented Corridor Qualities	Park-and-Ride Access Corridor Qualities	Transit-Optimized/Freeway Constrained Corridor Qualities
Ramp touchdowns distant from stations	Ramp touchdowns near stations	Upstream (non-CBD) side of freeway bottleneck: ramp touchdowns near stations
		Downstream (CBD) side of freeway bottleneck: ramp touchdowns distant from stations



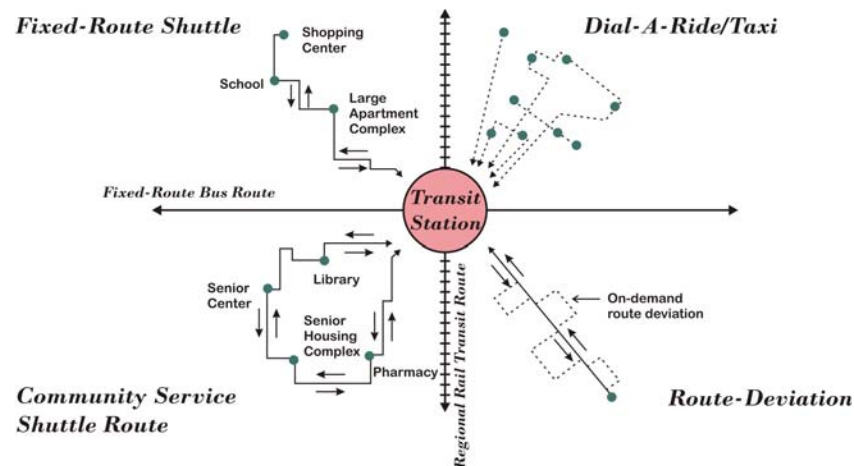
Source: Courtesy Washington State Department of Transportation and IBI Group, I-405 South Corridor Bus Rapid Transit Pre-Design, Final Report.

Figure 5-4. Conceptual in-median station and park-and-ride—plan view.



Source: Courtesy Washington State Department of Transportation and IBI Group, I-405 South Corridor Bus Rapid Transit Pre-Design, Final Report.

Figure 5-5. Conceptual transit center and park-and-ride—plan view.



Source: Based on an interpretation of a similar graphic from Cliff Chambers' "Community-Oriented Transit," developed for *AC Transit*, August 27, 2004. P. 1-4.

Figure 5-6. Community-oriented transit station access options.

Other Models of Motorized Station Access

In general terms, motorized access modes are best suited for intermodal stations that provide easy access to the freeway interchange ramps to ease transfers between the facilities, substantial park-and-ride and bus bays, and kiss-and-ride facilities located near the station entrances. However, there are effective and realistic motorized access options that do not depend on park-and-ride or kiss-and-ride access. Figure 5-6 illustrates four categories of community-oriented motorized access options that help move station areas away from a dependence on park-and-ride access toward a more transit-oriented relationship between stations and their surrounding neighborhoods.

Community-based station access options include fixed-route shuttles, dial-a-ride/taxi services, community service shuttles, and route-deviation bus and shuttle services.

Nonmotorized Station Access: "Green Connectors"

The old paradigm has dominated suburban transit station access planning over the past 50 years. In the case of San Francisco's BART, roughly 75 percent of suburban station patrons are park-and-riders.¹⁵ In low-density, suburban environments, this approach makes sense: automobiles dominate the travel markets for both short- and long-haul trips. A key challenge for the new paradigm involves encouraging patrons to access stations using transit, bicycles, or by foot in what would

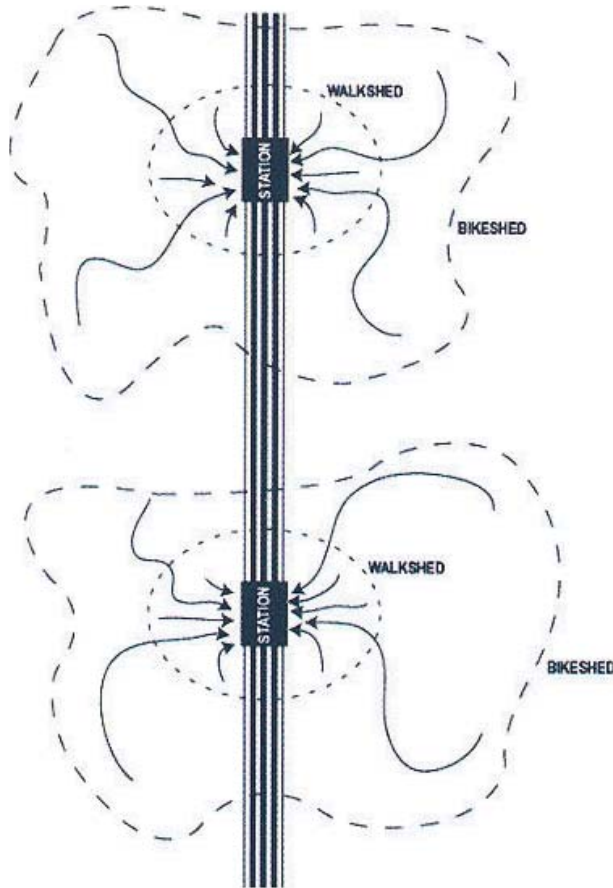
otherwise seem a totally automobile-oriented environment. Here, we can draw on the ideas and accomplishments from other countries. One of the most promising ideas of late, so-called green connectors, has been extremely successful at attracting large numbers of nonmotorized transit riders to travel to stations from long distances.

In Europe and Latin America, planners have been experimenting with developing networks of perpendicular, grade-separated bikeways and paths that lead to the nearest high-capacity transit station (see Figure 5-7).

To encourage green connectors, transportation planning and financing should prioritize nonmotorized mode improvements to station areas. There is perhaps no better example of successful nonmotorized station access planning than in The Netherlands, where nonmotorized modes account for 62 percent of all station access trips.¹⁵ This enviable achievement is the result of both concerted policy mandates favoring nonmotorized planning and a widely shared nonmotorized ethos. The transportation planning and financing priorities of the country reflect this emphasis. In Delft and Groningen, over half of the city transportation budgets go to bicycle and pedestrian facilities. When we compare this to the less-than-one percent of U.S. municipal transportation funds that go to nonmotorized modes, the differences between U.S. and Dutch station access travel patterns become understandable.

These national and municipal priorities have on-the-ground consequences in terms of station area designs. In Houten—a new town about halfway between Amsterdam and Utrecht—mixed-use areas and the central train station are all connected by a network of direct, exclusively nonmotorized greenways. Cars are forced to take more indirect routes to reach these destinations, often backtracking to reach an outer ring. This

¹⁵Cervero, R. "Green Connectors: Off-Shore Examples," *Planning*, American Planning Association, May 2003.



Source: Courtesy of Robert Cervero from "Green Connectors: Off-Shore Examples," Planning, American Planning Association, May 2003, p. 27.

Figure 5-7. Green connectors can provide enhanced non-motorized station access for new paradigm facilities.

concept would work well in retrofitting suburban neighborhoods in the United States, where the hierarchical street networks that isolate residential neighborhoods force drivers to take large arterial streets by more circuitous routes. By replacing the barriers between adjacent neighborhoods with green connectors, more direct, dedicated pedestrian and bicycle paths can be made to encourage suburban residents to walk or cycle to their nearest stations.

In Bogota, Colombia, the Transmilenio BRT line offers a fully realized vision of the potential for green connectors to facilitate nonmotorized access to new paradigm stations. The line's exclusive bus lanes are primarily in the medians of arterial boulevard medians—an automobile-oriented environment with nonmotorized access challenges very similar to new paradigm facilities (see Figure 5-8). To provide pedestrian access to these in-median stations, almost half of the line's 57 stations have pedestrian overpasses. Leading into these stations is a network of 130 miles of sidewalks and bikeways.



Source: Courtesy of Robert Cervero from "Green Connectors: Off-Shore Examples," Planning, American Planning Association, May 2003, p. 25.

Figure 5-8. Pedestrian access priorities for Bogota's Transmilenio Bus Rapid Transit system.

These green connectors have yielded substantial results, with around 45 percent of all Transmilenio riders arriving at their stations by bike or by foot. The city's long-range plans call for doubling the size of this green connector network over the next 30 years. These investments have paid off for the city of Bogota as a whole. In the 10 years since bikeways were introduced, cycling's share of total trips has risen from less than 1 to roughly 4 percent.¹⁵ Table 5-14 suggests the most appropriate station access measures for each new paradigm corridor type.

Summary and Conclusions

Transit-oriented corridors:

- High-capacity/fixed-capital-asset transit modes such as heavy rail, light rail and BRT
- Transit-dependent-rich market
- Concentrated station-area land uses:
- Distributed nodes maximize activities served along entire route
- Clustered mixed-use destination(s) at many locations along corridor
- Balanced jobs and housing in corridor (jobs clustered in station areas but dispersed along corridor)
- Limited parking supply and high cost of available parking within destination CBD
- Radial metropolitan alignment with transit line serving more than one activity center along route
- Transit-oriented land uses and urban design around stations
- Stations located either adjacent or offset from freeway
- Short station spacings
- Long interchange spacings

Table 5-14. Station design and access new paradigm characteristics.

Transit-Oriented Corridor Qualities	Park-and-Ride-Access Corridor Qualities	Transit-Optimized/Freeway Constrained Corridor Qualities
Intermodal stations only at terminal corridor locations and major freeway-to-freeway interchanges	Most corridor stations are intermodal	Downstream (non-CBD) side of freeway bottleneck: same qualities as Transit-Oriented Corridor
Ramp touchdowns far from stations	Ramp touchdowns near stations	Upstream (non-CBD) side of freeway bottleneck: same qualities as Park-and-Ride-Access Corridor
Emphasis on community-oriented station access modes	Large park-&-ride lots near station entrances	
“Green connectors” provided where possible to encourage nonmotorized station access	Kiss-&-ride zones near station entrances	
	Bus bays near station entrances	

- Ramp touchdowns located far from stations
- Station access:
 - Intermodal stations only at terminal corridor locations and major freeway-to-freeway interchanges
 - Community-oriented station access modes
 - “Green connector” paths leading to stations

Park-and-ride access corridors:

- At least one large activity center or anchor, usually a CBD with high levels of employment
- Direct access to the city center and other major “anchors” (This likely involves leaving the freeway to penetrate these areas)
- Limited and costly parking in the CBD
- Effective transit distribution in the CBD, preferably off-street
- Constrained freeway capacity such as lane drops, route convergence, and travel barriers
- Wide station spacing that permits high transit speeds

- Good access to stations on foot, by car, and/or by public transport; a minimum number of freeway interchange ramps within walking distance of transit stations
- A multimodal corridor that extends at least 10 miles and has at least eight residential “catchment” stations
- Transit-supportive development in the environs of key stations
- An interagency multimodal corridor overlay zone that can specify uses and densities and form guidelines and requirements

Transit-optimized/freeway-constrained corridors:

- Freeway bottleneck (lane drop or other capacity constraint) roughly mid-point in the corridor that gives transit a travel time advantage in CBD side of corridor.
- Transit-oriented corridor qualities downstream of freeway bottleneck
- Park-and-ride access corridor qualities upstream of freeway bottleneck

CHAPTER 6

The Institutional Landscape for Multimodal Corridors in the United States

This chapter addresses the roles of institutional stakeholders typically involved in multimodal corridor development projects and the relationships among them that are needed for the projects to be successful. Corridor responsibilities are often divided among a host of different agencies. Local governments typically have responsibility for land use; state highway departments design, build, and operate freeways; transit agencies plan, build, and operate transit services; and federal transportation agencies provide funding and oversight.

Multimodal corridors require close collaboration among these and other institutions that may not typically work together. This chapter discusses the institutional histories and perspectives of these stakeholders and how these narratives inform their roles and responsibilities when collaborating on new paradigm projects. Although the history of multimodal corridors and the various stakeholders involved in these past projects is briefly discussed in Chapter 2, this chapter focuses on the important historical developments of key new paradigm agencies and the potential for developing new institutional relationships among them.

New Institutional Relationships

New institutional relationships are often needed to capture the benefits of new paradigm corridors. Multimodal systems require cooperation and collaboration among different levels of government (that is, federal, state, regional and local), different agencies with mode-specific missions (for example, state highway departments, transit agencies, and city streets and roads departments), and different public agencies with divergent missions (for example, city land use planning departments and transit agencies). Inter-agency agreements and new legislation may be needed to allow new uses of rights-of-way, new types of partnerships, and new approaches to facility operations and management.

Multimodal Institutional Settings

Many barriers to building new paradigm corridors are institutional. The U.S. interstate freeway system was largely built by single-purpose state highway departments. Many of our post-World War II transit systems were built by agencies created solely for the purpose of building and operating them. This single-purpose agency model is well-suited to building unimodal transportation systems, but presents obstacles to planning, building, and operating new paradigm multimodal corridors.

The transportation system is multimodal by nature. Each agency type—transit, state DOT, local governments, MPOs—can and often do coordinate multimodal transportation services out of necessity. But new paradigm multimodal corridors derive their benefits from planned and coordinated multimodal systems, not from multimodalism as an afterthought. Building a new paradigm multimodal corridor requires highway and transit agencies (among others) to coordinate and collaborate on a day-to-day basis throughout all phases of project planning, design, construction, and operations. The institutional gaps between these agencies can create barriers that must be overcome to plan and develop a multimodal corridor. New paradigm projects require conscious, determined, and continuous efforts on the part of all stakeholders to identify, understand, and overcome these institutional gaps.

Bridging the Multimodal “Gaps” Between Unimodal Agencies

The landscape of agencies and stakeholders involved in multimodal corridor projects includes many agencies organized to fulfill a single, and often unimodal, purpose. Over time, these agencies have changed and new ones have been formed to address multimodal challenges. One of the most important

challenges is that multimodal projects must comply with all the local, regional, state, and federal regulations governing highways and the rules from the same that apply to transit. Understanding how to bridge these gaps and create successful new paradigm multimodal corridor projects requires an understanding of how these agencies were formed and how they have changed.

State DOTs provide perhaps the best example of agencies that started as unimodal, highway construction organizations, that have evolved over the years to become more multimodal and more collaborative. Many state DOTs were shaped by the objective of building the interstate system—using uniform standards established at the national level—and they did this well. These DOTs were not accustomed to planning and operating facilities for other modes such as transit, paratransit, bicycling, or walking—those not explicitly incorporated into the original interstate highway system.¹

Similarly, transit agencies are important in multimodal corridor projects, but they generally focus on operating and maintaining their existing services. As a result, when calls are made for transit agencies to expand and include planning for transit-oriented development and pedestrian and bike access to their systems, agencies often think that this will be more than they can handle.² As a result, transit and highway agencies in particular can appear to serve distinctly different constituencies, and the skill sets valued in one agency are not always transferable to the other. This can hinder effective coordination on multimodal projects.

Other agencies have evolved to bridge the gaps between unimodal transit and state DOTs and provide multimodal coordination. Some local governments and their transportation departments offer a multimodal focus, if at a smaller geographical scale. Local governments also control land uses, a critical component necessary to build new paradigm corridors. However, local governments typically do not control the key facilities of a multimodal corridor—the transit and freeway systems.

To effectively coordinate modes within a larger, regional context, MPOs were created by federal mandate and given substantial powers to influence transportation finance, policy, and planning decisions within their jurisdictions. Nevertheless, MPOs are not typically charged with project construction or operational duties, so their effectiveness is largely a function

of their capacities to influence and coordinate among their regional partners.

Multiagency Partnerships: The Key to Building Successful New Paradigm Corridors

The benefits of developing a new paradigm corridor are best ensured using multiagency partnerships, founded on the principles of shared responsibility and authority. The successes of Denver's T-REX project, for example, are largely owed to the collaborative partnerships forged between numerous agencies in the project's corridor. Sometimes, however, large collaborative teams can lead to suboptimal outcomes. In these cases (and in the case of the T-REX project) more advanced forms of cooperation can lead to successful new paradigm projects.³ Partnerships can take many forms, but new paradigm partnerships require a level of collaboration beyond those typically mandated by federal requirements for interagency coordination and consultation. Healey describes emerging approaches to government partnerships, which take two forms:

- **Consensus-building:** working with key stakeholders to reach agreement and adoption of a common strategic policy agenda.³ When developing new paradigm multimodal corridors, this is a critical first step in any partnership because coordination among modes in a corridor will yield performance benefits when all partners agree on the goals, objectives, and actions that will be shared by all partners.
- **Collaboration:** a form of consensus-building with a strong emphasis on including all stakeholders and establishing the institutional mechanisms that will formalize and ensure the rights, responsibilities, and opportunities of all to participate in the decision-making process.³

New paradigm facilities are complex systems requiring collaboration among many stakeholders to share power, authority, and expertise.

Sharing Power, Authority, and Expertise

Partnerships work best when the lead agency (that is, the agency with the most responsibility and authority) yields some degree of control over the decision-making process to the partnership. In exchange, the partnership gains the expertise and political support of the other members and will be capable of building and operating a multimodal corridor

¹Deakin, E., "The Social Impacts of the Interstate System: What are the Repercussions?" TR News, May-June 2006, 244, p. 16.

²Deakin, E., G. Tal & K. Frick, "What Makes Public Transit a Success? Perspectives on Ridership in an Era of Uncertain Revenues and Climate Change," Presented at the Transportation Research Board's 89th Annual Meeting, 2010.

³Goldman, T. & E. Deakin, "Regionalism Through Partnerships? Metropolitan Planning Since ISTEA," Berkeley Planning Journal 14 (2000): 46-75, <http://www.ced.berkeley.edu/pubs/bpj/pdf/bidl1405.pdf>

that performs beyond what would be possible if the most powerful agency in the partnership worked alone.³

Such a high level of collaboration puts different strains and pressures on each partner agency. The organizational and institutional history, culture, and legal mandates of each agency present different challenges to fully participating in the collaborative process. The discussion that follows addresses these different contexts as determined by the type of governmental agency involved. These include the organizational contexts of the federal Department of Transportation (USDOT), the state DOTs, transit agencies, and regional and local governments.

The USDOT Context

USDOT was originally established to fund and facilitate highway construction—a focus that has proven effective at building the nation’s interstate system, but has sometimes been an impediment to building effective multimodal corridors. In recent years the USDOT has evolved from being an agency focused exclusively on highway construction into an increasingly effective partner in facilitating multimodal corridors.

USDOT strengths as a new paradigm project partner include

- **Working relationships with federal legislators and other policymakers** who can help build political and financial support for a new paradigm project
- **Experience working with transportation planning, engineering, and construction firms**
- **Active collaborations with state DOTs and transit agencies**
- **An ability to set standards of practice** in transportation planning, engineering and financing practices that could benefit new paradigm projects
- An **increasingly multimodal perspective**, the result of a number of reforms both from within and outside of the federal government.

This historical evolution from a highway-focused to a multimodal agency make today’s USDOT a powerful advocate for and partner in building new paradigm corridors. These changes were marked by several watershed multimodal transformations, including the establishment of UMTA, the passage of ISTEA, and the changes under way in response to the increasing scarcity of federal transportation funds.

The Establishment of the Urban Mass Transit Administration (UMTA)

After passage of the 1956 Federal-Aid Highway Act, USDOT engaged the states as partners in building the interstate highway system. In the 1950s and 60s, even as the interstate highway system began to yield tangible successes, a confluence of social movements and political shifts led USDOT to take a more

multimodal approach to national transportation planning and financing.

The creation of UMTA in 1964 was driven both by the rise of the environmental and antifreeway movements (see Chapter 2), and a recognition in Congress that the nation’s transit system was in decline and needed financial support similar to that given highways with the interstate program. Transit’s decline and the consequent need for a more multimodal USDOT became widely apparent after the passage of the Transportation Act of 1958.

Prior to 1958, state governments were able to slow the decline of the nation’s passenger rail transit services by reviewing and declining petitions to abandon existing lines from railroad operators. The Transportation Act of 1958 moved control of this petition process from state governments—which generally favored maintaining passenger rail services—to the federal interstate commerce commission—which was given the mandate to “balance” the interests of passenger services with railroad profitability.⁴ This resulted in the immediate closing of several important commuter rail services and a public backlash that prompted key members of Congress to advocate for the establishment of a federal transit agency, originally known as UMTA.⁵

The largely grassroots antifreeway and environmental movements of the 1960s and 1970s also played an important role in the creation of UMTA. By the late 1960s, rising concerns about the effects of automobiles on the environment raised further questions about highway building and led to requirements for environmental reviews (NEPA, 1969). Arguments in favor of federal support for transit found traction in the John F. Kennedy and Lyndon B. Johnson administrations, and the UMTA Act of 1964 created the possibility of a different image of the modern city, one with transit as a key travel mode.

Once established, UMTA (later renamed, the Federal Transit Administration) became important in financing and advocating for multimodal corridor projects, but it was the passage of the Intermodal Surface Transportation Efficiency Act in 1991 that brought the practice of multimodalism to nearly every part of USDOT and its partner agencies across the United States. This multimodal perspective and its proliferation have made successful new paradigm project collaborations possible.

ISTEA and the Multimodal Transformation of USDOT

The passage of ISTEA in 1991 brought a fundamental shift in USDOT’s primary functions as a transportation policy and financing organization and dramatically improved the opportunities for multiagency collaboration and funding opportunities for new paradigm corridors. Prior to ISTEA, it was difficult to fund multimodal corridor projects since federal

⁴http://www.narprail.org/cms/index.php/resources/more/railroad_history/

⁵http://www.fta.dot.gov/about/about_FTA_history.html

funds were limited to mode-specific uses and largely funding highway construction. Since ISTEA, federal funds are increasingly used for non-highway projects with greater opportunities for multimodal corridor projects. ISTEA also enhanced the role of intermodal regional governments (MPOs) in deciding which projects would receive federal funding.

Nevertheless, significant barriers to federal transit project funding—and multimodal corridor project funding—remain. Thus far, requests for New Starts funds (the federal government's fixed-guideway transit project financing program) have exceeded supply, and although FTA is authorized to fund up to 80 percent of the capital costs of a transit project, most projects receive less than half. This is compared to the Highway Trust Fund, which has traditionally provided 90 percent of construction costs for the interstate system⁶ (although this percentage has dropped in more recent years).

Federal Transportation Project Funding: Advantages and Disadvantages for New Paradigm Projects

Institutional impediments to new paradigm projects within USDOT remain, even as multimodalism has become more important. For example, the New Starts program's transit project funding evaluation process tends to have a higher level of scrutiny and accountability than highway projects, adding impediments to transit project funding and making new paradigm corridor funding more complex as a result. The current process only approves funding projects in the final design phase, necessitating a substantial local investment before funding from the federal government can be secured and adding an additional hurdle to transit projects compared to highway projects.⁷

These federal funding issues have tended to favor park-and-ride access, automobile-oriented multimodal corridor projects in the past. However, more recent federal funding trends suggest that transit-oriented new paradigm projects could have a better chance at attracting financing in the future.

A Trend To Favoring Transit-Oriented New Paradigm Projects?

It seems reasonable to speculate that recent trends in federal transit funding may tend to favor more transit-oriented new paradigm projects in dense, transit-friendly urban areas. During the past decade, the 10 largest metropolitan areas in

the country received 62 percent of New Starts funding.⁸ FTA's New Start's evaluation criteria ranks projects highly that can show dense, transit-oriented land uses in the proposed corridor of operations.⁹

As a result, transit-oriented new paradigm multimodal corridor projects may fare better in competing against park-and-ride-oriented multimodal corridor projects that might have benefited from pre-New Starts funding priorities in the past. However, new paradigm projects are also faced with the increasing scarcity of federal transportation funds.

The Era of Underinvestment— Federal Transportation Funding Scarcity

In the current era of federal budget deficits, USDOT and Congress have struggled to maintain adequate funding levels for transportation. The National Surface Transportation Policy and Revenue Study Commission concluded in their 2008 report that transportation investment needs require \$225 billion per year. Meanwhile, we are currently only spending roughly 40 percent of this amount.¹⁰ Foremost among these challenges is the declining revenues from fixed-price gasoline taxes due to inflation.

Even so, since this scarcity of transportation funds is a challenge that all projects and modes face, the multimodal nature of new paradigm projects may help make them more competitive for federal funds in the future since they offer the potential for cost-savings, multimodal coordination, reduced environmental impacts, and greater person-carrying capacities than competing unimodal projects.

Working to fill the gap, local governments are increasingly levying sales taxes to fund transportation projects. In terms of planning practice, this has led to the devolution of transportation policy and fiscal responsibilities from the federal and state levels to the local level, with transportation investment decisions often being made within the local legislative and political arenas.¹¹ Therefore, it is possible that the success of new paradigm projects in the future will depend somewhat less on federal USDOT financing and policies and more on state, local, and regional decisions.

⁶Gifford, J., "The Exceptional Interstate Highway System: Will a Compelling New Vision Emerge?," TR News, May–June 2006, 244, p. 10.

⁷Emerson, D. J. & J. D. Ensor, *New Starts: Lessons Learned for Discretionary Federal Transportation Funding Programs*, Bipartisan Policy Center, January 25, 2010, <http://www.bipartisanpolicy.org/library/report/new-starts-lessons-learned-discretionary-federal-transportation-funding-programs>

⁸Emerson, D. J., "FTA New Starts: The ISTEA and TEA-21 Funding Commitments," March 29, 2002, http://www.pbworld.com/news_events/publications/technical_papers/pdf/44_FTA_New_Starts.pdf

⁹Deakin, E., C. Ferrell, J. Thomas, J. Mason. "Policies And Practices for Cost-Effective Transit Investments: Recent Experiences in the United States" Transportation Research Record 1799, 2002, pp. 1–9.

¹⁰Miller, D. L., "Testimony on the Financing of Future Investments in Highway and Mass Transit," Before the Committee on the Budget, U.S. House of Representatives, Tuesday, March 17, 2009, http://budget.house.gov/hearings/2009/03.17.2009_Miller_Testimony.pdf

¹¹Wachs, M. & T. Goldman, "A Quiet Revolution in Transportation Finance: The Rise of Local Option Transportation Taxes," *Transportation Quarterly*, 57, 1, Winter 2003, pp. 19–32.

The State DOT Context

State DOTs in the United States were originally established in the late 19th and early 20th centuries as highway departments. After World War II and the passage of the Federal-Aid Highway Act of 1956, state highway departments grew considerably as they took the lead role in planning, designing, building, and operating the interstate highway system. State DOT strengths as new paradigm project partners include

- **Real-world expertise** at planning, designing, building, and operating highway facilities and networks
- A close working **relationship with USDOT**, an important source of new paradigm project funding
- Relationships with highway planning, engineering, and construction firms
- **Relationships with local governments**, since state DOT highways often serve as primary travel arteries through and between cities and counties where new paradigm projects might be built
- **Access to alternate funding sources** such as state transportation funds and county and city sales taxes that are playing an ever-increasing role in meeting the shortfall in available federal funds
- **An increasingly multimodal perspective**, the result of a number of reform movements both from within and outside of state DOTs.

The trend toward a more multimodal orientation has made state DOTs an important partner in new paradigm project collaborations.

Multimodal Reform of State DOTs

The so-called “freeway revolts” also had a profound influence on the organizational structures of state DOTs. Many states added transit offices or divisions to their agencies and by the late 1960s and early 1970s, many had been renamed as departments of transportation (DOTs).

For example, in California, the passage of Assembly Bill (AB) 69 in 1972 directed regional transportation planning agencies to develop their own multimodal transportation plans and the state’s highway department to combine them into a single, statewide multimodal transportation plan.¹² This was followed a year later by changing the state DOT’s name from the Division of Highways to the California Department of Transportation (Caltrans, for short). In the late 1970s, the state removed several major freeway construction elements of its statewide transportation plan, sending the message that the freeway-building era had come to a close.¹²

¹²Brown, J., “Statewide Transportation Planning: Lessons from California,” *Transportation Quarterly*, Vol. 56, No. 2, Spring 2002, pp. 51–56.

While the freeway revolts challenged the existing, highway-centric transportation planning, financing, and operational emphasis in the United States, they also served to broaden the constituencies that set transportation priorities, introducing new and more multimodal perspectives. Although some state DOTs resisted these pressures, others experimented with more collaborative methods of decision making. These DOTs led the way in transforming their institutional structures and developing a more multimodal perspective—a trend that made multimodal corridors an attractive option for many state DOTs.

During this period of transition for state DOTs in the 1970s, the Oregon Department of Transportation’s (ODOT’s) role in the development of Portland’s MAX Blue/Red Line/I-84 multimodal corridor project (then called the Banfield Corridor) is emblematic of the changes in state DOTs and their approaches to transportation planning. While originally ODOT seemed to favor a highway-only capacity expansion for the corridor, the agency signaled a shift when, for the first time in its history, it appointed a citizens’ advisory committee for a regional transportation project—the Banfield Corridor Study. This study recommended the construction of the light rail line using the funds and right-of-way originally earmarked for the freeway expansion—arguably, one of the first successful cases of using federal highway funds for multimodal corridor project construction. The most important lesson learned from ODOT’s experience is the need for state DOTs to incorporate the public into their decision-making processes. In doing so, ODOT helped change the trajectory of the Banfield Corridor, placing their agency in the role of accommodating the desires of the public for a truly multimodal corridor.

ODOT’s evolution reflects the changes taking place simultaneously at state DOTs around the country as organizations redefined themselves as multimodal agencies responsive to societal pressures that favored multimodal transportation. Furthermore, this transformation is an example of how institutional reform can make new paradigm multimodal corridor projects possible.

ISTEA and the Multimodal Transformation of State DOTs

Since state DOTs are often the owner-operators of freeway facilities, the successful development of a new paradigm multimodal corridor often depends on their ability to function as multimodal agencies. This means they must be able to

- Plan, build and manage **freeways that accommodate transit** and other modes
- **Work collaboratively** with other agencies and stakeholders
- **Take advantage of flexible highway funds (ISTEA)**, using them for non-highway corridor improvements.

In practice, ISTEA has been somewhat inconsistent in influencing the multimodal transformation of state DOTs. When first passed, ISTEA required state DOTs to implement management systems and long-range plans. Unfortunately, these requirements were later relaxed and made optional. In a study by Lipsman and Walter of state DOTs in 1998—after ISTEA had been in effect for 7 years—many surveyed DOTs gave a relatively low level of attention to intermodal transportation.¹³

A 2007 study of seven state DOTs suggests these challenges persist, with respondent agencies reporting low levels of state funding for intermodal projects, investments in transit services, investments in bicycle and pedestrian facilities, and investments in intermodal connecting facilities.¹⁴

Even within state DOTs, there are considerable differences among departments and disciplines in embracing the multimodal implications of ISTEA. Although many have transformed their planning processes to a more multimodal approach, significant portions of these same agencies continue to see themselves as highway-building and maintenance organizations.¹⁴

In practice, many institutional and political barriers remained in the years after ISTEA's passage that prevented truly multimodal planning to flourish in many states, and as a consequence, pose a significant barrier to successful new paradigm projects as well. Despite the good intentions behind ISTEA's flexible funding mandate, only a few states and their MPO partners have diverted funds from highways to other modes. Between 1992 and 1999, of the \$33.8 billion in flexible funds available, only \$4.2 billion or 12.5 percent was actually transferred from highways to transit, and of this amount, the District of Columbia, Massachusetts, New York, Oregon, and California—all highly urbanized areas—accounted for one-third of these transfers. Metropolitan areas with the largest and most well-established transit agencies were the most likely to transfer funds from highway to transit projects.¹⁵

Reasons for the underuse of flexible funding vary, but an important one has been a continued emphasis within state DOTs on what they saw as their mission to complete the Interstate Freeway System.¹⁶ Lipsman and Walter's (1998) survey of state DOTs found they were struggling to incorporate multimodalism into their business models. When asked to rank the importance of eleven multimodal issues, the top three identified were highway-focused: urban rail-highway

conflicts, rural rail-highway conflicts, and intercity bus and rail terminal joint location. When asked what aspects of their transportation systems they modeled, they indicated that traffic models of state highway operations were twice as common as were any other infrastructure needs. In general, state DOT respondents indicated that their multimodal analytic skills needed upgrading to meet the multimodal expectations of ISTEA.¹³

Whether multimodal corridor projects are seen as a help or a hindrance to achieving this goal often depends on the degree to which state DOTs have successfully transitioned from a highway-oriented to a multimodal agency in line with the intent of ISTEA.

Colorado's Transportation Expansion (T-REX) project offers important insights into the perspectives of state DOTs involved in multimodal corridor projects. While a partnership consisting of the Colorado Department of Transportation (CDOT), Denver's MPO (DRCOG), the Regional Denver's Regional Transit District, and numerous local governments within the corridor commissioned the Major Investment Study in 1995, CDOT and FHWA were concerned that the recommendations were too transit-oriented and contained only minor freeway capacity improvements. At this point, the partnership took a step back, reassessed their priorities, and decided to focus on improvements that would enhance mobility for all modes of travel in the corridor, not just transit. As a result, they eventually identified a combination of freeway widening and light rail improvements that would satisfy CDOT, FHWA, and the transit interests in the partnership.¹²

With this balance of multimodal improvements, the stakeholders were able to support the proposed alternative. Equally important, this cross-agency collaborative structure and the widely supported multimodal package of improvements that resulted yielded additional benefits later. In 1999 when the project's federal funds were as yet unavailable, the voters passed Referendum A, allowing CDOT to borrow money for construction against those unallocated federal funds—a testament to the strength of the multiagency partnership that was able to rally public voter support to keep the project on track.¹²

The Way Forward for State DOTs: Promoting the Promise of Multimodal Planning

Several states have taken the lead in transforming their DOTs from highway departments into multimodal organizations. Colorado provides an important example of how the collaboration required for multimodal projects led to a transformation of the agency. With the growing strength of the state's MPOs after the passage of ISTEA, CDOT found it was necessary to collaborate with MPOs and a wide variety of other stakeholders in order to achieve these aims.

¹³Lipsman, M. & C. W. Walter, "Response of State Transportation Planning Programs to the Intermodal Surface Transportation Efficiency Act of 1991," Crossroads 2000 Proceedings, Ames: Iowa State University, August 20, 1998, pp. 167–171. <http://www.ctre.iastate.edu/pubs/crossroads/167response.pdf>

¹⁴Goetz, A. R., et al., "Assessing Intermodal Transportation Planning at State Departments of Transportation," World Review of Intermodal Transportation Research 2007; Vol. 1, No. 2 pp. 119–145.

¹⁵Puentes, P., "Flexible Funding for Transit: Who Uses It?" Center on Urban & Metropolitan Policy, The Brookings Institution, May 2000.

¹⁶[http://thomas.loc.gov/cgi-bin/query/F?c102:2:./temp/~c102DxKBg6:e1910:](http://thomas.loc.gov/cgi-bin/query/F?c102:2:./temp/~c102DxKBg6:e1910)

In the last decade, this transformation has been reflected in CDOT's organizational structures. In 2004, CDOT created several new divisions that would place more emphasis on multimodal planning, public transit, and collaborative planning techniques. CDOT's Division of Transportation Development has grown substantially and now houses an intermodal planning branch to address transit, bicycle, and pedestrian modes, as well as transportation demand management (TDM). This widened perspective includes a greater emphasis on freight planning within this multimodal planning unit.¹⁴ These changes have also taken root in CDOT's approach to planning activities. Multimodal and collaborative processes used to create elements of CDOT's recent long-range plan were cited by an FHWA study as representative of best practices.¹⁴

California's DOT (Caltrans) responded to calls from the electorate for more multimodal planning and operations by setting up the Corridor System Management Plan (CSMP) process. CSMPs are designed to evaluate how a travel corridor is performing, determine why it is performing that way, and identify system management strategies to improve the corridor's performance.

There are two key elements to the CSMPs that break new ground for Caltrans. First, the analytic process is focused on corridor mobility, rather than simply on the performance of a state highway, allowing consideration of a broad range of modes and facilities. Second, the CSMP process embraces collaboration with MPOs and other local government stakeholders as the key to successful transportation system management, planning, and project delivery. In the San Francisco Bay Area, Caltrans District 4 has developed a collaborative process for CSMPs with the region's MPO. As a result, CSMPs produced in the Bay Area are increasingly addressing multimodal issues and present an opportunity to develop new paradigm corridor projects as well.

Many other states have taken similar steps to organize their operations around multimodalism. Florida DOT has a Public Transportation Administrator that is responsible for coordinating department involvement in intermodal transportation issues. Louisiana DOT has established an Office of Public Works and Intermodal Transportation that includes Aviation, Public Transportation, and Marine & Rail Transportation sections. Mississippi DOT has an Office of Intermodal Planning that houses their Aeronautics, Planning, Public Transit, Rails, and Ports & Waterways divisions. Texas DOT has established a Multimodal Planning team that provides technical expertise for the development of their statewide intermodal plan.¹⁴

Nevertheless, creating a DOT department tasked with multimodal planning or being a liaison to public transit agencies and MPOs is a far cry from changing state DOT culture and approach to highway planning, design, and operations, let alone getting a new paradigm project built. A recent study

of multimodal planning at state DOTs reveals that many agencies have made significant strides in this arena in recent years, incorporating multimodal planning techniques into their long- and short-range plans. Colorado, Florida, Arizona, and Louisiana were recently cited by an FHWA study as successfully incorporating multimodal elements into their long-range plans.¹⁴ However, many of the respondents expressed concern about the continued highway orientation of many state DOTs, a lack of funding for multimodal projects in general, and too little investment in or attention to transit, bicycle, and pedestrian facilities and the intermodal connectors needed to integrate these modes.¹⁴

The Transit Agency Context

Like state DOTs, transit agencies tend to have specific and focused missions—in this case, the planning, designing, constructing, and operating of a transit system. This focus may tend to engender a view within transit agencies of freeways and the state DOTs that operate them as competitors. Even so, transit agencies often operate in freeway corridors and on freeways themselves. As a result, efforts to enhance transit services in freeway corridors through cross-agency partnerships can find willing and enthusiastic partners in transit agencies.

Efforts to build a multimodal corridor require active transit agency involvement. Whether this is obtained through partnering with an existing transit agency or by the creation of a project-specific one is a question that should be addressed at the earliest point possible in the conceptualization of the project.

Once the transit agency partner is identified and engaged in the project planning process, it is often found that they bring real strengths to the partnership. Transit agency strengths include:

- **Real-world expertise** at planning, designing, building, and operating transit infrastructure.
- A direct business **relationship with existing transit riders** and an understanding of the transit ridership market. These contacts can be particularly useful when advocating for project financing and building political support for the proposed multimodal corridor project. Transit agencies often have working relationships and familiarity with local transit advocates as well, offering an additional source of support for the proposed multimodal corridor project.
- **Relationships with transit planning, engineering, and construction firms.** These contacts are particularly useful when preliminary cost estimates of project alternatives are needed as well as judgments regarding the feasibility of these alternatives.
- **Relationships with local elected officials.** Transit agency governing boards are often populated with local politicians

who have contacts either with local government commissions and boards or with representatives of these local government-elected officials themselves.

Many transit agencies use these advantages within collaborative transportation planning efforts to great effect. In particular, transit agencies advocate for multimodal solutions to transportation problems and as new paradigm project partners with access to various federal, state, and local project funding sources.

Transit Agencies as Agents of Multimodal Compromise

In the case of the T-REX multimodal corridor project (see Figure 6-1), Denver's Regional Transit District (RTD) played a critical role in helping forge a compromise between the highway and transit interests in the corridor during the project planning process. Perhaps due in part to the wide variety of interests involved in the study, the initial Major Investment Study (MIS) was largely transit-oriented in its recommendations with relatively minor freeway improvements. However, FHWA and CDOT advocated for freeway-widening measures and after discussion, the lead agencies agreed that the MIS placed too much emphasis on transit.

The RTD's director reported, "We looked at ways to break down the freeway versus transit rivalry and started looking at mobility," and started to, "... look at freeway and transit as coordinated pieces of a comprehensive strategy to maximize mobility in a project with limited available right of way. We set our sights on a project that was a win-win [proposition] for both transit and freeway. What emerged was the T-REX project."¹⁷

These efforts to bridge the gap between freeway and transit interests also yielded a revised Major Investment Study for the corridor that combined freeway widening (with up to seven lanes in each direction) with fixed-rail transit improvements—a mix that all the project partners could support.

Transit Agencies as New Paradigm Project Funding Champions

The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) increased transit capital funding to \$52.6 billion over six years, an increase of 46 percent over TEA-21 levels. These increases in available transit capital funds suggest transit agencies can play



Source: Colorado Department of Transportation, T-REX Fact Book.

Figure 6-1. Denver's T-REX Project.

a critical role in obtaining funds for new paradigm multimodal projects.¹⁸

The Transportation Equity Act for the 21st Century (TEA-21), the successor to ISTEA, also brought changes to the relationship between transit agencies and the federal government. The most prominent change was the elimination of federal operating assistance to transit agencies in urban areas of more than 200,000. Operating expenses—including employee wages and benefits, vehicle maintenance, fuel expenses—typically account for more than two-thirds of a transit agency's annual expenses.

Since the federal government had been trying to reduce its commitments to funding transit operating expenses for years,¹⁹ transit agencies were able to fill this funding gap with local revenue sources. Over the past two decades, transit agencies have adjusted to the reality of reduced funding

¹⁷Civil Engineering News- Spotlight on Building The Future-T-REX project, <http://www.cenews.com/article.asp?id=1314>

¹⁸Millar, W. W., "Safe, Accountable, Flexible, Efficient Transportation Equity Act—A Legacy for Users: A Guide to Transit-Related Provisions," http://www.publictransportation.org/resources/laws/safetea_lu_brochure.asp#link2

¹⁹Brown, J. "Paying for Transit in an Era of Federal Policy Change," *Journal of Public Transportation*, Vol. 8, No. 3, 2005.

support from federal and state sources with funds from local sales taxes, gas taxes, and local government general revenue sources. Nationally, from 1984 to 2001, the average share of transit agency operating expenses that came from local dedicated sales taxes grew from 11.8 to 19.6 percent,¹⁹ a 66 percent increase. This agility at accessing funds speaks to the substantial political influence transit agencies can draw on within their operating jurisdictions and makes them potentially powerful partners in new paradigm projects.

The MPO Context

MPOs can play important roles in new paradigm projects as consensus-builders, planners, financiers, and political support builders at all levels of government. Their influence and potential effectiveness as multimodal project partners flow both from above and below in the government hierarchy, with their connections to federal, state, and local governments. MPOs coordinate short- and long-term transportation planning and federal funds programming for their regions. But their decision-making powers come from below, as their governing bodies are typically run by boards of constituent local government representatives.²⁰

The wide-ranging scope of their responsibilities for transportation modes in their region, their role as the funding conduit from the federal and state levels to local modal agencies, and their mandate to coordinate and prioritize the various transportation projects throughout their regions offer an opportunity to facilitate multiagency partnerships that are central to new paradigm projects.

MPO agency strengths in multimodal, new paradigm project partnerships include

- Regional-level **planning and project financing expertise**
- **Access to funding** from multiple levels of government
- Ongoing, staff-to-staff-level **working relationships and partnerships with local transit agencies, governments, state DOTs, and USDOT**
- Commission/board representatives typically drawn from **local government administrative and elected officials**

MPOs: Potential New Paradigm Consensus-Builders

Nevertheless, these MPO strengths can also manifest themselves as shortcomings and obstacles when undertaking a new paradigm project. With the exception of a few select funding programs MPOs do not have direct authority over federal funding decisions, but share these duties with state DOTs. An

MPO's plans and funding decisions are only a component of their state's transportation improvement plan (STIP), but the MPO's portion of the STIP must have the approval of the MPO to have official recognition from the federal government. Therefore, to be effective new paradigm partners, MPOs are at their best when working as consensus-builders. As a result, the state retains the official power over federal transportation funding allocations, but the MPOs can obstruct the state's power, forcing them to submit an incomplete STIP for approval to the federal government.²⁰

This role as potential spoiler is just one example of the double-edged nature of MPO powers. MPOs must navigate the political waters between their various partner agencies and overuse of their veto powers can disrupt the working relationships they have with their partner agencies. As a result, MPOs work best when they refrain from using their administrative "sticks" and rely on collaborative decision-making techniques to reach consensus with their partners. If MPOs emphasize these techniques, they can play a significant role as new paradigm project consensus-builders and project financiers. However, MPOs are increasingly being given more prominent roles as multimodal project advocates, financiers, and even operators.

High-Profile MPOs: Dangers and Possibilities

Some MPOs are also taking control of existing, or developing new, regional transportation funding sources. The San Francisco Bay Area Toll Authority (BATA) offers a good example of this trend. Prior to 1997, Caltrans was responsible for collecting and spending San Francisco Bay Area toll bridge funds. In 1997, the state legislature shifted responsibility for these funds to a new entity, BATA, which was governed by the same board as the region's MPO, the Metropolitan Transportation Commission (MTC). MTC's BATA has since used these toll monies to fund various projects around the region, including transit and highway projects in multimodal corridors. These projects include the Bay Area Rapid Transit (BART) expansion to Warm Springs in the Interstate 880 corridor and the addition of a fourth bore—effectively a freeway widening project—in the Caldecott Tunnel in the East Bay (BART) Pittsburg/Bay Point Line/S.R. 24 corridor.

The use of these funds for projects geographically distant from the toll bridge facilities that generated them has raised some objections in the region, and MTC's BATA has received some criticism for the process it uses to allocate these funds.²⁰ So while MPOs seem to be growing in influence, including control over funding sources previously administered by other levels of government, they are also entering into a more politically high-profile realm that may have some negative consequences for new paradigm projects that require collaboration with other agencies.

²⁰Institute of Transportation Studies & ICF Consulting, "Metropolitan-Level Transportation Funding Sources," December 2005, <http://www.transportation.org/sites/planning/docs/NCHRP%208-36%2849%29%20Final%20Report.pdf>

The effectiveness of MPOs in the future, both as revenue-collecting and project-financing bodies, will often depend on the cooperation of state DOTs. As seen with Caltrans and MTC, some states actively support new regionally based transportation funds. Indeed, where MPOs pursue a revenue collection and financing role that reduces state DOT responsibilities or replaces the need for scarce state funds, MPOs may find a willing and active partner at the state level. In some cases, however, state DOTs may perceive the financial empowerment of MPOs as a threat. Even states that willingly devolve responsibility to lower government levels may prefer to distribute that authority to counties rather than MPOs.²¹

To help build new paradigm project partnerships, the questions of roles, authority, and responsibilities need to be carefully and explicitly examined among project partners. While MPOs offer valuable qualities as a lead partner on new paradigm projects, each case will be different and the institutional relationships before, during, and after a new paradigm project is undertaken should be discussed, and in most cases, is best formalized in the form of joint powers agreements or other contractual mechanisms.

The Local Government Context

Local government participation and effectiveness are critical to the success of new paradigm corridors, both in the short and long terms. In the short term, the new paradigm approach requires effective local governments that can work with their partners to plan and build multimodal access facilities to and from the transit line's stations and the freeway's interchange ramps. In the long-term, the success of the new paradigm approach requires local government cooperation to shape the land uses and the urban design qualities of the corridor to reinforce and encourage the efficient and effective use of those facilities.

Local government strengths in multimodal, new paradigm projects include

- **Ownership and control of access** to corridor transit and freeway facilities
- **Ownership and control of** on-street and (often) off-street **parking facilities**
- **Corridor land use controls**
- **Close working relationships** with corridor residents, businesses, and politicians

Typically, local governments control the surface street network and are responsible for zoning corridor land uses. Streets are, by their nature, multimodal facilities, and local

governments have a vested interest in ensuring multimodal access to the land uses within their jurisdictions. Unfortunately, many of our existing freeway corridors are located in primarily automobile-oriented suburbs, where cars are often given priority on local streets at the expense of pedestrians, bicycles, and transit vehicles.

As discussed in previous chapters, an effective new paradigm transit line requires transit-oriented development clustered around its stations, while the freeway requires automobile-oriented development near its interchanges. Ultimately, the success of the new paradigm rests on the ability of local governments to comprehensively plan and implement corridorwide land use configurations. However, despite their importance, local governments are sometimes overlooked as multimodal corridor partners since they do not (1) have control of project funding sources; (2) plan, design, or operate the primary transportation systems (the freeway and transit line); and (3) generally take the lead in partnership coordination.

Policies and planning practices at the local government level can also hinder successful new paradigm corridor efforts. The land use policy barriers that disadvantage transit investments are well documented and include exclusionary and fiscal zoning policies, restrictions on density, and parking subsidies. These policies also impede the development of multimodal capacity, and it is worth considering their effects.

Inconsistencies in the way land use policies are implemented between local governments in the same corridor can also undermine the potential success of the new paradigm. Different communities along a corridor may have different or conflicting development policies and may compete for development.

Comprehensive land use and access planning often depends on cooperation between local governments. However, to be effective advocates for matching growth patterns and access improvements to the needs of the transit line and freeway in a new paradigm corridor, it is best if local governments are given the power to pool their efforts and coordinate their policies and programs between neighboring jurisdictions. Research on comprehensive planning techniques in highway corridors suggests that these goals can be achieved either by empowering local governments with state legislation to encourage cooperation in land use planning or by creating regional agencies that have authority to do land use and transportation planning at a regional level.²²

However, when local governments are determined to take a leadership role in new paradigm corridor development, state or other legislation may not be necessary. Indeed, although there are few examples of local governments taking a strong,

²¹Sciara, C. & M. Wachs, "Metropolitan Transportation Funding", *Public Works Management & Policy*, 2007, Vol. 12, No. 1, 378–394.

²²Carlson, D., and S. King. (1998). *Linking Transportation and Land use by Fostering Inter-jurisdictional Cooperation Enabling Legislation in Eight States*, Institute of Public Policy and Management, University of Washington, Seattle, Washington.

lead role in developing multimodal corridors, some of the most prominent examples of multimodal corridors in the United States owe their success to the efforts of local governments.

Chicago provides a clear example of how successful city and county governments can be when they have the will and are given the authority. Early in the 20th century, planners had envisioned a “west side superhighway,” along the Congress Street corridor. In 1939, the City of Chicago created the Department of Subways and Superhighways, a multimodal planning and operations agency with a mandate to build this facility, later to be named the Eisenhower Expressway, as a combined freeway and rapid transit facility.²³ The success of this early multimodal corridor project suggests that local governments can take the lead role in these projects, but they must be given the authority and resources to carry out their mission.

Similarly, the success of Washington DC’s Orange Line/I-66 corridor, which has the highest transit ridership of any multimodal corridor researched here, is due in no small part to the active participation and influence of Arlington County’s local government. These agencies fought to have the Orange Line diverge from its in-median alignment along I-66 and travel at a half-mile distance to the south through its planned commercial centers. By influencing the right-of-way choice for the transit line in this multimodal corridor, they were able to coordinate the land uses for the corridor as well, creating one of the most successful examples of a transit-oriented multimodal corridor in the United States.

Interagency and Intermodal Cooperation and Collaboration

Getting a multimodal corridor built is one thing, but building a successful, balanced, and coordinated new paradigm corridor requires a unique combination of collaboration, flexibility, and single-minded tenacity on the part of the project’s stakeholders. There are many causes of a lack of coordination between local governments, transit agencies, USDOT, and state DOTs that need to be taken into account when undertaking a new paradigm project. These include

- **Limited resources.** Even the best of intentions to coordinate among new paradigm corridor partners can be thwarted by a lack of financial, staff, or real estate resources. A lack of financial resources can prevent the planning and construction of station access facilities and services such as green connectors and neighborhood shuttles and the acquisition of intelligent transportation system infrastructure that can facilitate freeway-to-transit intermodal transfers. A lack of

experienced and available staff from partner agencies to work on the new paradigm project can keep the best corridor plans on a shelf gathering dust. A lack of available real estate in the corridor can prevent a new paradigm project from achieving its intended land use aims.

- **Conflicting priorities.** New paradigm project partners often have many competing projects, constituencies, and agendas among them and within their own organizations. Local governments, in particular, face these conflicts when the project corridor runs through other local government jurisdictions as well. In these cases, it can be difficult to reach consensus on development priorities in the corridor.
- **Ineffective regulations.** New paradigm projects, particularly those that seek to dramatically reshape corridor urban form and circulation patterns, can fail to meet expectations unless local governments are either willing to coordinate and share their land use or planning powers with other partner agencies, or cede those powers to a corridor- or regional-level agency. Often, a change in regulations is needed to facilitate this cooperation or consolidation of powers.
- **Controversial issues.** Existing controversies within and between communities and governments can thwart a new paradigm project, particularly if the project imposes costs on one constituency and offers benefits to another. New paradigm project partners need to thoroughly understand the political landscapes of each corridor jurisdiction and invest the time and resources necessary to compensate for these issues. Therefore, public outreach efforts that engage project partners in meaningful dialog with local communities are central to any successful new paradigm project. Successful outreach efforts require real commitment from project partner agencies to a process of open and honest, two-way communication with the community. If the flow of information is one-way, with partner agencies simply telling the community what their plans are without listening to the community’s concerns, values, and desires, multimodal projects are likely to find increasing public opposition. Successful outreach efforts will also work to engage the attention of the media as a means to communicate to as wide an audience as possible and as an additional source of information on how the community is responding to the new paradigm project. When public outreach is done right, a new paradigm project will (1) face less community opposition and fewer legal disputes that may delay the project and increase costs and (2) be more successful in the long term at serving the corridor and its communities.
- **Administrative procedures and obstacles.** Although the barriers to project development imposed by governmental administrative procedures are often viewed in a negative light (and sometimes derided as “red tape”), typically there were good reasons why these laws and administrative procedures were adopted. Often, they are the manifestations

²³McClendon, D., Encyclopedia of Chicago, “Expressways,” <http://www.encyclopedia.chicagohistory.org/pages/440.html>

of hard-won compromises that should be understood and respected. Once the underpinnings of these procedures are understood, alternative and less onerous forms of administrative oversight can often be identified that still meet the spirit and intentions of existing procedures while removing many of the impediments they pose to new paradigm project development. Land use controls that work to separate uses are a good example. Zoning codes that work to separate uses are intended to prevent pollution, vehicular traffic and other negative externalities from one use affecting another, but also tend to encourage the use of automobiles while suppressing pedestrian, bicycle, and transit activities. Form-based codes that regulate the relationships between building facades and the public realm instead of traditional zoning methods that regulate uses can help encourage pedestrian-oriented mixed-use development in a new paradigm corridor.

The Critical Role of State Governments in New Paradigm Projects

Beyond these basic reasons why effective collaboration is necessary, state DOTs can also play the role (along with USDOT) of the high-level arbiter among stakeholders, and when done properly, as a leader in formulating a vision of multimodal coordination at the policy level and as the agency leading big-picture multimodal planning efforts.²⁴

States play an important role in encouraging effective partnerships in new paradigm corridor projects. Carlson and King (1998) identified certain common, key factors in states that allow local governments to successfully engage in inter-jurisdictional cooperation:

- **Coordinated financial incentives** to encourage local government cooperation
- **Support for inter-agency collaboration** by state officials
- **Public recognition** in the state and the corridor **that the state has land use and transportation problems that require inter-jurisdictional solutions**²²

State legislation can help other new paradigm project stakeholders to collaborate, but research suggests that whether a state has such legislation or not, the willingness of a local government to partner with the DOT on corridor access management and land use issues is a critical factor determining the success of corridor planning efforts.²⁵

²⁴Peyrebrune, H. L., "Multimodal Aspects of Statewide Transportation Planning," Transportation Research Board, National Cooperative Freeway Research Program Synthesis of Practice 286, Washington DC: National Academy Press, 2000, 3.

²⁵Vanka1, S., S. Handy & K. Kockelman. "State-local Coordination in Managing Land Use and Transportation Along State Highways," Manuscript Number UP/2003/022238, http://www.ce.utexas.edu/prof/kockelman/public_html/JUPD, InteragencyCoop.pdf

Since multimodal corridors are often designed to take advantage of existing freeway rights-of-way as a means to add high-capacity transit, effective collaboration between state DOTs (who own and operate most freeway facilities in the United States), transit agencies, and MPOs (to name a few) is critically important. In the case of the Harbor Freeway Transitway project, the state's DOT (Caltrans) worked closely with their regional and local corridor partners to help design, build, and operate the facility. This included a corridorwide approach to managing the transportation systems, with attention paid to the corridor's arterial operations. In an effort to balance demand and capacity throughout the corridor, Caltrans has worked with the corridor's local governments to identify and obtain funding for arterial operations improvements, including bus priority signals to improve local bus operations.²⁶

In Arizona, the state's DOT (ADOT) was a prime mover in developing the Casa Grande Accord, an agreement between the state and its MPOs on how to share ISTEA transportation revenues. ADOT led the development of this agreement as a negotiation process and based allocations on long-range strategic planning and comprehensive planning principles, rather than by fiat.²⁷ While other states have struggled to effectively coordinate and foster cooperation among the state DOT and the MPOs, ADOT representatives surveyed cited cooperation among these groups as a strength, and specifically mentioned the Casa Grande Accord as the framework upon which this cooperative environment has been built.¹⁴

The successes of ADOT illustrate the paradox of ISTEA's influence on state DOTs, particularly with regard to flexible funding. As of 1998, 7 years after the passage of ISTEA, a survey of state DOTs asked if they believed ISTEA had accomplished the objective of making federal funding more flexible for multimodal projects. Forty-three percent said it had not.¹³ It appears that while ISTEA created opportunities for state DOTs to use highway funds for multimodal projects, it also took control of some of these funds away from state DOTs and gave it to MPOs. As a result, if state DOTs made a conscious choice to embrace the multimodal vision and use highway funds for nonhighway projects, it would be most effective to do so as part of a collaborative effort with their MPO partners, as illustrated by ADOT's successes.

Right-of-Way Planning and Acquisition: Legal and Institutional Issues

New paradigm multimodal corridors can be designed, owned, and operated in various ways, by a diverse collection

²⁶Interview with Frank Quon, Caltrans, 11/12/09.

²⁷<http://www.fhwa.dot.gov/planning/statewide/fcariz.htm>

of project stakeholders. A transit guideway (bus, rail) could be installed by dedicating an additional lane, reconfiguring lanes to add a transitway, operating on shoulders or in the median, operating on above-grade guideways in highway airspace, or even operating below the surface in tunnels under the highway ROW. Alternatively, the transit ROW could be adjacent to but not part of the highway ROW. Stations could be on-line in medians, shoulders, air rights, or subsurface, or could be off-line with dedicated access ways to the transitway. Often, the quality and form of partnerships between new paradigm stakeholders will play an important role in determining the way a high-capacity transit line is added to an existing freeway corridor.

Design, ownership, and operation and maintenance functions can be handled in a variety of ways. For example, the highway agency (state, county, or local) could run the multimodal facility. Alternatively, the highway agency could own the highway ROW and the transit operator the transit ROW, with each agency having responsibility for its own property, operations, and maintenance. Or the property could be owned by the highway agency, which could grant a right of passage for a term of years or could provide a permanent easement to the transit operator. In some states and regions, it might be advantageous to form a special district or joint powers agency to plan, operate, and maintain the facilities, separating these activities from ownership per se.

Stations also could be owned and operated by various parties, from state, regional, or local government agencies, to the private sector. The best solution will depend on the context, including public private partnership legislation and the availability of contracting approaches, such as build-operate-transfer.

Legal issues associated with new paradigm multimodal corridors can be federal, state, or local. At the federal level, a major issue is the “color of money” problem: while there are many different funding opportunities for multimodal corridors, there are many strings attached, limiting how funds can be spent, directing who has to approve the expenditures, and so on. While many funds can be transferred to other categories, there are complex mechanisms for such swaps.

The various states also have legal restrictions on how transportation funds can be spent. Some limit highway funds to highway uses. Others allow state highway funds to be used only for specified uses with regard to other modes. (For example, California restricts use to fixed guideways.) Some states disallow or restrict uses of excess right-of-way, a move that may reduce opportunities for joint development. States also have enacted laws governing access to HOV lanes and design standards for various facilities. These laws can restrict context-sensitive designs that are not “by the book.”

At the local level, many transit agencies have property or sales taxes that fund transit capital and operating expenses. However, the legislation authorizing the tax often restricts the use of the funds.

Institutional and Funding Considerations Relating to Multimodal Corridor Projects

There are a number of institutional challenges inherent to successfully coordinating the funding of multimodal corridors that derive from the coordination of two or more modes and their respective administrative requirements:

- **Mode-specific funding.** Although there is some flexibility in using highway funds to fund transit planning and vice versa and some highway trust fund programs have an explicit transit focus, taking advantage of this flexibility requires considerable time and expertise and risks a loss of transparency.
- **Mode-specific regulations.** Because there are separate procedures and regulations for funding highway and transit projects, any multimodal project that includes significant capital investment in both highway and transit infrastructure must navigate two distinct processes.
- **Mode-specific project review.** Aspects of the review process affect transit and highway projects differently; these may tend to stall funding and approval for one mode in a multimodal corridor, while the others proceed on a more advanced track.
- **State, regional, and local project participation and performance.** Various considerations affect the state and local levels. States tend to delegate transit planning to the local and regional levels, and because capital investments in transit are fewer and farther between, staff experience in working through the administrative process may be thinner. Furthermore (and as discussed previously), requests for New Starts funds have outstripped supply, and most of the projects approved for funding receive less than half of the needed amount. This is compared to the Highway Trust Fund, which has traditionally provided 90 percent of construction costs for the interstate system.⁶ Coordinating a transit funding process and a highway funding process places a premium on flexible funding, but because the flexible sources of funding are more limited, this poses a constraint on the magnitude of any request that depends on flexible funding. Thus, there will likely be considerable differences between state, regional and local project stakeholders in terms of their abilities to acquire the necessary approvals and funding commitments for multimodal corridor projects. New paradigm project partners need to be aware of these differences and share burdens and talents among stakeholders.

Summary and Conclusions: How to Turn Stakeholders into New Paradigm Project Partners

New paradigm corridors require complex collaborations among organizations and agencies, including the cooperation of mode-specific agencies such as highway departments and transit agencies. Similarly, because these projects are focused over wide geographical areas (corridors), they often cross jurisdictional boundaries and require the involvement of local city and county governments, particularly if an integrated, new paradigm corridor plan is to properly combine transportation and land use components into a cohesive, unified system. The institutional issues that are barriers to multimodal corridor projects are constantly changing over time and can differ substantially from project to project. At times, it can seem that there are few commonalities to point to that can help new paradigm projects avoid the pitfalls experienced in past projects. However, this variation in the landscape of multimodal planning and policies is instructive. By understanding the institutional histories of the various stakeholders, pitfalls can be avoided and strengths can be tapped.

- **USDOT** has pursued mutually supportive strategies of multimodalism and “devolution” of its funding authority for transportation projects to lower levels of government, first to State DOTs and later to MPOs. Multimodalism has been central to the reforms embodied in ISTEA and its successor legislation wherein USDOT has also gradually worked to level the playing field between modes when financing transportation projects.

New Paradigm Partnership Strengths: Arbitrator of conflicts between project partners and modal interests and funding agency for capital-intensive transportation project.

- **State DOTs**, although originally focused on highway planning, design, construction, and operations, have become increasingly multimodal in their outlook and mandates in recent decades.

New Paradigm Partnership Strengths: A history of close contact with the federal government as partners in building the Interstate system. State DOTs can play an important role in bridging the gap between highway and transit advocates when securing political support for a new paradigm project.

- **MPOs** have become important stakeholders in transportation planning and financing since the passage of ISTEA.

New Paradigm Partnership Strengths: Increasingly in control of regional transportation funds from state and federal sources, these agencies were established with a multimodal mandate, potentially making them ideal lead

agencies in developing new paradigm projects that will require collaboration among multiple stakeholders.

- **Local Governments** typically control land use planning and regulations as well as the local surface street networks.

New Paradigm Partnership Strengths: A direct conduit to local political leaders and their constituencies. The effective implementation of a new paradigm corridor project requires the enthusiastic cooperation of local governments to coordinate transportation investments with local land use controls.

This diverse group of stakeholders has an equally diverse list of reasons why they would be interested in collaborating on a new paradigm project. An effective new paradigm collaboration among these stakeholders requires two key elements: a well-defined and appropriate set of roles for each party and a project plan that serves the interests and needs of each stakeholder.

Effective new paradigm partnerships require the active and enthusiastic participation of all stakeholders. Generally, partnerships are successful when each party believes they have a say in shaping the outcome of the project and when they believe they can make a meaningful contribution.

New paradigm projects can learn from successful partnerships like those seen in the development of Colorado’s T-REX project, where all the partner agencies worked to shape the outcome. The active participation of a diverse set of stakeholders in this project was due in no small part to the open collaborative process developed for the project during the planning phase when the project’s major investment study was undertaken. This process recognized that the project’s definition—the goals and objectives of the project—needed to be determined through collaboration. Although this process was not always smooth, it provided all stakeholders with a sense of empowerment, making them willing partners that could bring the strengths of their individual agencies to the partnership. In doing so, each partner has brought their best capabilities to the table: local governments have provided land use controls and surface street facilities that support the transit line and the freeway; the MPO has played the role of consensus-builder and project financier; the transit agency has been the lead agency in designing, building, and operating the transit line; the state DOT has been both an advocate for a multimodal corridor design and the lead agency responsible for re-designing the freeway facility; and the USDOT has played the role of providing project oversight and advocating within the federal government. Successful new paradigm partnerships should be designed so that each party is given a role according to its strengths and is given a sense of empowerment in decision making.

CHAPTER 7

Lessons and Conclusions

The new paradigm for multimodal corridors offers opportunities to transportation policymakers, planners, engineers, and the traveling public. It emphasizes building transit lines and supporting pedestrian and bicycle facilities in existing freeway corridors, but in ways that avoid the pitfalls of old paradigm designs that did not effectively balance and coordinate the needs of all modes. New paradigm transit facilities are built with the following goals:

- **Enhancing corridor transportation capacity and performance** without adding freeway capacity, by building and operating transit lines (including bus rapid transit, light rail, heavy rail and commuter rail) in existing freeway corridors
- Building and operating successful transit systems in freeway corridors that attract **high transit ridership** levels and encourage **corridor livability and environmental sustainability**
- Transforming a corridor's land uses and activities to a more **transit-oriented pattern**.

The new paradigm can help achieve these goals through the process of market-segmentation within a multimodal corridor. Market-segmentation between transit and freeway is achieved using the following guiding principles and techniques:

- Market-segmented transit and freeway designs (multimodal coordination)
- Market-segmented urban form patterns
- Market-specific station access
- Market segmentation through constrained freeway capacity
- Coordinated and distinct intermodal operations
- Intermodal connections limited to key locations
- Intermodal intelligent transportation systems

The new paradigm offers a two-step process of multimodal corridor planning, design, and construction wherein transit facilities are designed and built in freeway corridors with performance characteristics that enable them to compete

with the freeway facility on a travel time basis. As the corridor evolves, infill stations can be built that provide greater coverage and accessibility for the transit riders to corridor land uses and activities, which can further encourage the corridor to develop additional TOD. Over time, this process will lead to the conversion from a purely automobile-oriented, freeway-dominated corridor, to a park-and-ride-access multimodal corridor, to a transit-oriented corridor.

Three types of multimodal corridors have been identified: transit-oriented multimodal corridors, park-and-ride-access multimodal corridors, and transit-optimized/freeway-constrained multimodal corridors. These are discussed in the following sections.

Transit-Oriented Multimodal Corridors

Transit-oriented multimodal corridors are designed to give transit a performance advantage in serving short and medium-length trips, while the freeway is given a performance advantage for serving long-haul corridor trips. This travel market segmentation is achieved through several means:

- Transit-oriented complementary multimodal coordination
- Transit-oriented urban form
- Transit-oriented station access
- Corridor-wide jobs-housing balance
- Limited intermodal stations

Park-and-Ride-Access Multimodal Corridors

Park-and-ride-access multimodal corridors are designed to provide high levels of automobile access within, and high transit speeds through, the corridor. This is achieved through several mutually supporting design and operational elements:

- Automobile-oriented complementary multimodal coordination

- Automobile-oriented urban form
- Automobile-oriented station access
- Corridor serves large central business district

Transit-Optimized/ Freeway-Constrained Multimodal Corridors

A transit-optimized/freeway-constrained multimodal corridor is designed to give transit a performance advantage in the corridor by constraining the capacity and performance of the freeway. This travel market segmentation is achieved through the following means:

- Capacity-constrained freeway
- Hybrid corridor configuration

Successful new paradigm corridor projects consist of several critical components:

- **A long-term vision for the corridor** that includes both a desired end-state (for example, a transit-oriented corridor) and the necessary steps to achieve that end-state.
 - **A committed, diverse, and flexible collection of project stakeholders.** These partnership commitments need to be formalized using joint powers agreements, memorandums of understanding, concept of operations, and other contractual documents that provide a structure for inter-agency cooperation, a clear definition of roles, and statements of resource commitments from each stakeholder. Partnerships can also elect to form a joint agency that combines staff and resources from all participating stakeholders. These project-specific organizations (such as those created for the T-REX project) can be very effective at improving cross-organizational communications and providing a clear structure for decision making.
 - **A project planning and design process that seeks to create segmented, specialized corridor travel markets for each mode of travel.** These segmented markets can be developed using the planning and design tools discussed in this report such as the following
 - **Segmented corridor urban form patterns** within the corridor that help provide a travel market friendly to each mode of travel.
 - **Complementary multimodal coordination** between high-capacity modes/facilities such as transit and freeways.
 - **Targeted transit station access facilities and services** that are consistent with the surrounding urban form patterns (planned or existing) and the desired multimodal coordination plan. Station access designs include
 - **Intermodal stations** that encourage freeway-to-transit transfers and bus-to-transit transfers
 - **Transit-oriented stations** that encourage non-automotive modes of travel to and from stations
-

APPENDIX A

Multimodal Corridors Table

Catalogued Corridors by Proximity of Transit to Roadway—US & Canada			
United States/Canada			
Corridor	Location	Transit	Station Locations
1A MEDIAN			
Red Line/Dan Ryan Expwy.	Chicago, IL	Commuter Rail	Elevated Median Platforms
Harbor Fwy. (I-110)/Harbor Transitway	Los Angeles Metro	Dedicated HOV	Elevated Median Platforms
I-395	Washington DC	Dedicated HOV	Median at grade
Houston US 290 Northwest Corridor	Houston, TX	Dedicated HOV	Adjacent P&R/Stations
BART Concord Line/SR 24	SF Bay Area	HRT	Elevated Median Platforms
North Line/Route 400	Atlanta, GA	HRT	Elevated Median Platforms
I-66/Orange Line	Washington DC	HRT	Elevated Median Platforms
I-95/Market-Frankford Line	Philadelphia, PA	HRT	Elevated Median Platform
BART Dublin Line/I-580	SF Bay Area	HRT	Elevated Median Platform
Guadalupe LRT Line/Rts. 87 & 85	SF Bay Area	LRT	Elevated Median Platforms
Green Line/Century Fwy. (I-105)	Los Angeles	LRT	Elevated Median Stations
Metro/I-795	Baltimore	HRT	Median
DART, North Line/Central Expressway	Dallas, Texas	LRT	In Tunnel Under Expressway
Gold Line/I-210	Los Angeles, CA	LRT	Median
North Line/SR 160/I-80	Sacramento, CA	LRT	Median
TTC-Yonge University Line/Allen Expressway	Toronto, ON	HRT	Median
1B MEDIAN/IMMEDIATELY ADJACENT			
Blue Line/Eisenhower Expwy., Kennedy Expwy.	Chicago, IL	HRT	Elevated Median Platforms
San Bernardino Metrolink Line/El Monte Busway	Los Angeles Metro	HRT	Elevated Platforms
TREX Project	SE Denver Metro	LRT	Median/Adjacent
Metra, Rock Island/I-90	Chicago, IL	Commuter Rail	Side/Adjacent
New Haven Line/I-95	New York Metro Area	Commuter Rail	Side/Adjacent
Regional Rail/I-95	Philadelphia, PA	Commuter Rail	Side/Adjacent
Southeast Line (Folsom)/US 50	Sacramento, CA	LRT	Side/Adjacent
1C IMMEDIATELY ADJACENT			
Shore Line East/Metro-North/New England Thruway	Connecticut	Commuter Rail	At grade
Metra, NW Line/Kennedy (I-90)	Chicago, IL	Commuter Rail	Side
South Shore/I-80/I-94	Chicago, IL	Commuter Rail	Side
2 PROXIMATE - LESS THAN 1/4 MILE			
Framingham Commuter Rail Line/Mass. Turnpike (I-90)	Boston, MA	Commuter Rail	At grade
BART Fremont Line/I-880	SF Bay Area	HRT	Underground/Elevated Platform
BART SFO/Colma I-280	SF Bay Area	HRT	Underground/Elevated Platform
BART SF Daly City I-280	SF Bay Area	HRT	Underground/Elevated Platform
Denver Southwest Line Corridor	Denver, CO	LRT	At grade
Banfield Fwy./I-84/Red Line	Portland, OR Metro	LRT	Elevated Platforms

Catalogued Corridors by Proximity of Transit to Roadway—Europe

Europe			
Corridor	Location	Transit	Station Locations
1A MEDIAN			
Essen Spurbus/A430	Essen, Germany	Guided Busway	Median at grade
1C IMMEDIATELY ADJACENT			
La Provençal/SCNF	Nice-Antibes	Commuter Rail	At grade
East Cross Route/Central Line	London	Subway	Underground
Itavayla/Itakatu/170/Ruolahti Line	Helsinki	Commuter Rail	At grade
3 Merenweg/Zuidtangent	Haarlem/Schiphol, Ne	Dedicated Buswa	At grade
Strada Aldo Moro/ Auto Strada, Milan Genova	Genova	Subway	Underground
Route 52/Line S8/Line S80	Vienna	Tram	Streetside
A1L Autobahn/Line 9	Zurich	Tram	Streetside
A-35/Rue de l'Unterelsau/Line A/Line D/Line E	Strasbourg	Tram	Streetside
2 PROXIMATE - LESS THAN 1/4 MILE			
A81 Autobahn/S1	Stuttgart	Commuter Rail	At grade
Uferstrasse M10/S1	Stuttgart	Commuter Rail	At grade
M14/M29/S2	Stuttgart	Commuter Rail	At grade
Autopista De Montserrat/E9/Funicular	Barcelona	Funicular	Underground
M-30/Autovia de la Sur/Line 3 Legazppi	Madrid	HRT	Underground
Gran Via de Les Corts Catalanes/L2 Pep Ventura	Barcelona	HRT	Underground
A9 Autobahn/U6	Munich	Subway	Underground
Industrialstrasse/12	Cologne	Tram	Streetside
3A VARIABLE ADJACENT UP TO 1/2 MILE			
A2 Autobahn/S4	Lucerne-Stansstad	Commuter Rail	At grade
Route de Romelles	Geneva	Commuter Rail	At grade
A12 Autobahn/S1	Friborg-Bern	Commuter Rail	At grade
A6 Autobahn/S3	Biel-Bern	Commuter Rail	At grade
A5 Autobahn/R line	Neuchatel-Verdon les I	Commuter Rail	At grade
A3 Autobahn/S4/S8	Zurich-Horgen	Commuter Rail	At grade
A1 Autobahn/S7/S8	Zurich-Winterthur	Commuter Rail	At grade
A2 Autobahn/S2	Bellinzona-Locarno	Commuter Rail	At grade
A3 Autobahn/S1	Baeel-Rheinfelden	Commuter Rail	At grade
Route 150/Kai Munks vei/Line 4/Line 6	Oslo	Commuter Rail	At grade/Subway
Avenue Jean Paul Sarte/Ligne 1	Marseilles	HRT	Underground
Ronda De Da Via Favencia/L3 Canyelles	Barcelona	HRT	Underground
Via Del Mare/Romanoli/Metro Lido Line	Rome	HRT	At grade
Cv 35 Avenida de la Virgen de la Cabeza/Line 4	Valencia	HRT	Underground
M3/Line 62/Line 67V/Line69	Budapest	Tram	At grade
Via Palmanova/Metro L2	Milan	Subway	Underground
A27/Line 4 Weserpark	Bremen	Subway	Underground
3B - PROXIMATE - 1/4 TO 1/2 MILE			
Autostrada del Sole/ Autostrada Napoli-Solerno	Naples-Pompeii	Commuter Rail	At grade
N13/Rer C	Paris	Commuter Rail	Streetside
A86/Rer B	Paris	Commuter Rail	At grade
A86/Rer E	Paris	Commuter Rail	At grade
AutoStrada Fiumicino Roma/ Fiumicino Aeroporto FR 1	Rome	HRT	At grade
A55 L'Autoroute du Littoral/Ligne 2	Marseilles	HRT	Underground
Ronda Del Litoral/L4 La Pau	Barcelona	HRT	Underground
L4 Trinitat Nova/L11 Can Cuias/ Autopista del Valles	Barcelona	HRT	Underground
Avenida de Portugal/Line 10	Madrid	HRT	Underground
Avenida De America/M-14/Line 5	Madrid	HRT	Underground
A-3/Line 1/Line 9	Madrid	HRT	Underground
Rurshenellweg/Westfallendamm/U47	Dortmund	Subway	Underground
Rosa-Luxemburg Strasse//U3	Frankfurt	Subway	Underground
A73 Frankenschneelweg/U11/U1	Nuremburg	Subway	Underground
4 - PREDOMINANTLY - 1/4 TO OVER 1/2 MILE			
A7 Autovia Del Mediterraneo/Line 1 South	Valencia	HRT	Underground
CV-30/V30Line 1 Northwest	Valencia	HRT	Underground
Avenida de La Paz/M 30/Line 6	Madrid	HRT	Underground
Autovia de Toledo/Line 12	Madrid	HRT	Underground

Catalogued Corridors by Proximity of Transit to Roadway—Australia/New Zealand/Latin America/Asia/Africa

Australia/New Zealand			
Corridor	Location	Transit	Station Locations
1C IMMEDIATELY ADJACENT			
Northern Busway/Northern Busway	Auckland, NZ	BRT	Side
Various Bus Routes/Southeast Expressway/M-13	Brisbane, Australia	BRT	Side
2 PROXIMATE - LESS THAN 1/4 MILE			
M-13/South East Busway	Brisbane, Australia	Elevated busway	Elevated Platforms
Latin America			
Corridor	Location	Transit	Station Locations
1A MEDIAN			
Via Expressa	Lima, Peru	Dedicated busway	Median at grade
Metro System Line 3/ Avenida Insurgentes Norte	Mexico City, Mexico	Subway	Underground/Median at grade
Asia/Africa			
Corridor	Location	Transit	Station Locations
1A MEDIAN			
EDSA	Manila, Philippines	LRT	Median
BRT Line 1/Southern Axis Freeway	Beijing, China	BRT	Median
1C IMMEDIATELY ADJACENT			
Ikurodu Road - Ojota Section	Lagos, Nigeria	BRT	Side

APPENDIX B

Evidence on the Patronage Impacts of Multimodal Corridors

This appendix presents evidence suggesting that transit and freeways can coexist and thrive in the same corridor. These findings also provide evidence to support the concepts and tools of the new paradigm, including separated corridor travel markets that can be achieved through complementary multimodal coordination, transit-oriented land uses and station access, constrained freeway capacity and, where appropriate, high transit operating speeds.

Total Corridor Performance: How Well Do Transit and Freeways Work Together?

Although some may believe that freeways and transit do not mix, analysis of existing multimodal corridors suggests this is not always true. There are examples of transit lines that thrive in the same corridors as freeways. These corridors have varying combinations of characteristics that can help the transit line compete effectively for patronage. They are

- Multimodal corridor coordination
- Transit-oriented corridor urban form
- Transit-oriented station access
- High transit operating speeds (where appropriate)
- Constrained freeway capacity

Although there are several ways to evaluate the patronage performance of multimodal corridors, the total patronage of both the transit and freeway facilities gives an indication of how well these two modes are working together as a multimodal system to facilitate travel along the corridor.

However, focusing on total throughput can mask cases where one mode dominates the other—specifically, when freeways capture most of the corridor travel market. Therefore, while our discussion of multimodal corridor performance begins by looking at total patronage, we follow this by looking at

transit ridership in each corridor to evaluate how well each transit line competes with its freeway neighbor. Transit's share of total corridor patronage is a useful metric to see how well transit competes with the freeway.

Table B-1 shows the estimated total, freeway-only, transit-only, and transit mode share of patronage in each multimodal corridor studied. These data are used to evaluate how well transit lines perform in multimodal corridors, whether and how transit and freeways can work together, and what corridor conditions help foster success for all modes.

Multimodal Corridor Coordination

As discussed in previous chapters, coordination between the various transportation facilities in a corridor can be achieved by complementary or supplementary coordination.

In complementary coordination, the transit and freeway facilities are designed and operated to serve different travel markets, activity patterns, and land uses within the same corridor. A corridor with supplementary coordination has roughly equal station and interchange spacings. These corridors put their freeway and transit components in direct competition with each other for the same travel markets.

Two complementary coordination configurations were also proposed in previous chapters:

- **Transit-oriented complementary coordination** has long interchange spacings on its freeway component and relatively short station spacings on its transit line.
- **Automobile-oriented complementary coordination** has long station spacings on its transit facility and relatively short interchange spacings on its freeway component.

There are few real-world examples of transit-oriented complementary multimodal corridors, but there are cases where sections of corridors have transit-oriented characteristics.

Table B-1. List of study multimodal corridors and key performance measures.

Corridor ID	Multimodal Corridor	Transit Mode	Freeway Lanes	Estimated Daily Patronage			
				Freeway	Transit*	Total	% Transit
1	Atlanta North-South Line/Route 400	HRT	10	326,000	22,000	348,000	6%
2	Chicago Blue Line/Eisenhower Expwy.	HRT	8	255,000	24,000	279,000	9%
3	Chicago Blue Line/Kennedy Expwy. (I-90)	HRT	6	400,000	59,000	459,000	13%
4	Chicago Red Line/Dan Ryan Expwy.	HRT	6	312,000	42,000	354,000	12%
5	Denver Central/I-25	LRT	6	270,000	18,000	288,000	6%
6	Denver TREX/I-25	LRT	6	270,000	23,000	293,000	8%
7	Houston Northwest/U.S. 290	BRT	6	316,000	6,000	322,000	2%
8	Los Angeles El Monte Transitway/I-10	BRT	8	287,000	7,000	294,000	2%
9	Los Angeles Gold Line/I-210	LRT	6	242,000	24,000	266,000	9%
10	Los Angeles Green Line/Century Freeway	LRT	10	311,000	42,000	353,000	12%
11	Los Angeles Harbor Freeway (I-110)/Harbor Transitway	BRT	6	387,000	4,000	391,000	1%
12	New Haven Line/I-95	CR	6	163,000	87,000	250,000	35%
13	Portland MAX Airport/I-84 Red Line	LRT	6	195,000	7,000	202,000	3%
14	Sacramento North Line/S.R. 160 & I-80	LRT	6	70,000	6,000	76,000	8%
15	San Francisco Daly City Line/I-280	HRT	8	254,000	51,000	305,000	17%
16	San Francisco (BART) Dublin Line/I-580	HRT	8	257,000	20,000	277,000	7%
17	San Francisco (BART) Pittsburgh/Bay Point Line/S.R. 24	HRT	8	204,000	57,000	261,000	22%
18	San Jose Guadalupe/San Jose S.R. 87 & 85	LRT	6	182,000	7,000	189,000	4%
19	Washington D.C. Orange Line/I-66	HRT	6	127,000	139,000	266,000	52%
		Average	7	261,400	33,750	295,150	12%

Source: TCRP H-36 Interim Report March 2009

Note: Transit patronage figures were typically available for entire lines and have been adjusted to represent travel within the study corridors (which are often portions of larger lines).

* - Transit daily patronage estimated using daily boardings.

The Benefits of Complementarity

Complementary corridors have several distinct advantages over supplementary corridors:

- **Separated Corridor Travel Markets for Transit and Freeway:** The combination of long interchange and short station spacings (transit-oriented complementary) encourages short- and medium-distance corridor travelers to use transit while long-distance travelers are encouraged to use the freeway. The combination of short interchange and long station spacings (automobile-oriented complementary) encourages long-distance corridor travelers to use transit while short- and medium-distance travelers are encouraged to use the freeway. In both configurations, direct competition between the transit and freeway facilities is minimized.
- **Competitive Transit Operating Speeds:** When there are fewer transit access points (stations) along congested corridors, transit can operate at higher average speeds and compete favorably with automobile trips in travel time and travel-time reliability.
- **Increased Local Access for Transit and Increased Freeway Speeds:** Providing fewer freeway access points allows for increased freeway speeds, higher flow rates, and higher volumes. This can be supported by providing transit alternatives for local trips, especially in or near more densely developed areas.

- **Fewer Station/Interchange Conflicts:** By offsetting transit stations from freeway interchanges it is possible to increase and diversify the “customer” base for travel along a given corridor.
- **Enhanced Potential for Transit-Oriented Development:** When interchanges and stations are separated, the automobile traffic associated with interchanges is removed from transit station walking environments, allowing clustered, high-density, pedestrian-oriented development patterns to take root.

The Effects of Multimodal Coordination on Corridor Patronage

The performance of a corridor can be understood in many ways. For the purposes of this analysis it is not important to establish results in terms of return on investment or the relative performance of transit versus auto. Rather, a simple aggregate measure of person-trip throughput provides an adequate indicator of corridor performance.

Based on a review of existing multimodal facilities in the United States, corridors with complementary coordination tend to carry more total patrons. Most corridors that carry more passengers either have a combination of long station spacings and short interchange spacings, although in one case it is the opposite.

Measuring Multimodal Coordination

The following formula was used to construct a measure of multimodal corridor coordination for the study corridors:

$$\text{Multimodal Corridor Coordination} = \frac{|\text{Median Interchange Spacing} - \text{Median Station Spacing}|}{\text{Median Interchange Spacing} + \text{Median Station Spacing}}$$

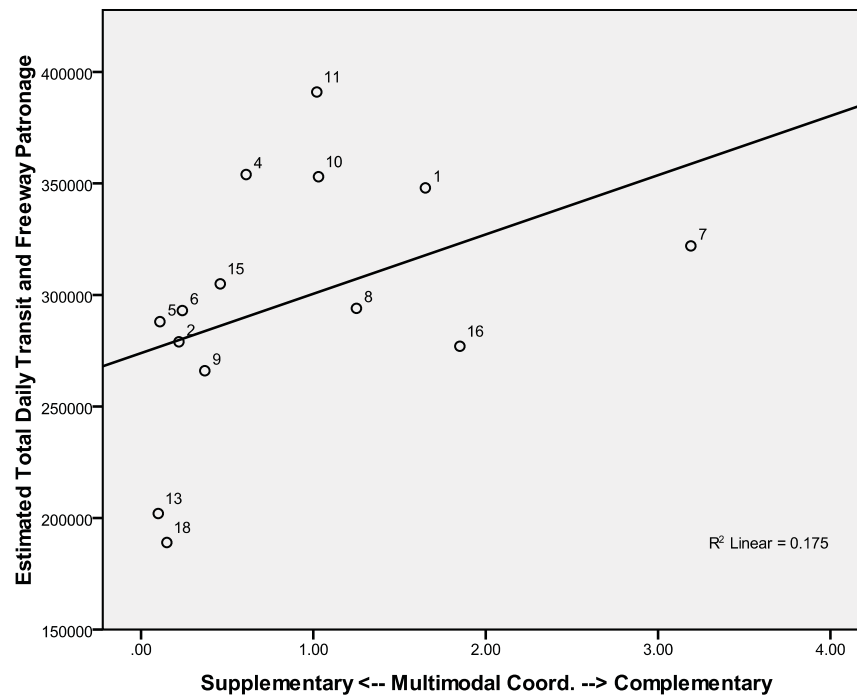
The higher the calculated value for a corridor; the more complementary the freeway and transit services in the corridor, while the lower the value, the more supplementary the corridor. By taking the absolute value of this calculation, this measure does not distinguish between complementary corridors where transit provides area coverage and the freeway emphasizes operating speeds, and complementary corridors with the reverse configuration.

Figure B-1 provides a graph of multimodal coordination and total corridor patronage (daily freeway patrons plus daily transit boardings) for each of our study corridors. A linear regression line drawn on this graph indicates that if there is a statistically valid relationship between these variables, it is not linear.

Additional exploratory analysis of these data showed that the relationship between multimodal coordination and corridor patronage is not linear. A log-log model was fitted and graphed in Figure B-2.

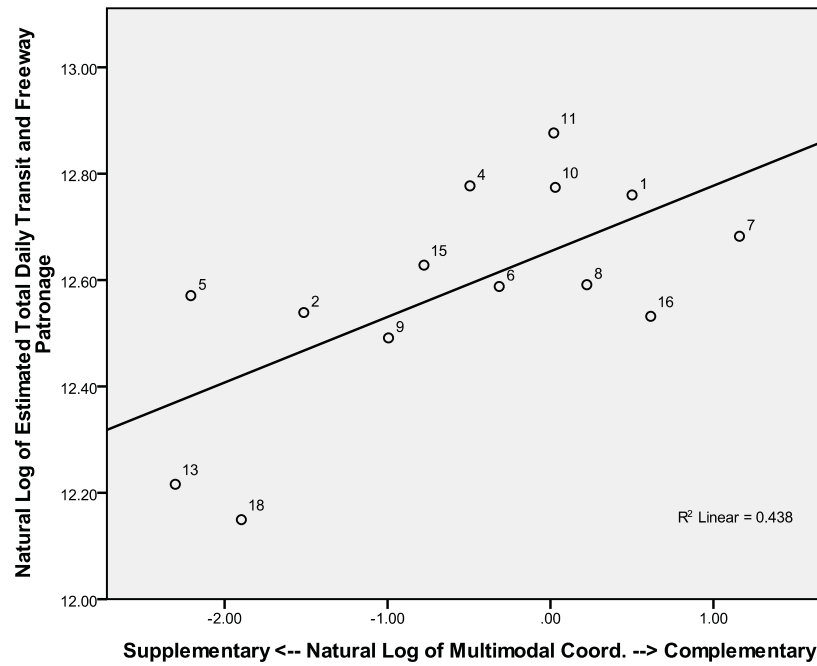
By graphing the relationship between multimodal coordination and total corridor patronage (Figure B-2) a positive relationship is suggested (though not statistically proven due to an insufficient sample size) where complementary corridor coordination is associated with more total corridor patronage. More detailed multivariate linear regression results are presented in Table B-2. The coefficient for multimodal coordination score in predicting throughput was significant at the $p = 0.05$ level.

To further test this relationship, a series of additional regressions were performed to determine to what extent the relationship is driven by either sensitivity to interchange spacing or sensitivity to transit station spacing irrespective of complementary multimodal access. For example, no statistically significant correlation was identified for either the influence of interchange spacing on freeway throughput without transit or the relative influence of transit station spacing on transit ridership.



Note: Commuter rail cases (i.e.; the New Haven Line/I-95 corridor) have been excluded since they tend to attract automobile and bus access riders from further distances from their stations than other transit modes. Transit-Optimized/Freeway Constrained cases (i.e.; Chicago Blue Line/Kennedy Expwy. (I-90), Washington D.C. Orange Line/I-66, and San Francisco East Bay (BART) Pittsburgh/Bay Point Line/S.R. 24) were also excluded since their freeway capacity constraints give their transit lines an operational advantage that masks the benefits of complementary coordination. Sacramento's North Line/S.R. 160 & I-80 was also excluded since the freeway sample txt point was along S.R. 160 where volumes are low.

Figure B-1. Multimodal coordination and total corridor patronage—linear regression line.



Note: Commuter rail cases (i.e.; the New Haven Line/I-95 corridor) have been excluded since they tend to attract automobile and bus access riders from further distances from their stations than other transit modes. Transit-Optimized/Freeway Constrained cases (i.e.; Chicago Blue Line/Kennedy Expwy. (I-90), Washington D.C. Orange Line/I-66, and San Francisco East Bay (BART) Pittsburgh/Bay Point Line/S.R. 24) were also excluded since their freeway capacity constraints give their transit lines an operational advantage that masks the benefits of complementary coordination. Sacramento's North Line/S.R. 160 & I-80 was also excluded since the freeway sample txt point was along S.R. 160 where volumes are low.

Figure B-2. Complementary multimodal coordination is associated with improved corridor performance—log-log transformation.

Table B-2. Log-linear regression model results predicting total corridor patronage (freeway & transit).

	Coefficients		
	B	Std. Error	t-stat. Sig.
(Constant)	10.046	1.12E+00	8.94 ***
Natural Log of Multimodal Coordination	0.152	4.81E-02	3.16 **
Park-&-Ride Spaces per Station	0.000	8.89E-05	-2.63 *
Average Ramps Touching Down w/in 1/4-Mile of Stations	0.102	6.30E-02	1.62
Total Freeway Lanes	0.031	2.70E-02	1.15
Heavy Rail Dummy (0=No, 1=Yes)	-0.008	9.51E-02	-0.08
Housing Unit Density w/in 1/2-Mile of Stations	0.000	4.62E-05	-0.93
Natural Log of CBD Size (Sq. Ft. Office)	0.136	5.98E-02	2.28 *

Notes:

R-Square = 0.56

F-Sig. = 0.03

N = 16

*** = $p < 0.01$

** = $p < 0.05$

* = $p < 0.10$

While the planning and design of multimodal facilities is more complicated than the planning or design of either transit or automobile facilities in isolation, the potential benefits of doing so suggest that both can and should be planned and designed in a coordinated and mutually beneficial fashion. This analysis suggests that multimodal coordination may be an important factor in planning successful new paradigm corridors. However, the lack of data and consequent inability to perform a statistically valid analysis means that this concept requires further study.

Can Transit Thrive in Multimodal Corridors?

While it seems obvious that transit and freeways tend to conflict with each other's operations, there is no evidence that they have to. The success of one does not mean the other must suffer.

Figure B-3 shows the estimated daily patronage for each multimodal corridor studied, for both the freeway and transit facility components. The cases in this figure are sorted by decreasing freeway patronage estimates from left to right.

If transit patronage success always came at the expense of freeway patronage, then we would expect to see increasing transit patronage as freeway patronage decreases. But while we see cases with large transit ridership values—cases such as the Washington DC Orange Line, the Chicago Blue Line/Kennedy Expressway, and San Francisco's Pittsburg/Bay Point Line corridors—these cases do not have consistently lower freeway patronage levels.

If transit ridership always suppressed freeway patronage, we would expect that corridors with low transit ridership would have consistently high levels of freeway patronage. This too, is not the case, since the San Jose Guadalupe Line, the Portland MAX Red Line, and the Sacramento North Line all have very low transit ridership and low-to-moderate freeway patronage. These findings suggest that the performance of transit and freeways in multimodal corridors is not a zero-sum game, where only one mode thrives, not both.

Other dynamics might also be at work, other ways that transit and freeways might be affecting each other when sharing a corridor. In most of the United States, the automobile is the dominant mode of travel. This could mean that while transit does not take patrons from freeways, freeways may prevent nearby transit lines from thriving. Figure B-4, where corridors are sorted by freeway patronage descending from left to right, suggests this is not the case.

If it were impossible for transit to successfully attract riders in a multimodal corridor, we would expect to see the lowest transit ridership cases on the left (where freeway patronage is the highest) and the highest transit ridership cases clustered on the right of Figure B-4. Since cases with high freeway patronage appear on the left, we would expect to see low transit patronage cases on the left as well, with high transit patronage cases clustered to the right of the graph where the cases have low freeway patronage. This is not the case. Instead, high transit ridership corridors appear to be spread evenly throughout the graph, without reference to the patronage of their adjacent freeway facilities.

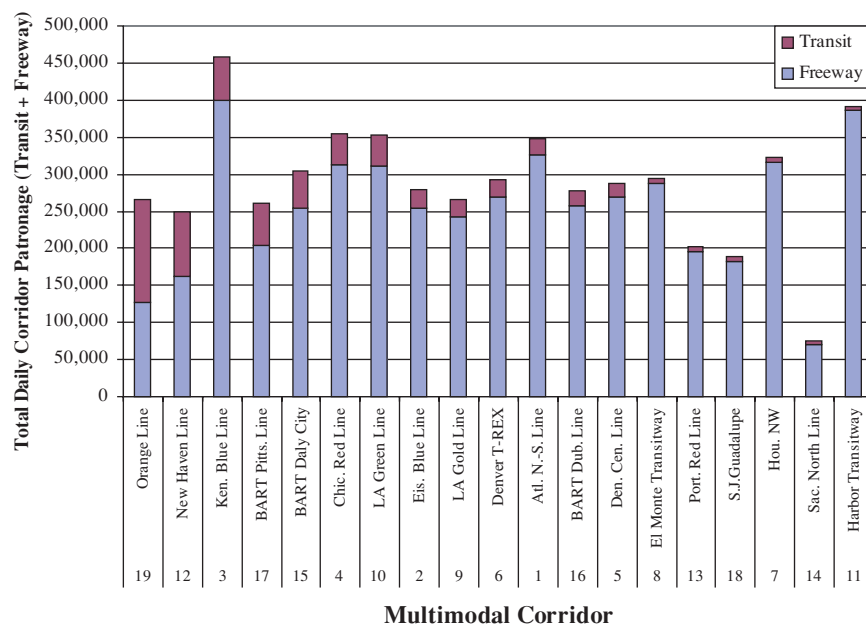


Figure B-3. Transit success does not always mean low freeway patronage in multimodal corridor.

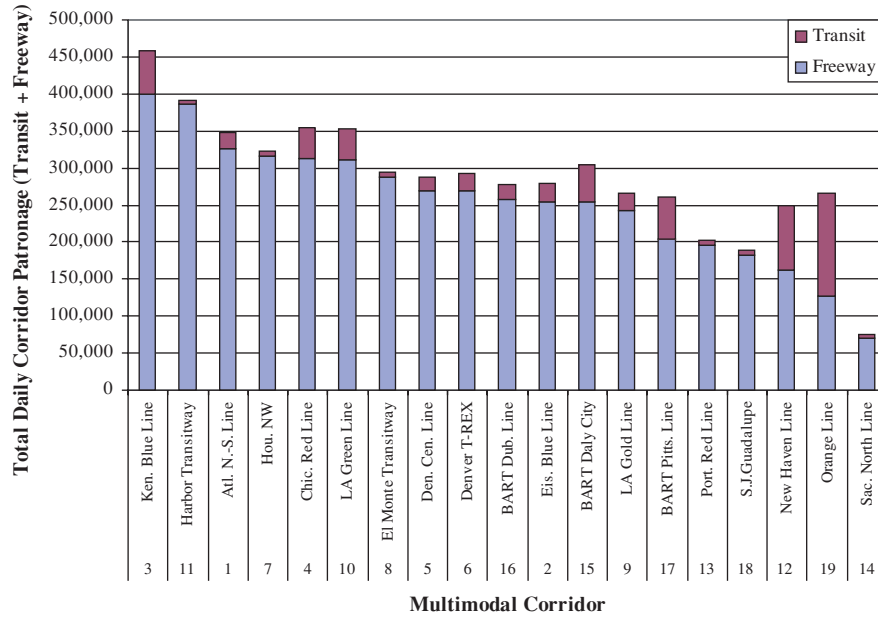


Figure B-4. Freeway success does not always mean low transit patronage.

More important, there are several cases where transit is high—both in absolute terms and in comparison to the neighboring freeway facilities. Figure B-5 shows the estimated daily transit ridership for the study multimodal corridors.

Three of the four corridors with the highest transit ridership share some key characteristics. Washington DC’s Orange Line/I-66 corridor has the best-performing transit line (in terms of ridership) of any multimodal corridor evaluated for this study. The second, third, and fourth best-

performing transit lines are the New Haven (commuter rail) line, Chicago’s Blue Line (Kennedy), and San Francisco’s BART Pittsburg/Bay Point Line. These findings confirm expectations that high-capacity and high-speed transit lines attract more patronage, even in multimodal corridors.

Clearly, freeways do not always make a corridor inhospitable to transit. Other factors that determine the success of each facility at attracting patrons must be at work.

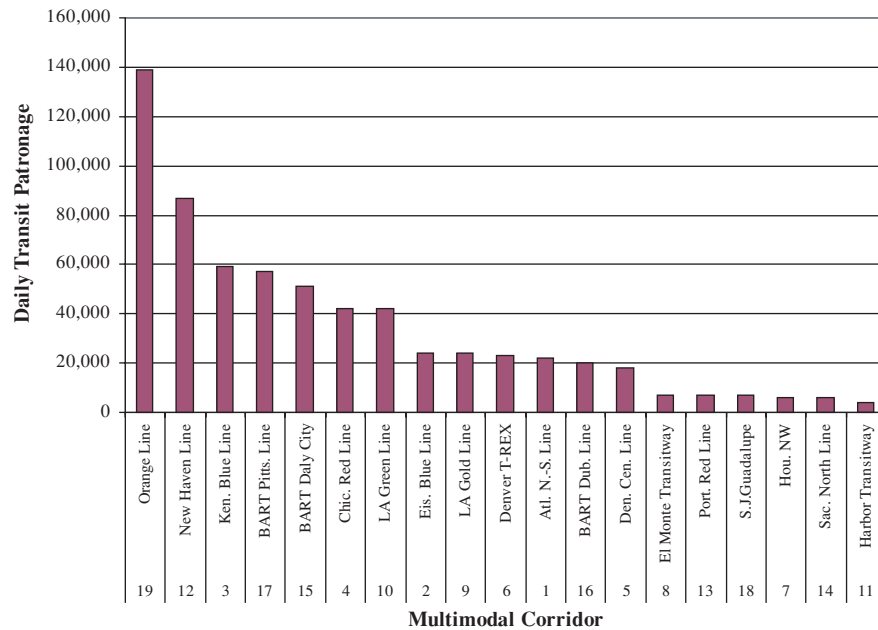


Figure B-5. Transit line ridership in multimodal corridors.

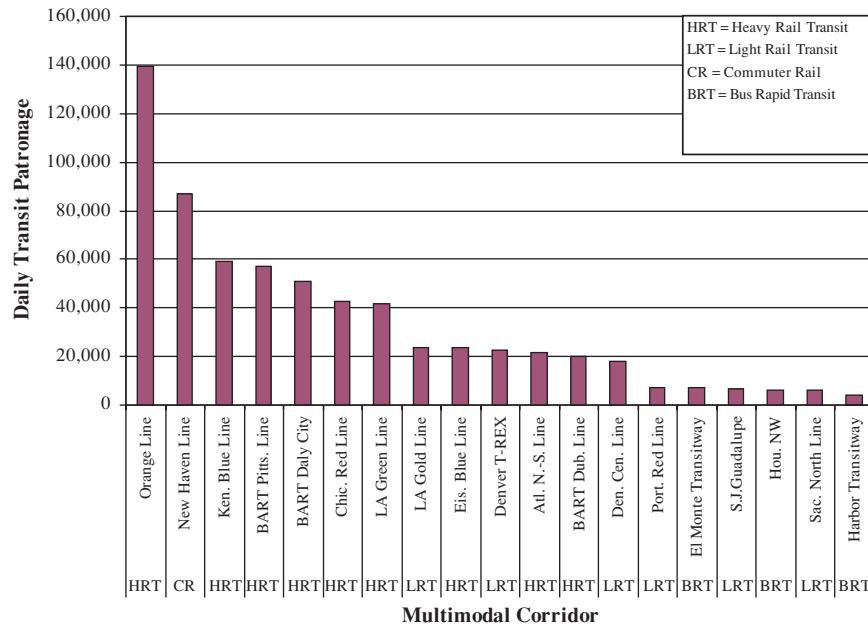


Figure B-6. Transit patronage and transit mode.

The Effects of Transit Mode on Transit Ridership

The operating characteristics of the transit line can play an important role in determining transit ridership. For the sake of brevity and ease of analysis, the type of transit mode in each study corridor was used as a proxy to suggest their operating characteristics. Therefore, in general it was assumed (as discussed in Chapter 5) that heavy rail has the highest carrying capacities and operating speeds, followed by commuter rail, light rail, and BRT. Figure B-6 confirms this point.

The best-performing cases in terms of transit ridership are heavy rail transit (HRT), while the lowest-ridership cases are bus rapid transit (BRT) and light rail transit (LRT). Five of the top six transit ridership cases are HRT, while two of the bottom five are LRT and the other three are BRT.

These differences are partially due to the operating characteristics of the various transit modes (see discussion in Chapter 5 for further details). LRT vehicles run singly or in short trains on tracks in various right-of-way environments, including mixed-flow surface streets, dedicated lanes with grade crossings, and fully grade-separated dedicated facilities.¹ Therefore, depending on the design of the right-of-way (grade-separated or mixed-flow), fare collection systems, station platforms, and station spacings, light rail systems can approach heavy rail performance in terms of capacity and operating speeds.

The flexible performance parameters of LRT can be seen in several cases, where light rail lines attract riders at similar levels to heavy rail. Three cases stand out in this regard. The Los Angeles Green Line, Denver's T-REX, and the Los

Angeles Gold Line all attract between 23,000 and 42,000 week-day boardings within the multimodal corridor sections of each line.

BRT is often seen as a low-cost alternative to more capital-intensive fixed-rail alternatives. One of the most important features of BRT (unlike regular bus service) is that it runs on a dedicated, exclusive lane of travel, giving it a high level of service reliability (since it does not compete for right-of-way with other modes) and speed. When running in mixed-flow traffic, bus priority technologies (such as signal prioritization) are often used to improve travel times and provide a competitive edge to BRT vis-à-vis other modes in the corridor. Off-bus fare collections as well as platform boarding and alighting are frequently used to reduce dwell times at stops.¹ In addition to operational improvements, the cost of a BRT system can be about one-third that of a light rail system.² This makes BRT cost-feasible for somewhat less dense and smaller central business district corridors than more capital-intensive rail systems.

Consequently, BRT systems are often used in the United States as an alternative to more expensive fixed-rail options and are typically deployed in corridors where these other options are infeasible. Therefore, although BRT has proven capable of performing at levels equal to fixed-rail in other countries, the locations where it has been implemented in the United States have tended to limit its success at attracting riders at levels equal to fixed-rail alternatives.

¹Pushkarev, B. and J. Zupan, 1971. *Public Transportation and Land Use Policy*. Don Mills, Ontario: Indiana University Press.

²Leal, Monica T. & Robert L. Bertini, *Bus Rapid Transit: An Alternative For Developing Countries*, <http://web.pdx.edu/~bertini/brt.pdf>

These limitations are manifest in the patronage rankings of BRT multimodal corridors shown in Figure B-6. Three of the four-lowest ridership cases are BRT systems—Los Angeles’s El Monte Transitway and Harbor Transitway, and Houston’s Northwest/U.S. 290 corridor. In these three cases, BRT does not run in its own right-of-way, but shares HOV lanes with automobiles. Therefore, when traffic congestion slows traffic in the HOV lane, BRT suffers as well and cannot offer a travel time premium compared to the freeway.

It should also be mentioned that the operational characteristics of each transit mode are not the only factors that determine performance in a multimodal corridor. For example, HRT not only offers speed and capacity advantages (and thus time competitiveness with the automobile-freeway system), but in most cases studied here, HRT corridors tie into larger regional transit networks that provide comparatively high levels of regional rail accessibility. The HRT multimodal corridor transit lines in San Francisco; Washington, DC; and Chicago feed into many destinations in each region’s central city, providing the transit rider with wider spatial coverage and higher regional connectivity/accessibility. These higher levels of accessibility and connectivity give the transit lines that run in multimodal corridors additional performance advantages.

Corridor Orientation and Transit Ridership

The performance of a multimodal corridor’s transit line also depends on its relationship to its surrounding environment. We refer to this transit-environment relationship as corridor orientation, comprised of two components: corridor urban form and corridor station access. Each component is described in greater detail and analyzed in terms of its effects on corridor performance below.

Corridor orientation is described in Chapter 4 as a continuum with two poles: transit- and automobile-orientation (see Fig. 4-1). Automobile-oriented corridors are planned to optimize automobile mobility over nonautomobile access.

Transit-oriented corridors, on the other hand, are designed to maximize nonautomobile access to land uses and transit stations. Land uses are generally high-density with minimal parking.

Multimodal corridors are, by definition, neither purely automobile- nor transit-oriented, but lie between the extremes of the corridor continuum, as shown in Fig. 4-1. Each point along the multimodal corridor continuum has a different combination of the critical facility design and surrounding land use factors that serve to optimize (or degrade) the capabilities of the corridor to function as a balanced, multimodal system.

As discussed previously, factors that support a multimodal transit-oriented corridor are those that maximize access to transit stations by all modes of travel, but particularly by pedestrians. As a freeway facility will be running near it, a key challenge to creating an effective multimodal transit-oriented corridor is to minimize the negative externalities of the vehicular traffic traveling to and from the freeway.

Factors that support a multimodal automobile-oriented corridor are similar to those typically used to describe a purely automobile-oriented corridor (see Fig. 4-1), and like the multimodal transit-oriented corridor, its differences are mainly those of emphasis. Transit stations or stops are designed to maximize automobile access and parking. Park-and-ride lots dominate the immediate station environments, and high-capacity road connections between station areas and the freeway encourage peak-period commuters to reduce freeway congestion by parking their cars and transferring to transit.

The Effects of Corridor Urban Form

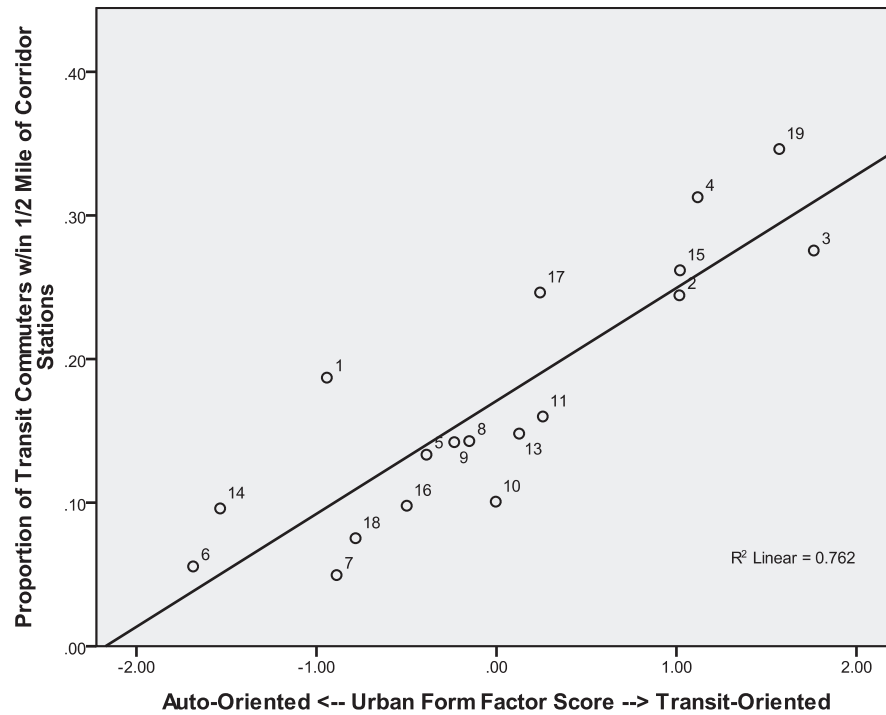
Corridor urban form plays an important role in determining mode choice for corridor residents, visitors, and employees. The critical factors that describe urban form are discussed in Chapter 4.

To measure the urban form orientation of each study corridor, several variables (see Table B-3) were chosen to represent each of the four “D” factors. From these variables,

Table B-3. Urban form corridor orientation index components.

Theoretical Component	Component Measure
Density	Housing Units per Square Mile
Diversity	Entropy Index (Jobs-Housing Balance)
Design	4-Leg Intersections per Square Mile
Corridor Clustered Destinations	Sq. Ft. Office Space in CBD

Note: Entropy (Diversity) index calculated as mixed-use entropy (within 1/2 mile of each station) = $-1 * \{ \sum_i (p_i) (\ln p_i) / \ln k \}$, where p = proportion of total land uses; k = category of land use (single-family housing units, multifamily housing units, retail/service employment, office employment, manufacturing/trade/other employment); ln = natural logarithm.



Note: Commuter rail cases (i.e.; the New Haven Line/I-95 corridor) have been excluded since they tend to attract automobile- and bus-access riders from further distances from their stations than other transit modes.

Figure B-7. Transit-oriented urban form increases corridor transit patronage.

factor analysis was performed, and a single urban form factor score variable was created.

The relationship between multimodal corridor urban form and the percentage of station area commuters using transit (see Figure B-7) suggests a positive relationship. Consistent with theory and the discussions above, the more transit-oriented the corridor urban form, the more riders the transit line attracts from its station neighborhoods (that is, within a half-mile of each station). However, as discussed earlier, caution should be used when interpreting these graphs, since the low sample size prevented more robust and statistically reliable testing.

Figure B-7 also suggests the following five cases are the top performers, both in terms of running through corridors with predominantly multimodal transit-oriented urban form and attracting riders within a half-mile of their stations:

- #2 Chicago Blue Line/Eisenhower Expressway
- #3 Chicago Blue Line/Kennedy Expressway
- #4 Chicago Red Line/Dan Ryan Expressway
- #15 San Francisco Daly City Line/I-280
- #19 Washington D.C. Orange Line/I-66

San Francisco's Daly City Line/I-280 offers a good example of a multimodal transit-oriented urban form corridor. A combination of residential density, mixed uses, pedestrian-oriented design, and a large CBD make this one of the most transit-oriented multimodal corridors in the United States.

Table B-4 compares the urban form measures values for the Daly City Line corridor and the median values of the study corridors. The Daly City values are all above the study median, with the CBD size substantially higher, suggesting that size of

Table B-4. Urban form characteristics of the San Francisco Daly City/I-280 corridor.

Component Measure	Study Median Value	S.F. Daly City Corridor Value
Density (DUs/Ac.)	4.9	5.3
Diversity (Entropy Ind.)	0.85	0.86
Design (4-Leg Int./Ac.)	0.12	0.16
Destination (CBD Size)	42 mil. s.f.	110 mil. s.f.

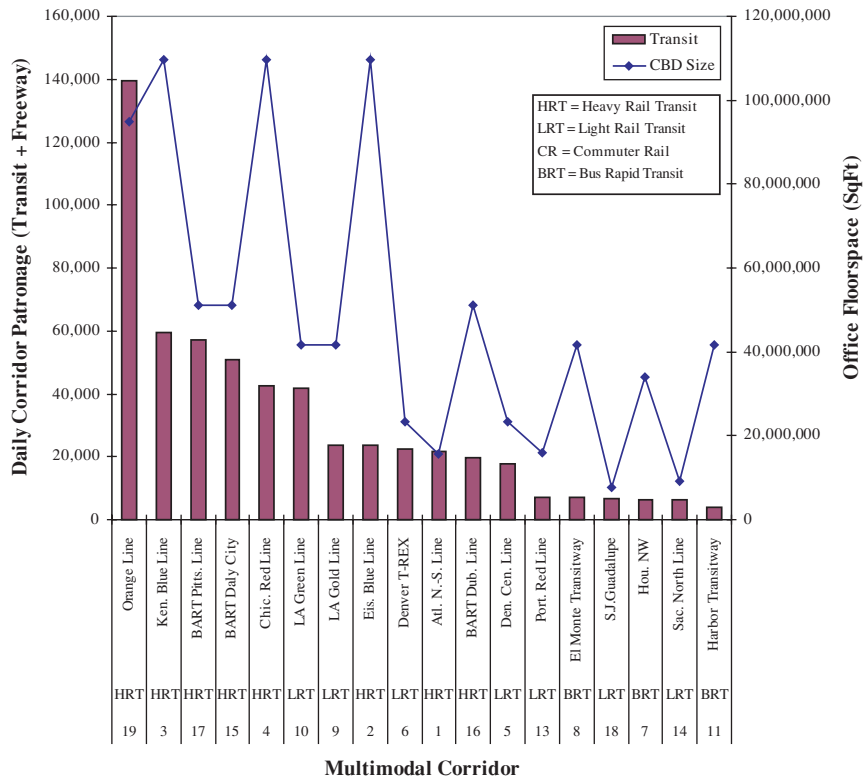


Figure B-8. Transit patronage and central business district (CBD) size.

a corridor’s anchor plays a critical role in determining transit ridership performance.

Review of other cases suggests that while CBD size is important in determining transit line ridership in multimodal corridors, it does not guarantee it. Figure B-8 shows that while none of the top five transit ridership cases have CBDs smaller than 60 million square feet of office floor space, several cases with moderate or low transit ridership have CBDs of equivalent or greater sizes.

Chicago’s multimodal corridors illustrate this point. Downtown Chicago has one of the largest concentrations of office floor space in the United States. This provides a large trip attractor at the end of each study corridor that encourages

commuters to use both the transit and freeway facilities. Analysis of Chicago’s three multimodal corridors suggests that CBD size does not guarantee transit line ridership.

Chicago’s dominant CBD helps the Blue Line/Kennedy Expressway corridor to attract the second-largest number of transit riders of any multimodal corridor transit line studied, but does not help the Blue Line/Eisenhower Expressway corridor place in the top five.

When these corridors all serve the same, large CBD, what is different about the Blue Line/Eisenhower corridor that keeps it from attracting the same ridership as the Blue Line/Kennedy and the Red Line corridors? Table B-5 compares the transit ridership, the corridor’s commuter mode share, and the

Table B-5. Comparison of transit patronage and corridor urban form for Chicago’s multimodal corridors.

Ridership/Component Measure	Eisenhower	Kennedy	Dan Ryan
Transit Line Ridership (Daily Boardings)	20,070	59,390	42,460
Corridor Transit Commuter Mode Share	24%	28%	31%
Density (DUs/Ac.)	4.7	7.4	5.3
Diversity (Entropy Index.)	0.61	0.91	0.86
Design (4-Leg Int./Ac.)	0.18	0.15	0.15

non-CBD urban form characteristics of each Chicago multimodal corridor.

In terms of ridership performance, the Eisenhower corridor underperforms its neighboring Chicago corridors, with less than half of the daily boardings of the Kennedy and Red Line transit lines, and a lower commuter transit mode share for residents living within a half-mile of its stations.

The lower commuter transit mode share for the Eisenhower line suggests that the urban form in this corridor is more automobile-oriented than its neighboring corridors. For the most part, this appears to be the case, with housing densities and land use diversity (the amount of mixed use) substantially lower in the Eisenhower than in the two other corridors. While the urban design (as measured by the number of four-legged intersections per acre within a half-mile of the corridor's stations) of the Eisenhower corridor appears to be somewhat more transit-oriented than either of its neighbors, all three Chicago cases have intersection densities above the study median of 0.11 four-legged intersection per acre.

Therefore, while the Eisenhower corridor has development densities in its surroundings that are higher than many suburban corridors in this study, they are lower compared to its neighboring Chicago multimodal corridors. So while its densities are not adequate to provide high levels of walk-on patronage, park-and-ride is not practical because many stations are too close to the city center and pedestrian security can be a problem.

It is reasonable to conclude that while a large CBD can help create a successful, well-patronized transit line, the line will benefit from a transit-oriented urban form along the rest of the corridor as well. Although it would be best to build all multimodal facilities in corridors with transit-oriented urban form characteristics, most freeway corridors in the United States—where the lion's share of multimodal corridor opportunity sites exist—have decidedly automobile-oriented land uses and urban design qualities.

Therefore, as discussed in Chapter 3, we suggest that the new paradigm offers a two-step process of multimodal corridor

planning, design, and construction, wherein transit facilities are designed and built in freeway corridors with the performance characteristics that allow them to compete with the freeway facility on a travel time basis using automobile-oriented multimodal coordination as the first step. Later, as conditions and resources permit, more transit-oriented land uses and operational characteristics can be introduced that will help the transit line reach its full potential as part of a larger new paradigm corridor.

Therefore, our conception of the new paradigm does not discriminate against corridors with automobile-oriented urban form; rather, we see them as opportunities to build cost-effective, automobile-oriented transit lines that can be slowly transformed into transit-oriented lines. There are several examples of automobile-oriented multimodal corridors that have successfully taken this crucial first step.

Urban form in Denver's T-REX/I-25 corridor suggests a decidedly automobile-oriented pattern, but its early success at capturing transit riders suggests this as a prime example of "step one" in the new paradigm evolution toward a transit-oriented corridor (see Table B-6).

Ridership for this new light rail line is excellent considering the fact that it is just over the study median (which includes many heavy rail lines that tend to attract higher ridership numbers) and is 26 percent higher than the median for study light rail lines. That T-REX's station areas have a very low (6 percent) transit commute mode share compared to the study median of 15 percent suggests it draws most of its riders from beyond the half-mile walking distance buffer—a distance at which most patrons are likely to use buses or automobiles to park-and-ride.

These ridership patterns are consistent with an automobile-oriented urban form pattern. The urban form metrics confirm this conclusion. Housing densities were among the lowest found in the study group, with less than one unit per acre (gross), substantially less than the study median of roughly five. The corridor is also decidedly residential in character; with a diversity score less than one-quarter that of the study median.

Table B-6. Transit patronage and urban form characteristics of the Denver T-REX/I-25 corridor.

Ridership/ Component Measure	Study Median Value	Denver T-REX Value
Transit Line Ridership (Daily Boardings)	20,070	23,000
Corridor Transit Commuter Mode Share	15%	6%
Density (DUs/Ac.)	4.9	0.18
Diversity (Entropy Ind.)	0.85	0.19
Design (4-Leg Int./Ac.)	0.12	0.05
Destination (CBD Size in Office Space)	42 mil. s.f.	23 mil. s.f.

Table B-7. Transit patronage and urban form characteristics of the San Francisco Pittsburg-Bay Point Line/S.R. 24 corridor.

Ridership/ Component Measure	Study Median Value	Pittsburg-Bay Point Value
Transit Line Ridership (Daily Boardings)	20,070	57,110
Corridor Transit Commuter Mode Share	15%	25%
Density (DUs/Ac.)	4.9	4.5
Diversity (Entropy Ind.)	0.85	0.85
Design (4-Leg Int./Ac.)	0.12	0.09
Destination (CBD Size in Office Space)	42 mil. s.f.	51 mil. s.f.

In terms of urban design characteristics, the T-REX corridor is also decidedly automobile-oriented, with an average density of 0.05 intersection per acre compared to the study median of 0.12. The size of Denver’s CBD (roughly 23 million square feet) and the fact that the line serves the Denver Tech Center—an office park concentration south of the CBD—appears to make up for some of the automobile-oriented characteristics of the T-REX corridor, providing a relatively strong anchor on which to build the light rail line’s ridership. The line is also in a corridor that is growing in population. Given T-REX’s surprisingly low residential densities and high ridership (with the Denver Tech Center as a major trip generator), it seems likely that the design feature that matters more than anything in a park-and-ride access corridor is the number of park-and-ride spaces it provides at its stations.

If Denver’s T-REX corridor is an example of a nascent park-and-ride access multimodal corridor with potential to evolve into a transit-oriented one, San Francisco’s Pittsburg-Bay Point line/SR 24 offers an example of a more mature and successful automobile-oriented corridor already undergoing some of the transformations into a more transit-oriented one. Table B-7 shows the relevant transit ridership and urban form metrics.

The corridor serves a combined 51 million square feet of office space in the heart of the Bay Area—an important factor determining the corridor’s high transit commuter mode share (25 percent), and suggesting that a substantial number of its 57,000 daily boardings are coming from within a half-mile walking distance of its stations.

As the corridor has developed over the last 36 years, the urban form of its stations’ areas has become steadily more transit-oriented. Currently, housing densities and mixed-use are roughly equal to the study medians, suggesting the corridor is neither automobile- nor transit-oriented in terms of urban form. However, its urban design qualities (as suggested by the density of four-legged intersections) are still somewhat automobile-oriented, with an average density of 0.09 four-

legged intersection per acre compared to the study median of 0.12.

As this corridor continues to evolve, planning policies that encourage TOD, the construction of infill stations along the corridor, and station access measures that encourage non-automobile access could lead to this case reaching its full potential as a multimodal transit-oriented corridor. Anecdotal evidence suggests these changes are already underway at several corridor stations.³

Determining successful transit line performance depends on which ridership performance measure is used. Transit line ridership counts—obtained from the transit agencies themselves and adjusted to estimate the ridership along each study corridor segment—provide a measure that takes into account riders no matter how far they traveled to reach the transit line, or by what mode they arrived there.

The “Transit Commuter Mode Share” value offers a different take on transit ridership success. This measure suggests how well the transit line competes with other modes in capturing commuter trips in the corridor—in essence, the transit orientation—specifically within reasonable walking distance of the corridor’s stations (0.5 mile).

As a result, it can (and does) happen that a particular transit line may attract high transit ridership numbers, while attracting a low share of the transit commuters within a half-mile of its stations. A comparison of Los Angeles’s Green Line/I-105 and Harbor Transitway/I-110 corridors illustrates this point (see Table B-8).

The Green Line (LRT) serves roughly 42,000 daily boardings, while the Harbor Transitway BRT line only serves roughly 4,000. However, the transit mode share within a half-mile of each line’s stations tells a different story. While the Green Line’s station areas have roughly 10 percent commuter mode share

³Cervero, R., et al. *TCRP Report 102: Transit Oriented Development in America: Experiences, Challenges, and Prospects.*

Table B-8. Comparison of transit line patronage and corridor urban form for the Los Angeles Green Line and Harbor Transitway corridors.

Ridership/ Component Measure	Green Line	Harbor Transitway
Line Ridership (Daily Boardings)	42,000	4,000
Transit Commuter Mode Share	10%	16%
Density (DUs/Ac.)	7.2	24.7
Diversity (Entropy Ind.)	0.94	0.79
Design (4-Leg Int./Ac.)	0.11	0.10
Destination (CBD Size in Office Space)	42 mil. s.f.	42 mil. s.f.

among its residents, the Harbor Transitway's station area residents have a 16 percent mode share.

These seemingly contradictory results suggest that the Green Line is more successful at attracting riders from beyond its one-half mile station area radius, while the Harbor Transitway is successful at helping to encourage transit mode share within a half-mile of its stations, but does not attract riders from beyond.

Part of the reason why the Harbor Transitway may be more successful in its immediate neighborhoods is the relatively higher transit-orientation of its corridor's urban form. The Harbor Transitway corridor is substantially different from the Green Line corridor's urban form in only one urban form characteristic—residential density, where the Harbor Transitway station areas are more than three times as dense as the Green Line's. So while encouraging transit-oriented station area urban form can be an effective tool for encouraging station area ridership, it may not be sufficient to ensure high transit line ridership.

The Effects of Corridor Station Access

Similar to urban form, corridor station access reflects the design and operational elements within and near stations that encourage either automobile access (automobile-oriented) or pedestrian- and other non-automobile access (transit-oriented)

modes. A high number of freeway ramps that touch down near transit stations can impede pedestrian station access. Similarly, the negative externalities of the freeway itself (for example, noise and air pollution) near transit stations can discourage pedestrian activities. Finally, although park-and-ride lots encourage automobile access to transit stations, they tend to impede pedestrian access.

Our analysis used the variables shown in Table B-9 to represent the four components of corridor station access.

Analysis of each variable individually, collectively as part of factor-analysis-generated index scores, and as part of multivariate linear regression models found that the most important station access variable affecting multimodal corridor transit ridership was the number of freeway ramps that touch down within a quarter-mile of a station.

Figure B-9 provides a graph of the average number of freeway ramps that touch down within ¼-mile of stations per corridor station and the estimated transit line patronage (daily transit boardings) for each of our study corridors. A linear regression line drawn on this graph indicates that if there is a statistically valid relationship between these variables, it is not linear.

Further exploratory analysis of these data suggests that the relationship between corridor patronage and multimodal coordination may be non-linear. Figure B-10 illustrates this relationship, where the more freeway ramps there are near

Table B-9. Corridor station access index components.

Theoretical Component	Component Variable
Freeway Ramps Impede Pedestrian Access but Enhance Automobile Access	Number of Freeway Ramps that Touch Down within ¼-Mile of Stations per Corridor Station
Freeway Facility Negative Externalities	Average Distance from Corridor Stations to Freeway Facility
Park-&-Ride Lots Impede Pedestrian Access but Enhance Automobile Access	Average Number of Park-&-Ride Spaces per Corridor Station
Bus Access to Stations	Average Number of Bus Lines Serving Stations per Corridor Station

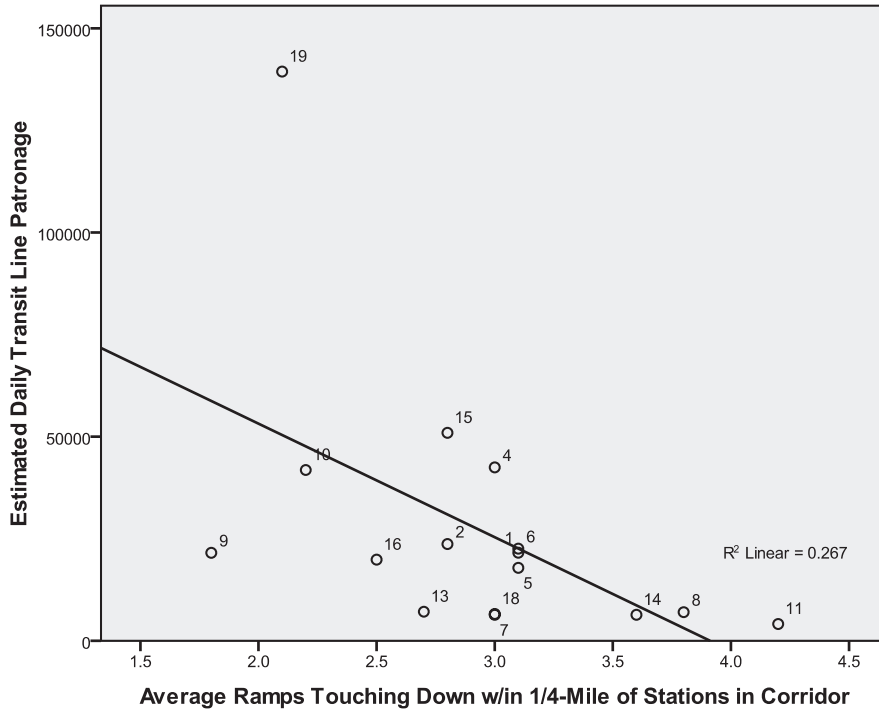


Figure B-9. Average ramps that touch-down within ¼-mile of corridor stations and the estimated transit line patronage—linear regression line.

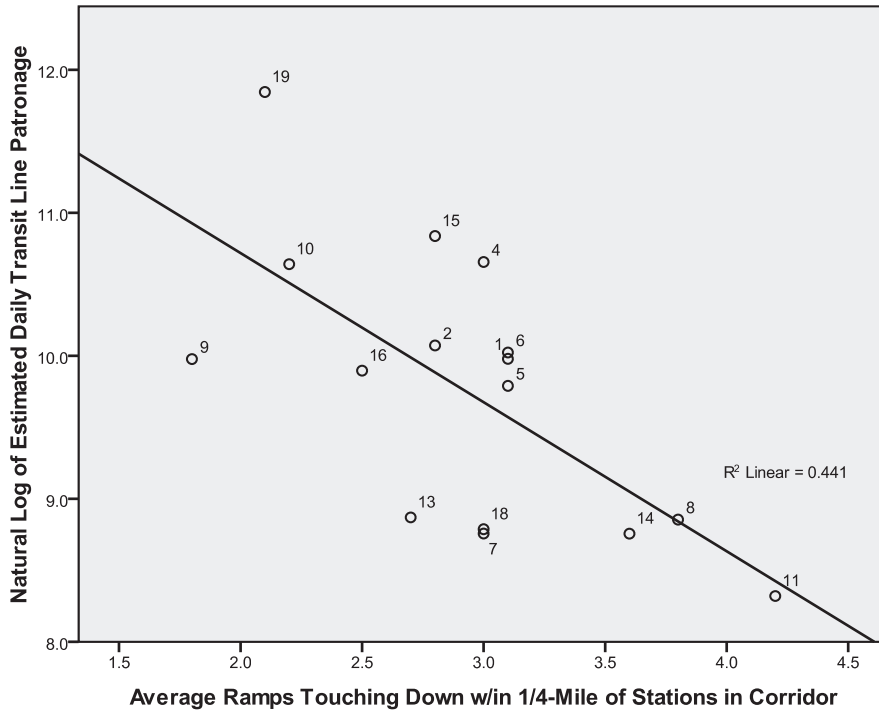


Figure B-10. Transit ridership is higher when there are fewer freeway ramps near stations.

Table B-10. Transit patronage and station access characteristics of Chicago's Blue Line/Eisenhower Expressway corridor.

Ridership/ Component Measure	Study Median Value	Eisenhower Value
Transit Line Patronage (Daily Boardings)	23,500	24,000
Corridor Transit Commuter Mode Share	15%	24%
Average Number of Ramps per Station	2.8	2.8
Station to Freeway Dist.	0.09	0.02
Park-&-Ride Spaces/Station	4420	81
Bus Lines/Station	6.2	3.3

corridor transit stations, the lower the patronage for the transit line as a whole.

There are several case studies that illustrate the importance of station access. Table B-10 compares the ridership and station access characteristics of the Eisenhower corridor with the median values of the study's cases.

While the urban form of the Eisenhower corridor is automobile-oriented, its station access characteristics tend to be more transit-oriented. This mismatch may be partially responsible for this transit line's lower patronage levels than other Chicago area heavy rail lines. The corridor's stations have the lowest number of park-and-ride spaces of any study case. Since park-and-ride spaces encourage automobile access to stations and discourage pedestrian, bicycle, and bus access, this implies that the transit line is designed to primarily serve corridor trips for people living near the corridor's stations, rather than attracting automobile-to-transit transfers that often originate further away.

That the corridor's stations have a lower-than-median number of bus lines per station (3.2 versus 6.2 per station for all study corridors) reinforces the impression that the Blue Line's stations in the Eisenhower corridor are designed to serve

walk-access residents in its directly adjacent neighborhoods. However, its catchment area is limited because there are parallel rapid transit lines less than a mile to the north and about 1.5 miles to the south.

The placement of the Blue Line's stations in relation to the freeway facility discourages non-automobile access as well. The average distance from the corridor's stations to the freeway is roughly 0.02 miles—essentially directly adjacent to the freeway and significantly lower than the median distance for the rest of the study corridors of 0.09 miles. This relatively short separation distance serves to increase the negative impacts of the freeway on the transit line.

It is useful to contrast station access at the stations along the Eisenhower corridor to those along the Kennedy. Table B-11 compares the patronage and station access characteristics of the Kennedy and Eisenhower corridors in reference to the study median values.

The success of the Kennedy corridor branch of the Blue Line at attracting transit patrons, both from within a half-mile walk-ing distance of its stations and beyond, is partially due to the reinforcing and complementary effects of the corridor's transit-orientation, both in terms of urban form and station access.

Table B-11. Transit patronage and station access characteristics of Chicago's Blue Line/Kennedy Expressway corridor.

Ridership/ Component Measure	Study Median Value	Eisenhower Value	Kennedy Value
Transit Line Patronage (Daily Boardings)	23,500	24,000	59,000
Corridor Transit Commuter Mode Share	15%	24%	28%
Average Number of Ramps per Station	2.8	2.8	2.6
Station to Freeway Dist.	0.09	0.02	0.20
Park-&-Ride Spaces/Station	420	81	166
Bus Lines/Station	6.2	3.3	5.1

While the median number of ramps that touch down within a quarter-mile of the corridor's stations is only slightly lower than that seen in the Eisenhower corridor and the study cases as a whole, its stations are 10 times as far from its freeway neighbor as in the Eisenhower corridor, and more than double the distance seen in the study as a whole.

While the number of park-and-ride spaces per station in the Kennedy corridor is roughly double the number found at the typical Eisenhower corridor station, Kennedy's number is less than half that typically seen in the study cases, suggesting this corridor's stations are designed to favor nonautomobile access.

Furthermore, compared to the Eisenhower corridor, Kennedy corridor stations have been designed to encourage bus access. While the number of bus lines serving Kennedy stations is slightly lower than the typical study station, it is substantially higher than that seen in the Eisenhower corridor, suggesting these stations have been designed to encourage bus access.

Seen as a whole, station access design in the Kennedy corridor's stations are transit-oriented, thus reflecting and reinforcing the transit-orientation of the corridor's land uses. This impression is consistent with the Blue Line's history in this corridor, where the elevated line was built in the late 1890s and the subway portions were built in the 1950s and 1970s. Thus, these areas were designed for an era where the primary modes of station access were non-automotive. These characteristics help explain the disparities in patronage performance between the Eisenhower and Kennedy corridors.

Consistent with the automobile-orientation of its corridor land uses and its multimodal coordination (that is, its station spacings are longer than its interchange spacings), access to the T-REX line's stations are decidedly automobile-oriented as well (see Table B-12).

On average, there are roughly three freeway ramps touching down within a quarter-mile of each station (slightly higher than the 2.8 study median), suggesting that the T-REX light rail line was designed to offload traffic from the freeway onto transit. The average distance between stations and the freeway is roughly 0.05 mile, well below the study average of 0.9. While the number of park-and-ride spaces per station in this corridor (513) is below average compared to the study group (420), it is well above the median for study corridors that have light rail transit (261), suggesting that for a light rail line, this corridor's stations are highly automobile-oriented. The automobile-orientation of this corridor's stations complements and enhances the automobile-orientation of its corridor land uses, helping to make this new light rail line a ridership success.

The Pittsburg-Bay Point/S.R. 24 corridor's stations offer a useful example of automobile-oriented stations within an increasingly transit-oriented urban form context (see Table B-13). Prominent in this assessment is the fact that the average number of park-and-ride spaces per station in this corridor is roughly 1,600—more than double the study average of 420. The corridor's stations are also close to the freeway (roughly 0.05 mile on average, compared to the study median of roughly 0.09), providing an attractive option to freeway drivers to exit, quickly park, and complete their trips via BART.

While an automobile-oriented station access profile is consistent with the corridor's history of automobile-oriented urban form patterns, the transit line would benefit from measures to enhance the transit-orientation of its stations to match its transit-oriented urban form. The number of ramps per station is just below average and the number of bus lines per station is better than average, suggesting that the station access orientation can be made to favor pedestrians and transit relatively easily by consolidating or removing park-and-ride spaces.

Table B-12. Transit patronage and station access characteristics of Denver's T-REX/I-25 corridor.

Ridership/Component Measure	Study Median Value	T-REX Value
Transit Line Patronage (Daily Boardings)	23,500	23,000
Corridor Transit Commuter Mode Share	15%	6%
Average Number of Ramps per Station	2.8	3.1
Station to Freeway Dist.	0.09	0.05
Park-&-Ride Spaces/Station	420	513
Bus Lines/Station	6.2	3.9

Table B-13. Transit patronage and station access characteristics of San Francisco's Pittsburg-Bay Point Line/S.R. 24 corridor.

Ridership/ Component Measure	Study Median Value	Pittsburg-Bay Point Value
Transit Line Patronage (Daily Boardings)	23,500	57,000
Corridor Transit Commuter Mode Share	15%	25%
Average Number of Ramps per Station	2.8	2.5
Station to Freeway Dist.	0.09	0.05
Park-&-Ride Spaces/Station	420	1,600
Bus Lines/Station	6.2	6.8

The Effects of Constrained Freeway Capacity

Of the common threads found among the case studies, constrained freeway capacity may be one of the most decisive factors in enabling transit to compete with the adjacent freeway. A constrained-capacity freeway has a substantial capacity bottleneck that creates congestion and causes delay. The bottlenecks found in this project are either caused by lane drops where the number of freeway lanes is reduced or where the capacity of the freeway was designed and built intentionally to be lower than forecast demand.

As discussed previously, Washington D.C.'s Orange Line/I-66 Corridor is an excellent example of a corridor where the freeway was purposely built as a capacity-restricted facility. As part of the financing package from Congress to fund the construction of the Orange Line, the Interstate was restricted to six lanes.⁴ This case sets an example of how freeway capacity restriction can substantially boost parallel transit line ridership and may also restrict total corridor throughput. As a result, this corridor is the only case studied for this project where the estimated transit mode share exceeds the estimated freeway mode share.

The success of Chicago's Kennedy corridor stems from several interlocking and mutually supporting factors. First, it has a heavy rail line, which provides fast, high-capacity transit service directly to downtown Chicago. This transit advantage is complemented by the freeway's design, which has a relatively modest six lanes in its western portion, giving the rail line an advantage during peak congestion hours on the freeway. This capacity constraint allows the transit line to effectively compete with the freeway, garnering roughly 59,000 daily passenger boardings in the corridor.

For San Francisco's Pittsburg/Bay Point corridor, as in the case with Washington DC Orange Line/I-66, the restriction

of the freeway's capacity plays an important role in the story of the adjacent transit line's success. Where Highway 24 and the BART line bore through the Oakland/Berkeley hills to reach the core Bay Area, the Caldecott Tunnel shrinks the freeway's capacity from eight to six lanes. The center bore of the tunnel is reversible, so during commuting hours, the peak direction of flow always has four lanes of travel. However, the non-peak direction is reduced to two lanes, and as a result, there is always congestion and delay in both directions of travel during the A.M. and P.M. peak commute hours at the tunnel. While this nonpeak direction capacity constriction does not directly encourage peak direction use of the BART line, it does restrict nonpeak direction flow, thus providing a direct incentive for nonpeak direction BART ridership and indirectly promoting the general perception that BART is the more hassle-free corridor alternative.

Summary

The analysis of case studies of multimodal corridors in the United States for TCRP Project H-36 suggests that the following factors contribute to the capability of transit lines to effectively compete with and survive in a corridor with a freeway facility: a large CBD with limited and expensive parking, constrained freeway capacity, urban form, station access, multimodal coordination, and transit operating speeds.

Based on our review and analysis of the case studies, the research team has identified the following desirable attributes for multimodal corridors:

- **Complementary multimodal coordination** between transit and freeway facilities
- **Transit-oriented land development around key stations** that is readily accessible from station platforms
- At least one **large activity center or anchor**, usually a CBD with high levels of employment

⁴Wikipedia, http://en.wikipedia.org/wiki/Interstate_66, accessed March 1, 2009.

- **Limited and costly parking in the CBD**
- **Effective transit distribution in the CBD**, preferably off-street
- **Constrained freeway capacity** such as lane drops, route convergence, and travel barriers
- **Good access to stations on foot, by car, and/or by public transport.** This includes a minimum number of freeway interchange ramps within walking distance of transit stations

The multimodal corridors examined in this study are generally successful in terms of transit riders carried and

performance (that is, transit speeds). They are perhaps less successful in enhancing pedestrian access to stations and in achieving transit-oriented development. While it appears that a multimodal corridor need not possess the best qualities and quantities of each of these factors to perform well, it seems that there are optimal combinations of these qualities that lead to superior performance. It is intriguing to consider an optimal multimodal corridor system that combines, for example, a capacity constrained freeway, a large CBD, transit-oriented corridor urban form and station access, and high transit operating speeds.

APPENDIX C

Applying Conventional Planning Concepts Toward a New Paradigm

An important concept of the new paradigm is that multi-modal corridors will encourage sustainable regional growth patterns. New paradigm corridors hold promise for supporting a diversity of land use and travel markets and allowing individual users and communities more seamless transitions from a freeway- and automobile-dependent pattern toward more sustainable ones.

The pursuit of these goals does not require a revolution in the practices of transportation and land use planning to become a reality. Most of the concepts required to make the shift are fairly well established; particularly when considering the physical and spatial challenges to planning and designing multimodal corridors.

Fortunately, transportation and land use planners have devoted a considerable amount of time and effort over the past quarter century to refining the tools and concepts applicable to conventional planning problems. As a result, it is possible to identify various conventional planning concepts and tools that support and encourage development of a mix of activities and land uses along a corridor which in turn can justify and support new paradigm infrastructure investments.

New Paradigm Physical and Spatial Planning Challenges

As with any form of infrastructure, the geography, topography and built form of a region pose tangible limitations to (and opportunities for) the successful placement and operations of multimodal corridors. Physical and spatial factors can raise the costs of implementation or diminish the ultimate patronage of the multimodal facilities. Such actions include technical design challenges to engineering and the ability to design seamless integration of the various modes of transportation in a corridor. Furthermore, spatial challenges arise from the regional distribution of activities, the influence

of other transportation facilities, and the configuration of individual districts comprising station and interchange catchment areas.

The effects of the physical and spatial environments can be differentiated based on scale. The spatial features that make a potential corridor attractive at a regional scale (for example, dense and heterogeneous development patterns) are often associated with conditions at the scale of physical design that can restrict options for alignment and station placement.

At a regional scale, the spatial structure of a region largely determines the market opportunities for corridor development. At the physical design (small) scale, the physical dimensions of obtainable rights-of-way dictate feasible alignments and station and interchange options and influence selection of transit technology once a particular corridor is identified as having multimodal potential. Each intermediate geographic scale is the focus of a specific stage in the planning and design lifecycle of a multimodal project.

Regional Planning Concepts

Background regional patterns of land use, demographics, and travel are a major determinant of success for new paradigm corridor implementation and performance. These have historically and will continue to play an important role in determining whether one or more multimodal corridors can be supported and what configuration is best for a particular corridor. For the new paradigm it is important that regional factors be considered above and beyond conventional thresholds applied to justify transit.

Transit Thresholds

Generally, transit line planning and design efforts have relied on planning thresholds or rules-of-thumb, intended to ensure

a sufficient level of patronage.^{1,2,3} As a result, transit lines are conventionally anchored by major activity centers because bigger and more compact activity centers generally are associated with higher levels of patronage.

Conventional standards identifying threshold size and density requirements are closely associated with the development of rail transit infrastructure in the last quarter of the 20th Century. Updated assumptions about sensitivity to service characteristics, road congestion, and fuel cost may lower some of the minimum standards for population and employment densities, but these thresholds still provide a useful first-order test to assess the strength of potential candidates for multimodal investments.

It is significant that most thresholds were developed when fuel prices were stable or falling relative to incomes and when decentralization was increasing in most urban centers. As a result, the cost-effectiveness of transit use has been constrained during periods of low fuel cost automobile use. Recent trends in transit use following the volatility in fuel prices should lead to a reevaluation of some of these thresholds.

Alternative Fundamental Considerations

Accepting that strict thresholds are no longer appropriate tests for the viability of multimodal corridors, other regional characteristics should be explicitly considered for their influence on the planning and successful development of multimodal corridors. These are as follows:

- **The corridor must include employment and housing** whether segregated at separate ends or accumulated as mixed-use areas of sufficient density and scale to generate continuous and balanced two-way travel patterns.
- **The core areas and inner rings of large metropolitan areas of a size exceeding historic thresholds for transit service¹** should be built-out, with limited vacant or otherwise available land for assembling a right-of-way, let alone for easy land development to begin the task of reshaping regional growth patterns.
- **The relative spatial distribution of people and activities around the urban center(s) of a region may be a more significant barrier to new paradigm investments than the**

¹Pushkarev, B. & J. Zupan, 1971. *Public Transportation and Land Use Policy*. Don Mills, Ontario: Indiana University Press.

²“MTC Resolution 3434 Transit-Oriented Development (TOD) Policy For Regional Transit Expansion Projects,” July 27, 2005, http://www.mtc.ca.gov/planning/smart_growth/tod/TOD_policy.pdf

³Demery, L., J. W. Higgins & M. D. Setty, “Traffic Density Thresholds for Rail Transit: A Retrospective,” Special Report No. 2, February 15, 2005, <http://www.publictransit.us/ptlibrary/specialreports/sr2.trafficedensityretrospective.pdf>.

absolute thresholds established in the post-World War II era to screen transit projects for market feasibility.

- **Existing suburban activity centers often are not large enough or designed in a transit-friendly manner to support a high-capacity transit line because they typically lack a critical mass of activities to attract work trips, yet may generate automobile congestion at levels that discourage pedestrian, bicycle, and park-and-ride activities.**
- **Sections of freeway corridors that tend to have largely low-density residential, industrial, or even agricultural uses present both opportunities and barriers to the successful introduction of a high-capacity transit line.** While an underdeveloped corridor offers the opportunity to buy land for a transit line right-of-way and stations at a low price, they also offer low-quality transit markets to support it.

Influences Versus Thresholds

Consideration of regional characteristics should not simply replace one set of rigid rules with another. Although it is true that cities without strong radial patterns and without large, dense urban centers can be hard-pressed to justify multimodal corridor development, a decentralized region is not an impossible barrier to successful multimodal corridor development. The Los Angeles Green Line/Century Freeway Corridor is an example of a successful project within a dispersed, polynucleated region. Although it does not directly serve a large activity center and runs in a circumferential pattern relative to the region’s largest CBD, downtown Los Angeles, the transit line serves a respectable 43,000 riders per day. Its success can be attributed to specific attention to high-quality feeder service. That service effectively addresses the decentralized nature of individual station areas which could be considered an insurmountable impediment from a conventional perspective.

Reorienting Regional Development Momentum. Exemplary successes such as the LA Green Line arise from specific efforts to overcome the inertia of background regional patterns. Although this inertia currently presents an obstacle, the hope of the new paradigm is that a focused set of planning and market forces that provide segmented travel markets matched to each mode can promote the success of all modes.

It is important to note that, once established, regional development patterns tend to be repeated and reinforced in the future. A region’s transportation and land development decisions are important tools in reinforcing or, with determined action, reforming these patterns.

Our contemporary experience is that regions consisting of a constellation of small- and medium-sized communities are likely to have their investment decisions guided by these polynucleated growth patterns. Over the last half of the 20th century,

market forces, regulatory processes, and traveler preferences have adapted to, and in due course, driven these land use patterns making low density and decentralized growth the expected norm in most of the United States.

The objective of adopting a new paradigm is to stimulate and leverage changes in market, regulatory, and user practices by taking advantage of opportunities to first complement the currently exhausted regional structure of passenger transportation and land use with multimodal services and, over time, replace parts of it with robustly multimodal and transit-oriented features that support sustainable economic and lifestyle choices.

Regional/Strategic Planning Approaches. Many metropolitan areas have embraced the goal of better organizing development to make individual communities and their whole region more livable and sustainable. New paradigm, multimodal freeway corridors can help to achieve these broader development objectives.

An important element of a strategic approach is that regional spatial patterns should be leveraged to advance multimodal development. It should be recognized that the congestion resulting from regional growth is the feedback generated by a metropolitan system, indicating the strain generated by prevailing trends in land use, activity, and circulation patterns. This congestion tells planners that current trends are not sustainable and that redirection is in order. Effective regional planning requires strategies to accommodate and, in some cases, encourage growth and other shifts in development patterns. This creates opportunities to explore the role multimodal alternatives have in deliberately focusing land use and economic development activity around high-capacity transportation infrastructure.

The key is to identify the means by which resources and other benefits can be systematically extracted from growth pressures to help cover the long-term environmental and financial costs of that growth. A corollary expectation is that this creates an incentive to minimize those long-term costs.

A strategic approach to multimodal development seeks to organize such value capture on a regional scale. The benefit for the region is in better environmental and fiscal outcomes, and the direct benefit for infrastructure development is a sounder basis for attracting investment and justifying subsidies. This possibility makes the new paradigm multimodal corridor concept attractive as a means to capture and manage regional growth and travel congestion simultaneously.

The background arrangement of activity centers and their relationships to existing transportation facilities often seems to preclude transit investments. However, the possibility of developing multimodal capacity proactively, as an encouragement to future transit-supportive development, should

be considered in the context of financial and institutional considerations.

From this point of view, the decision-making process should take a regional perspective on how much growth is likely to occur in potential corridors and, given that growth, whether it is possible and desirable (for example, from a sustainability perspective) to focus so as to maximize the use and viability of one or more multimodal corridors. At a strategic level, particular attention is warranted for tools that enhance cost- and revenue-sharing, market making, and other linkages on a regional scale.

Corridor Planning Concepts

From a land use perspective, a successful corridor is one that achieves vitality by attracting an effective mix of employment, housing, retail, and recreational activities. This generates travel and, with success, comes congestion. At its root, corridor planning boils down to managing tradeoffs between mobility, accessibility, and economic and social development. Transportation infrastructure of a multimodal corridor can effectively unify the communities along its length, providing similar mobility options throughout and essentially democratizing access. It also lays the foundation for the economic and social interaction among communities with disparate incomes, lifestyles, activity patterns, and levels of mobility.

Near the urban core, a radial corridor is characterized by a dense street grid, various modal opportunities, congested roadways, multiple travel path options, and the need for frequent modal transfers. Modifications to built form and transportation infrastructure are constrained by high land prices and multiple claims on the character of the urban space. Freeway access in dense areas can be minimal with isolated, single off- or on-ramps separated by blocks, whereas transit access can be dense and even redundant in areas of concentrated activity.

Moving away from the urban core, metropolitan space, land uses, travel behavior, and economic activities are more often influenced by the capacity of the freeway facilities. The built environments surrounding freeways tend to be dominated by the structures and land uses that are needed to support freeway travel and access. High-capacity freeways often require large, complex ramp and interchange structures that allow high-speed, high-capacity transitions between surface streets and freeways (for example, see Figure C-1). Wide, high-capacity freeways often influence street and urban design patterns well beyond their immediate areas. High-capacity surface streets are often needed to feed traffic from the corridor's outlying areas to the freeway facility as well. Wide arterial streets often connect to or parallel freeway facilities.

Larger, wider freeways also influence corridor land uses. Large freeways will often dominate their corridors, with



Source: Google Earth

Figure C-1. Los Angeles Metro Rosa Parks Station area.

development patterns arranged to minimize automobile congestion by separating uses, providing ample parking, and lowering built densities. Junctions between freeways and major arterials commonly become focal points for major commercial centers. Usually pedestrian and transit access is difficult.

Corridor access management is important to better manage existing roadways. It also can be applied in multimodal freeway corridors. Roadway options include adjusting interchange locations and configurations, ramp metering, and access spacing. For transit, opportunities include station placement, pedestrian connections, feeder bus service, and park-and-ride facilities. Designs and mix will vary among locations.

The Federal Transit Administration (FTA) suggests five key factors to consider when making tradeoffs among access, mobility, and social and economic factors. These are: citizen participation, design, economic development, financing, and governance. In each instance, a premium is placed on collaboration between corridor stakeholders.⁴ Successful collaboration depends on identifying common goals and values among stakeholders, but the jurisdictions that constitute a corridor may seem not to have much in common. The corridor-planning process provides a forum and a framework for collaborative planning, but the disparate interests of near urban and far suburban communities that reside along a corridor can lead to conflict. Cases of successful corridor planning are most often based on a process of compromise. An important spatial basis for this compromise can be coordination of the activity and growth potential of individual corridor station and interchange areas.

⁴Federal Transit Administration, Hubert H. Humphrey Institute of Public Affairs, "Keys to Corridor Planning," June 2007.

Access Points as Coordinated Markets

Access point land use and built form has significant implications for corridor performance and development. The spacing of access points can define, and in some ways constrain, corridor performance, but some limitations also present opportunities. The long-standing view is that a corridor is best for transit where land uses are segregated with a large activity center (such as a downtown) at one end and a series of largely high-density residential centers located at station areas along the corridor. In adopting a new paradigm, multimodal corridors can succeed by adopting a strategic approach in which the spacing and land use character of interchange and station area are coordinated across the corridor to optimize long-term patronage potential.

Since freeways define the structure of most U.S. metropolitan areas, a challenge is to successfully identify opportunities along the existing or planned freeway network that can support a new paradigm corridor. In regions with a large metropolitan core, these opportunities will consist of network extensions to planned or growing suburban and exurban activity centers. These extensions (or radii) can be the basis for a more compact corridor of future growth along new paradigm rights-of-way.

In polynucleated regions, this challenge can be met by identifying high-growth nodes (activity centers) that can support increased activities near network junctions (access points such as interchanges and transit stations). Such corridors will not tend to be "straight line shots."

A key here is to exploit tradeoffs between long-spaced freeway access points (interchanges) that leave some communities without access and dense freeway access (interchanges) that lead to congestion and unreliable freeway performance. Taking advantage of these tradeoffs, opportunities emerge to move the corridor toward more balanced multimodalism by introducing transit access at key locations and clustering corridor growth at these points to stimulate patronage and transit-supportive activity patterns.

Freeway facilities with large interchange spacings optimize speed and reduce congestion bottlenecks by reducing the amount of merging and weaving that occurs at these access points. They also tend to have a lighter impact on their surroundings since they do not attract as much surface street traffic (going to and from the freeway), do not require the same magnitude of high-capacity supporting surface streets, and do not generate the same magnitude of automobile-oriented development as facilities with short distances between interchanges.

Generally, land values fall as distance from an interchange increases, with the result that a dense pattern of interchanges will result in denser (although typically still automobile-oriented) land uses along the corridor. This has clear implications for the mix of uses as well, so that high-revenue commercial

destinations crowd out other uses. Since similar uses generate similar travel patterns, this amplifies peaks in trip generation and congestion.

Sparse freeway access creates an opportunity because travel markets between interchanges are underserved and land use markets can be immature. Once it is established that the corridor is the preferred location for growth to concentrate in a region, these underserved areas become attractive for new transit service along the corridor and new transit-oriented development. Automotive travel can be served more modestly with parallel arterials, and local circulation can be planned around high-quality bus service and non-motorized transportation facilities.

In most metropolitan areas, the accumulation of dense freeway access points has created a failure in the transportation system. From the perspective of multimodal development this failure is an opportunity because the resulting degradation in the level and reliability of private automobile mobility stimulates demand for a transit component within congested freeway corridors. More congested nodes can be singled out for transit-oriented development; improvements to bus feeder service and start-up investments in BRT can prove to be effective near-term measures. Over time, these areas can be encouraged to become denser with more transit-oriented development along the corridor supporting additional investments in transit service.

On the basis of demographics and geography, some zones will likely maintain their automobile-oriented character while others will be aggressively developed as transit-oriented areas. As regional growth proceeds and congestion effects accumulate over time, supportive policies should be in place to allow low-density nodes to transform themselves, providing more opportunities for density and mix of use on the land use side and increasing transit service options to include new access points on the transportation side.

Right-of-Way and Design Considerations

Right-of-way must be acquired for the construction of transportation facilities, and topography and land uses will constrain the options and opportunities. The grade, curvature, and cross-sectional dimensions of each component, as well as the degree of offset (or conversely, co-alignment) of right-of-way reserved for each direction of each mode, will dictate the cost of a corridor alternative.^{5,6}

The dimensions of the right-of-way are affected significantly by the level of co-alignment between the transit component

and the roadway. All together, a minimal urban freeway ROW will be roughly 60 feet.⁶ Levinson recommends 12 feet in *TCRP Report 90* for each dedicated bus lane (for a total of 24 feet), 28 feet for a center or set of side platforms (at station locations), and an additional 8 feet for two barriers between the freeway and the bus-way, totaling an additional 60 feet.⁷ The American Association of State Highway and Transportation Officials (AASHTO) recommends roughly 80 feet of ROW to provide adequate width for a double-track rail line and station platforms,⁶ although rail lines such as that seen in the median of the Dan Ryan Expressway in Chicago use a ROW as narrow as 60 feet.

Cost, equity, and environmental concerns are the secondary impediments that can also limit options. Preliminary designs that involve an accumulation of minor deviations from co-alignment (often due to a mature built environment) pose significant design challenges. Heavy rail cars, typically faster and with more carrying capacity, require more right-of-way. Vehicles traveling at higher speeds require smoother grade transitions. These factors have repercussions on corridor performance and marketability. The development of higher-performance light rail vehicles may mitigate some speed benefits of heavy rail, but there are tradeoffs in capacity. Multimodal concepts making effective use of BRT effectively circumvent these concerns and, even when ultimately travel demand community preferences are for fixed-rail options, BRT can provide a flexible first phase of multimodal corridor service.

Elevated, At-grade, or Underground?

Co-alignment of the transit and freeway components of a facility where the freeway facility was designed and built first, typically occur only as a result of the subsequent conversion of existing shoulder, median, or travel lane capacity. The feasibility of retrofitting a freeway facility with transit is greatly enhanced if the freeway is at-grade because elevated freeway structures require complex and extensive structures to support them—structures that typically would complicate retrofitting for transit. Tunneled and trenched freeways have similar limitations. When a new freeway is built, it can (and should) be designed to allow a future transit facility.

Platforms

Along with conventional transit planning standards and objectives, multimodal stations and station areas should be

⁵Parkinson, T. & I. Fisher, "Rail Transit Capacity," Transit Cooperative Research Program Report 13, Washington D.C.: National Academy Press, 1996.

⁶American Association of State Highway and Transportation Officials (AASHTO), *Geometric Design of Highways and Streets*, 1994

⁷Levinson, H. et al., *TCRP Report 90: Bus Rapid Transfer; Volume 1: Case Studies in Bus Rapid Transit*, Transportation Research Board, Washington, DC, 2003.

designed to emphasize their role in maximizing user travel and lifestyle options. As such, a new paradigm should provide exemplary ADA access and accommodation.

For the corridor to be attractive, access points (stations and interchanges) need to emphasize acceptable proximity to desired activities. Design factors are important in this regard since the benefits of reducing the perceived time cost of access is disproportionately larger than improvements in actual cost.^{8,9} Benefits in access time are valued more than benefits in line haul travel time. Designers of multimodal facilities and supportive environments should recognize that convenience is not necessarily synonymous with line-haul corridor travel speed.

Practical Planning Tools

Many approaches applicable to any kind of infrastructure project are particularly critical to the success of new paradigm projects. It should be recognized that the success of new paradigm multimodal project development depends in part on how deftly advocates can use conventional planning tools to overcome obstacles to multimodal investments. The experience documented in several multimodal freeway corridor case studies demonstrates that the actions of key individuals can be the difference between success and failure in guiding a multimodal corridor project to completion and that these leaders typically rely on the same tools available in most contexts in order to achieve their objectives. General guidance would be to

- Use routine processes to advance a region's multimodal potential,
- Focus on quality design and service,
- Identify potential linkages, sharing, and trades,
- Prioritize access area land uses and connectivity,
- Identify flexible and incremental multimodal opportunities.

Use Routine Processes to Advance a Region's New Paradigm Potential

In the course of normal corridor planning all options should be on the table, and planning organizations should routinely incorporate multimodal alternatives in corridor plans and corridor management plans (see Table C-1).

⁸Kato, Hironori & Axhausen "Value of Travel Time Savings Incorporating the Value of Access," Presented at the First International Time Use Observatory Workshop, Santiago De Chile, 2009.

⁹Metz, David "The Myth of Travel Time Savings," *Transport Reviews*, Volume 28, Issue 3, London, 2008.

It is important that early in the project conceptualization and planning process, project champions lay the groundwork for consideration of new paradigm projects. In many instances, an effective environmental review process has given project participants a golden opportunity to conduct outreach.

Development of multimodal facilities combines a wide range of skill sets and brings together actors who do not always interact. Advantages result from delegating staff to collaborate in project-focused institutions where the mission of developing the corridor can be prioritized and communications and decision making made more efficient. Federal and state agencies are aware of the complications inherent in planning and deploying major infrastructures and encourage specific practices to address these.^{10,11,12}

Focus on Quality Design and Service

Providing a mix of differentiated transportation services allows travel benefits to be experienced more seamlessly across travel sub-markets. When access points (interchanges and transit stations) are designed to be good fits with the community they reside in, this contributes to the identity and acceptance of the corridor. Single-mode access points, whether interchanges, platforms, or other structures, should address design challenges arising from the convergence of multiple streams of traffic in a small area (see Table C-2). Good design can offset or eliminate negative outcomes and perceptions about accessing and transferring along the corridor.

Identify Potential Linkages, Sharing, and Trades

Linkages are institutionalized relationships and connections among stakeholders around issues common to them (see Table C-3). Relying on and fostering linkages gives multimodal corridors promise as a potential foundation of balanced and sustainable regional growth.

Economic growth and demographic changes not only bring considerable benefits to a region but also incur significant economic, environmental, and social costs. Under the new paradigm, each multimodal corridor can help organize that

¹⁰FHWA, ACTION: SEP-15 Application Process, Memorandum, October 14, 2004, <http://www.fhwa.dot.gov/programadmin/contracts/101404.cfm>

¹¹AASHTO, "Transportation Invest in our Future—Accelerating Project Delivery" http://www.transportation1.org/tif7report/why_trans.html

¹²APTA Recommendations on Federal Public Transportation Authorizing Law http://www.apta.com/gap/legissues/authorization/Documents/apta_authorization_recommendations.pdf

Table C-1. Applying routine planning tools to new paradigm corridor development.

Tool/Approach	Use	Relevance for Multimodal Corridor Development	Common Area of Application
Corridor Plans	...document and evaluate comprehensive alternatives for corridor circulation and land use. Build political support for specific project alternatives.	...allow for direct comparison between multimodal and other corridor options and recommendation of alternatives and action items to pursue multimodal investment. Highlight the ways multimodal alternatives provide benefits beyond highway expansion – only projects.	Alternatives Analysis; Policy Implementation
Corridor Management Plans	...identify and evaluate specific options for detailed design and management for operational improvements	...can bring focus to changes that will improve multimodal performance or enhance the long-term potential of a corridor for major investments in multimodal infrastructure	System Management; Alternatives Analysis; Policy Implementation
Integrated Planning and Environmental Review	...allows for the simultaneous completion of studies and documentation required to complete long-range plans and obtain clearances.	...provides a basis for identifying preferred multimodal alternatives and establishing the environmental costs and benefits in light of other alternatives.	Fast-Track Project Delivery
Programmatic Agreements	...pre-establish compliance for defined categories of project based on pre-negotiated conditions among review agencies.	...provide a model for the rapid review of multimodal projects conforming to predetermined characteristics. Programmatic agreements offer the possibility of institutionalizing the benefits of multimodal projects with respect to regulatory review.	Fast-Track Project Delivery

Table C-2. Encouraging quality multimodal designs and service.

Tool/Approach	Use	Relevance for Multimodal Corridor Development	Common Area of Application
Congestion Roadway Pricing/ Off-peak Transit Discounts	...provides system users with monetary feedback on the variable cost of system use at different times.	...establishes direct financial links between roadway and peak transit use and the expansion of multimodal capacity. Allows users to manage their own mobility in light of alternative activity and travel patterns.	Corridor Finance/ Management
Schedule-Free Transit Service	...facilitates user trip planning and improves travel time reliability by implementing high frequency service on key corridors and establishing headways rather than arrival and departure times	...provides a model for dependable transit service appropriate to “final-phase” high-intensity multimodal corridor development. Provides an incremental improvement option with high-patronage rapid bus transit	Transit Service Planning
User Information Systems	...facilitates user trip planning and travel response by supplying real-time information on sources of delay or changes in travel options	...supports informed mode choice and real-time mid-trip mode transfer decisions to better exploit the reliability benefit of the multimodal system.	Intelligent Transportation Systems; Corridor Management
Smart Fare/Toll Collection	...minimizes system access and transfer penalty by allowing convenient payment of fares and tolls seamlessly across modes and operators.	...promises to eliminate an impediment to mode transfer through integration of payment of fares, tolls, and parking fees. This maximizes traveler utility of the corridor by allowing mode switching	Intelligent Transportation Systems; Transit Service Planning
Vehicle Sharing	...provides automobile access to non owners	...encourages multimodal patronage by eliminating transit dependence as a liability along the corridor and maximizing flexibility and choice for corridor use.	Transportation Demand Management

Table C-3. Tools to maximize linkages.

Tool/Approach	Use	Relevance for Multimodal Corridor Development	Common Area of Application
Land Costs Underwriting	...provides public leverage to private partners in the acquisition and consolidation of land.	...has proven a valuable tool for assembling suitable parcels for high-density development in transit station areas.	Transit-Oriented Development
Tax Exempt Bonds	...are attractive because they off set some of the risk carried by investors, allowing for lower financing costs.	...can facilitate regionwide participation in corridor development through bond initiatives.	Corridor Finance; Transit-Oriented Development
Tax Increment Financing	...seeks to capture value of future tax revenues flowing from development to finance the infrastructure that development requires.	...monetizes the expected benefit of multimodal development in supporting sustainable growth and links this to the funding requirements to let such investment happen.	Corridor Finance; Transit-Oriented Development
Joint Development	...encompasses isolated agreement and broad authority for cost and/or revenue sharing arrangements between transit agencies or local governments and private developers.	...formalizes the connections between the project participants and private interests that drive land use and activity patterns toward transit-supportive mixes and densities.	Transit-Oriented Development
Transferable Development Rights	...allows property owners in controlled or restricted development low-density areas to benefit from the sale of their development rights to high-density areas with high development pressure.	...creates a market mechanism for focusing and organizing regional growth patterns along sustainable multimodal growth "armatures."	Regional Growth Management
Transportation Benefit Districts	...allow for communities to be assessed to finance transportation improvements.	...provide a basis for individual communities to achieve desired corridor access conditions on the front end of project development and a model for funding infrastructure corridor wide.	Corridor Finance
Capital Funding Transfers	...include grants and other funds awarded from one government body to another to fund capital improvements, meeting mutual planning goals.	...allow regional and higher level bodies to incentivize the participation of local governments and eliminates a hurdle where inter-jurisdictional infrastructure partnerships are not workable for legal or administrative reasons.	Corridor Finance; Transit-Oriented Development
Tax Credits	...are awarded to individuals and developments satisfying beneficial criteria, e.g. project density and mix of activities.	...provide incentives for private market decisions to establish land use and activity trends to support multimodal patronage and performance.	Transit-Oriented Development
Special Districts	...are territorial government entities organized to be independent of cities and counties. Enabling legislation can empower special districts to undertake planning functions, redevelopment, and even assess fees and taxes.	...provide a model for designating an entire corridor as a regional special district with corridor-specific, multimodal planning and fiscal policies and implementation power.	Transit-Oriented Development

growth and minimize the associated costs. By definition, multimodal corridors are collaborative, multi-jurisdictional, and multidisciplinary endeavors, so they provide an opportunity for comprehensive planning. The corridor concept provides a planning framework for maintaining the regional benefits and minimizing many of the costs, and, in fact, a portion of the benefits to pay the costs.

There should be a greater likelihood that linkages can be established precisely because multimodal corridor projects

bring together more stakeholders than do other projects. This can support the aggregation of local funding, sharing the planning burden, and trading of local rights and resources within a regionally defined framework.

Prioritize Access Area Land Use and Connectivity

Regional policies that support compact development will enhance transit orientation, and these policies must be

Table C-4. Encouraging supportive land uses around multimodal projects.

Tool/Approach	Use	Relevance for Multimodal Corridor Development	Common Area of Application
Planning Grants	...enable states, MPOs and other regional bodies to support regional goals by providing funding for planning efforts that fall outside the normal range of activities conducted at the local level.	By targeting the funding to compact transit-oriented development near key stations, corridor planners acquire leverage over local land use and activity patterns even when there is no inter-jurisdictional authority.	Fast-Track Project Delivery; Livability Planning
Overlay Zones	...provide additional specificity to guide development within planning areas. For multimodal corridors, overlay zoning can guide station areas toward density, mix of uses, and design features that improve access.	...can force the development around corridor access points to fit a profile consistent with the market objectives of the corridor as a whole and specifically to achieve desired mix and density at planned transit-oriented locations along the corridor.	Transit-Oriented Development
Density Bonuses	...allow developers to respond to strong demand by increasing unit densities and floor area ratios above normal limits	...can induce the development around corridor access points for planned transit-oriented locations along the corridor.	Transit-Oriented Development
Connective Design	.. improves access among commercial and residential locations in the access areas, reducing or eliminating automobile dependence for neighborhood trips.	... supports automobile independence and enhances the marketability of multimodal corridor access points.	Transit-Oriented Development

applied at station areas to help the corridor evolve, station by station, toward multimodal success (see Table C-4). A goal of the corridor may be to reduce the prevalence of automobile-supportive infrastructure (for example, parking) over time as the market will bear these changes. Converting some parking areas to transit-oriented development may be possible. New or redeveloped areas in the vicinity of stations could incorporate context-sensitive designs that emphasize walkability.

Identify Flexible and Incremental Multimodal Opportunities

Flexible and gradual development of multimodal freeway facilities may be desirable in some cases. This is particularly so when resources are limited or markets are underdeveloped. In these cases, provisions should be made for developing the multimodal potential of corridors, flexibly and/or in stages over time (see Table C-5).

Table C-5. Encouraging flexible and incremental multimodal options.

Tool/Approach	Use	Relevance for Multimodal Corridor Development	Common Area of Application
Express and Limited Bus Service	... combines travel on segments of freeway and parallel arterial facilities, maximizing HOV and transit priority infrastructure.	...can support constituencies for transit service in undeveloped and growing markets, including low-density land use environments.	Transit Service Planning
Bus Bridges	...provide connections between other modes, including fixed-rail transit systems or ferry systems, expanding the market for transit use.	...can revive demand for existing transit services and support significant improvement in regional automobile free mobility for minimal investment.	Transit Service Planning
Demonstration Bus Rapid Transit	...allows for proof of concept demonstration of the viability of multimodal connections for limited investment.	...can spur interest in permanent multimodal alternatives on subject corridor and alternate corridors and places multimodal alternatives on list of viable options for regional mobility needs.	Transit Service Planning

Investments in small-scale and flexible multimodal facilities will weigh the tradeoffs of construction investments against the actual or expected benefits of operational accommodations to maximize corridor performance. Construction investments in incrementally achieved multimodal facilities will be limited to specific portions of the corridor that can be funded through pre-existing programs addressing regional congestion management, context sensitivity, or transportation enhancement objectives.

An obvious impediment to success arises from limited experience with planning and implementing multimodal projects. A benefit of flexible approaches is that there is an opportunity to develop the proficiency of planners and managers as they develop the skills and relationships required for successful collaboration. A second benefit is that incremental approaches support routine evaluation and course correction if the costs and benefits of outcomes do not meet expectations.

APPENDIX D

Existing Multimodal Corridor Case Studies

To understand the characteristics of multimodal highway corridors, how they function, and what the best configurations might be for future deployments, this study surveyed existing multimodal highway corridors. The survey focused mostly on those within the United States. The following criteria were used to screen and select these case studies:

- Access-limited highway facility (freeway)
- High-capacity transit facility (heavy, light, or commuter rail transit, or bus rapid transit)
- Transit and highway should run roughly parallel and be no more than one-half mile apart

Data collection on existing multimodal highway corridors was performed using a combination of web searches, discussions with team members, and input from the project's panel members.

Multimodal Corridors in the United States

Los Angeles Region

The Los Angeles urbanized area has a population of about 12 million, of which more than 10 million live in Los Angeles County and 4 million reside within the city of Los Angeles. Employment in the 20 square mile central business district exceeds 200,000. Many daily travelers are served by extensive freeway and public transit systems.

The area has more than 40 miles of bus and rail transit lines located in or alongside freeways, although about half of the mileage is also used by car and van pools. Most of the 20-mile Green Line LRT is in the median of the Century Freeway (I-110). Some three miles of the 14-mile Gold Line LRT are in the median of the Foothills Freeway (I-210). The 12-mile San Bernardino Transitway (buses and three-person car pools) operates within the median or alongside the I-10 freeway. An

11-mile Transitway (for buses and car pools) is elevated over the Harbor Freeway. These facilities are important complements to the rail and bus rapid transit systems; the regional HOV and freeway network serves the second largest urban region in the United States.

Los Angeles Harbor Freeway (I-110)/ Harbor Transitway Corridor

Limits

From: Artesia Transit Center
To: 37th Street Transitway Station

Context and Project Development History

In the mid-1970s, Southern California's Regional Transit District (SCRTD), California Department of Transportation (Caltrans), and other regional transportation agencies began to study the prospects for a regional rapid transit system that would include both bus and rail options along major regional transportation corridors. In 1976, the U.S. Department of Transportation (US DOT) approved \$11.08 million for studying these options, with most of those funds (about \$7.8 million) allocated to Caltrans to study freeway transit and highway-related alternatives. As the decade progressed, interest in freeway corridor transit options, in particular those involving bus rapid transit along freeway facilities, intensified. In 1978, Caltrans and SCRTD selected two high-priority corridors, the Harbor Freeway and Santa Ana corridors. After study and community outreach, the Harbor corridor transitway project was selected based in part on the low costs of construction estimated for the project and the lack of any significant neighborhood opposition in the corridor to the proposed project.¹ In 1980, Caltrans completed a Draft Initial

¹Interview with Frank Quon, Caltrans, 11/12/09.

Study/Environmental Assessment for the Harbor Freeway Corridor. Five years later, the final EIS was complete, the administrative hurdles had been overcome, and the project was ready for construction.² But more delays were in the offing, as federal funding constraints led Caltrans to recommend that the transitway project (which would involve the construction of elevated bus lanes over the existing Harbor Freeway) be delayed.³

By 1989, funding had been secured and construction began on the Harbor Transitway.⁴ Caltrans was identified as the lead agency, but the partnership included SCRTD, the Southern California Association of Governments (SCAG), and others. No joint powers agreements or other new project-specific agencies were formed for the project.⁵ Construction was largely complete by 1996 and the official opening of the Transitway to buses and carpoolers occurred on June 26th 1996.⁶

Design Features

Carpool and transit lanes were installed in a separate roadway as part of rebuilding the Harbor Freeway Interstate 110. The lanes extend about 11 miles, and seven bus stations are provided at key intersecting roads. Two HOV lanes are provided each direction from Martin Luther King Boulevard to Interstate 105; single lanes run between that point and State Route 91 in each direction. The transitway right-of-way, which primarily runs down the median of the Harbor Freeway, was already owned by Caltrans,⁷ so very little land acquisition was required. The two-lane transitway is generally elevated above the general purpose lanes. This elevated alignment was specifically chosen in order to minimize the environmental impacts on the corridor's neighborhoods.⁸

Stations

In general, transit stations on the Harbor Freeway are consistent in their design with all but the Artesia Station (located adjacent to the freeway/transitway) located in the freeway



Source: Courtesy of METRANS Transportation Center.

Figure D-1. 37th Street Station in the median of the I-110 Freeway/Harbor Transitway.

median. Since there are no sound barriers between the station platforms and the adjacent freeway lanes (see Figure D-1), bus riders waiting on the platforms endure very noisy conditions (70 to 90 decibels).⁹ As buses approach the stations they cross over so that bus doors are alongside the station platforms.¹⁰ Buses entering stations are given the right-of-way.

Pedestrian access to the Transitway's stations is difficult, in part due to their placement within the freeway right-of-way, but further compounded by inadequate signage. Improved signage would better direct and encourage pedestrians to venture into the automobile-dominated freeway environment. Therefore, many people in the Transitway corridor may not be aware of the existence of these stations, let alone how to access them. This lack of pedestrian signage is in stark contrast to the ample number of signboards indicating directions to the automobile driver for the 110 Freeway.¹¹ Pedestrians are further discouraged from accessing the stations from surrounding neighborhoods due to narrow and unsafe station-area sidewalks. According to a study of the Transitway's design and how it affects patronage, ". . . most of the stations look empty and forlorn, and provide little chance for people to interact with each other," and, "The waiting areas are not accommodated with sufficiently attractive features or amenities, such as art, sculptures, or landscaping."¹²

²Banerjee, T., et al., "Highway Oriented Transit System: A Comprehensive Land Use/Transportation Strategy to Improve Transit Service Delivery A Case Study of (I-110) Harbor Transitway Stations," METRANS Transportation Center, April 30, 2001.

³Trombley, W. "El Monte Busway Is Rousing but Solitary Success in L.A.," Los Angeles Times, September 26, 1985. http://articles.latimes.com/1985-09-26/news/mn-1357_1_el-monte

⁴Feldman, P. "Harbor Freeway Double-Decking Gets Under Way," Los Angeles Times, April 20, 1989. <http://pqasb.pqarchiver.com/latimes/access/66438055.html?dids=66438055:66438055&FMT=ABS&FMTS=ABS:FT&type=current&date=Apr+20%2C+1989&author=PAUL+FELDMAN&pub=Los+Angeles+Times+%28pre-1997+Fulltext%29&desc=Harbor+Freeway+Double-Decking+Gets+Under+Way&pqatl=google>

⁵Interview with Frank Quon, Caltrans, 11/12/09.

⁶Simon, R. "Street Smart; High Rolling; New Elevated Roadway Offers Fast, Quiet Ride Above Harbor Freeway," Los Angeles Times, June 26, 1996.

⁷Interview with Frank Quon, Caltrans, 11/12/09.

⁸Interview with Frank Quon, Caltrans, 11/12/09.

⁹Banerjee, T., et al., "Freeway Bus Station Area Development: Critical Evaluation and Design Guidelines—A Case Study of (I-110) Harbor Transitway Stations," METRANS Transportation Center, Metrans Project 00-12, July 1, 2005.

¹⁰Note: if buses also had doors on the left side, the crossing could be eliminated and the operation simplified.

¹¹Ibid, Banerjee, T., et al., 2005.

¹²Ibid, Banerjee, T., et al., 2005, p. 5-1

Operations

Buses using the Transitway include six LA Metro and two Orange County Express bus routes. City of Gardena and City of Torrance buses also operate on sections of the Transitway. As with other busways, various routes use portions of the Transitway and then disperse to other communities in the region. The land use is heavily commercial and industrial at either end of the Transitway with some residential land use in between.

Metro Routes 444, 446, 447, 450, and 460 use most of the Transitway. Route 445 uses the Transitway and the HOV lanes; it runs from Exposition Park to San Pedro.

Orange County Express bus lines 701 and 721 go from Huntington Beach and Fullerton, respectively, to downtown Los Angeles on the Harbor Transitway.

Service is concentrated in peak periods. Buses running along the Transitway include Orange County Transit bus lines and six LA Metro Express buses. The bus running times for the facility total 19 minutes—resulting in an average speed of 35 miles per hour (mph).

Patronage

- 4,100 average weekday boardings (estimated for study corridor) on the Transitway.¹³
- Highway I-110:
 - 298,000 vehicle-trips per weekday (estimated for study corridor) on I-110.
 - 387,400 person-trips per weekday (estimated for study corridor) on I-110.

Several factors contribute to the low bus ridership: (1) the freeway and Transitway are located in a “gore” between major population concentrations; (2) the stations are relatively inaccessible to pedestrians or transferring patrons; (3) the station environment is isolated and is noisy from the passing freeway traffic; (4) service frequency varies widely throughout the day; and (5) the Blue Line light rail line is located nearby, runs parallel to the Transitway, runs more frequently, and costs less to use.

A survey of patrons in 2005 found that the top five problems they faced using the Harbor Transitway were (1) Irregular and unreliable frequency of bus service, with roughly 41 percent of respondents picking it as the primary difficulty; (2) Poor noise protection at the station, with 28 percent of respondents selecting this as a major problem; (3) Poor station area maintenance came in as the third

biggest problem (25%); (4) The presence of trash at the stations (22.%); and (5) The presence of homeless people at the stations (17%).¹⁴

Benefits

Buses using the Transitway average 35 mph. This speed substantially exceeds the 15 to 20 mph express bus speeds achieved on city streets.

Los Angeles Green Line/Century Freeway Corridor

Limits

From: Norwalk Station

To: Redondo Station

Context and Project Development History

The Green Line was built as a precondition for building the Century Freeway (I-105) and was part of the consent decree signed by Caltrans in 1979. It serves the communities of Manhattan Beach, El Segundo, Hawthorne, Lynwood, South Gate, Los Angeles, and Norwalk.

While the Century Freeway was established in plans as early as 1958, the changing development patterns of the Los Angeles region meant that the freeway’s path would have to cut through established suburban neighborhoods. The freeway’s right-of-way from Norwalk to El Segundo travels through traditionally minority and poor neighborhoods such as Hawthorne, Inglewood, and Downey. While many of the freeways previously constructed in the Los Angeles region could take advantage of ample and inexpensive land—often right-of-way from the recently defunct Interurban transit system—the Century Freeway would come to represent the future of freeway construction in the region in terms of the obstacles faced, the political fights that would occur, and the bargains that would be struck.¹⁵

Beginning in 1958, the California Division of Highways (which later changed its name to Caltrans) proposed and studied six alternate alignments for the freeway, all within a few blocks of each other. In the mid-1960s, a preferred alignment was selected and property owners along the proposed path began to receive notices of their evictions. However, one family living in the path of the proposed freeway chose to fight the plan in court. They were soon joined by the City of Hawthorne (which would be bisected by the proposed

¹³Ridership is for Los Angeles Metropolitan Transportation Agency (LA MTA) bus only. Data for Orange County Transportation Agency (OCTA) buses that run along this facility could not be obtained.

¹⁴Ibid, Banerjee, T., et al., 2005.

¹⁵Ellars, M. S. “Never Again: The Century Freeway,” March 31, 1998, accessed on August 26, 2009, <http://msenet.org/three/shell/chambers/century.txt>.

alignment), the Sierra Club (which claimed that the region's air quality would worsen once the freeway was completed, not improve as the State's Environmental Impact Statement asserted), and the NAACP as co-litigants. In 1972, their lawsuit succeeded in winning an injunction against the project and a court order to conduct a more thorough Environmental Impact Statement. After 7 years of study, all parties signed a consent decree that would allow the project to continue, with modifications. Not until 1981, when several amendments were signed to the consent decree, did construction begin anew. These critical amendments included the inclusion of the light rail line down the median of the freeway and the conversion of the planned freeway lanes from eight "mixed-flow" to six with two high-occupancy vehicle (HOV) lanes.¹⁶ Construction on the Green Line began in 1987 and when completed in 1995, cost \$718 million dollars.¹⁷

Since opening, the following three criticisms have been leveled against the Green Line:

- **Lack of Connections to Major Activity Centers:** The line was constructed in a circumferential alignment to downtown Los Angeles, meaning it does not serve the region's largest activity center. It also skirts the Los Angeles International (LAX) Airport and relies on a shuttle service to take passengers from the nearest station to the terminals.¹⁸ Although originally planned (and partially constructed) to connect with LAX, there were concerns that the overhead lines of the rail would interfere with the landing paths of airplanes. Furthermore, the owners of parking lots surrounding LAX were fearful that the train would create competition, since there is ample free parking at numerous points along the Green Line. When the project was conceived in the 1970s, the defense industry employed thousands in the corridor cities of El Segundo and Redondo Beach, but these businesses suffered large contractions and layoffs, depriving the transit line of a reliable ridership base.¹⁹
- **Inadequate Project Justification:** The project was originally conceived in the 1970s in response to opposition to the proposed Century Freeway's route which was planned to pass through established urban communities. The route would require the acquisition and demolition of hundreds of homes and businesses. Opponents of the project filed lawsuits to block the freeway. As part of a 1979 court-mandated consent decree, the Green Line was part of a compromise

between the state and the freeway opponents.²⁰ However, critics of the project argued that the Green Line was not justified as a stand-alone transit project and was unduly placed as a higher priority compared to other regional transit projects as part of a political bargain to build the Century Freeway. However, Green Line project proponents saw it as an opportunity to build both projects at the same time, at a lower total cost.²¹

- **Poor Design of Freeway Median Stations:** The Green Line has nine stations located in the median of the Century Freeway, creating aesthetic and physical discouragements for transit riders to use them. High noise, airborne dirt and particulate matter levels on the platforms are generated by the adjacent freeway travel lanes. The long walks to the platforms from bus stops, park-and-ride lots, and adjacent communities often include flights of stairs and multiple ramps or bridges that cross over or under freeway travel lanes and other structures. These conditions are generally thought to discourage transit ridership.²²

Design Features

The 20-mile 14-station Green Line opened in 1995. Some 16 miles and 9 stations are located in the median of the Century Freeway (I-105 between Hawthorne and I-605).

The fully grade-separated line interchanges with the Harbor Transitway and with the Blue Line LRT between downtown Los Angeles and Long Beach.

Stations

Center-island high-platform stations are provided within the freeway median. There are about 6,700 park-and-ride spaces along the Green Line, of which about 5,500 are at stations along I-105. The largest facilities are at the Norwalk Station (with 2,050 spaces) and the Imperial Station (with 975 spaces).

Operations

The Green Line operates a single service from 4:30 A.M. to 12:30 A.M. the following day. A fleet of 34 Light Rail Vehicles (LRVs) is used. Trains run at maximum headways of about 7 minutes during peak periods and headways up to 20 minutes during off-peak periods. The end-to-end travel time for the 20-mile line is 35 minutes. The high operating speeds of

¹⁶Ibid, Ellars, M. S.

¹⁷Mieger, D., Chu, C., "The Los Angeles Metro Green Line: Why Are People Riding the Line to Nowhere", Compendium of Technical Papers, 86th Annual Meeting, Transportation Research Board, Washington D.C., January 2007.

¹⁸Mieger, D., Chu, C., "The Los Angeles Metro Green Line: Why Are People Riding the Line to Nowhere", Compendium of Technical Papers, 86th Annual Meeting, Transportation Research Board, Washington D.C., January 2007.

¹⁹http://en.wikipedia.org/wiki/Metro_Green_Line_%28LACMTA%29

²⁰Mieger, D., Chu, C., "The Los Angeles Metro Green Line: Why Are People Riding the Line to Nowhere", Compendium of Technical Papers, 86th Annual Meeting, Transportation Research Board, Washington D.C., January 2007.

²¹Mieger, D., Chu, C., "The Los Angeles Metro Green Line: Why Are People Riding the Line to Nowhere", Compendium of Technical Papers, 86th Annual Meeting, Transportation Research Board, Washington D.C., January 2007.

²²Mieger, D., Chu, C., "The Los Angeles Metro Green Line: Why Are People Riding the Line to Nowhere", Compendium of Technical Papers, 86th Annual Meeting, Transportation Research Board, Washington D.C., January 2007.

about 38 miles per hour are a result of the wide 1.5 mile station spacing.

Patronage

- 37,000 average weekday boardings (estimated for study corridor) on the Green line.
- century freeway:
 - 258,000 vehicle-trips per weekday (estimated for study corridor) on I-105.
 - 335,400 person-trips per weekday (estimated for study corridor) on I-105.

Ridership on the Green Line has grown steadily from an average of 13,650 weekday boardings in 1996 to 37,490 riders in 2006. This growth is attributed to a strong feeder bus network, high operating speeds, and connectivity with the Blue Line²³.

A review of Fiscal 2006–2007 rail passenger weekday activity by station indicates the following:

- The largest eastbound boardings are at Imperial/Wilmington [Blue Line Connection (3,160)] and Aviation (2,560).
- The largest westbound boardings are at Imperial/Wilmington (5,200) and I-605/I-105 (3,880).
- The largest eastbound alightings are at Imperial/Wilmington (5,270) and I-605/I-105 (4,110).
- The largest westbound alightings are at Imperial/Wilmington (3,220) and Aviation (3,000).

Some highlights of rider surveys are as follows:

- A. Income
 - less than \$15,000 40%
 - \$15000–\$50,000 40%
 - Over \$50,000 20%
- B. Car Availability 37%
- C. A.M. Peak Hour: See Table D-1.

Benefits

The corridor scores high in providing a multimodal facility within a combined right-of-way, and it has substantially reduced travel times by public transportation.

Assessment

The line has had little land use impact—even where it crosses the Blue Line. Access to stations is difficult. The line comes close to, but does not directly serve, the Los Angeles Inter-

²³Mieger, D., Chu, C., “The Los Angeles Metro Green Line: Why Are People Riding the Line to Nowhere”, Compendium of Technical Papers, 86th Annual Meeting, Transportation Research Board, Washington D.C., January 2007.

Table D-1. A.M. peak hour access/egress by mode for the Green Line.

Access/ Egress Mode	Access	Egress
Bus	43%	45%
Car	28%	5%
Walk	15%	28%
Blue Line	12%	19%
Other	2%	3%
Total	100%	100%

Source: Los Angeles Metro

national Airport. The line’s eastern terminus is 2 miles short of the heavily used Norwalk/Santa Fe Springs Metrolink Station where several Metrolink commuter rail lines operate. Thus, the line has no major anchor—usually a prerequisite for rail transit development. Some contend this is a train “from nowhere to nowhere.” However, the line’s surprisingly high ridership levels have been attributed to

- A **strong bus feeder network** providing a steady supply of transit riders,
- The **survival and partial rebound of the defense and aerospace industry** (it was estimated to have the 10th largest employment concentration in the LA metropolitan area, with 54,000 jobs in 2004) in the corridor after the initial post-Cold War collapse, and
- **High running speeds** and a **direct connection to the Blue Line** that facilitates train-to-train transfers for riders traveling to downtown Los Angeles.²⁴

The Green Line, however, is important in several aspects from a “New Paradigm” perspective. It is the only crosstown (circumferential) multimodal corridor in North America. While it does not have any major land use anchor, it shows that high speeds and good connections to radial rapid transit lines *can* attract riders.

Los Angeles Gold Line/I-210 Corridor

Limits

From: Mission Station
To: Chinatown Station

Context and Project Development History

The 13.7-mile \$740 million Gold Line was placed in service July, 2003. The 13-station line runs from Union Station

²⁴Mieger, D., Chu, C., “The Los Angeles Metro Green Line: Why Are People Riding the Line to Nowhere”, Compendium of Technical Papers, 86th Annual Meeting, Transportation Research Board, Washington D.C., January 2007.

at the eastern edge of downtown Los Angeles to Sierra Madre Villa.

Several extensions are in progress or are being planned:

- An Eastside extension connecting Union Station to Little Tokyo, Boyle Heights, and East Los Angeles is scheduled to open by the end of 2009. There will be twin 1.7-mile tunnels with two underground stations on this extension.
- A Foothills Freeway extension from the terminus on the east side of Pasadena to the City of Azusa is in the final design stage (2008). Opening is reportedly scheduled for 2010.
- A planned extension to Montclair is scheduled for 2010. This segment would be entirely above ground with a small portion in the median of I-210.

The initial concept for the Gold Line was to connect it via subway to the Blue Line LRT, thereby providing several stops in downtown Los Angeles, and allowing through service between Pasadena and Long Beach. In contrast, the connection to East Los Angeles under construction will still require transfers at Union Station to the Red Line subway.

As part of an initiative in 1980 to pass a half-cent sales tax increase to fund county transportation projects (Proposition A), the Los Angeles County Transportation Commission (LACTC) presented a plan to the voters for a regional network of rail transit lines, including a line from downtown Los Angeles to Pasadena. In 1992, the LACTC (having merged with the Los Angeles Regional Transit District to form the Los Angeles County Metropolitan Transportation Authority [LACMTA]), acquired a 38-mile-long BNSF right-of-way from Los Angeles to Claremont (passing through Pasadena). Construction of the line began in 1994 and was scheduled for completion by 2001, but the project was halted in 1995 due to cost overruns, engineering complications, and charges of favoritism in the awarding of contracts by LACMTA. To reduce costs, a station (Avenue 51 at Highland Park) was eliminated and a standard design for all stations was implemented (with the exception of a few designated “landmark” stations which were deemed tourist “gateways”). During this period, serious consideration was given to eliminating the Pasadena Blue Line (later to be renamed as the Gold Line) altogether. However, the cities of Pasadena, South Pasadena, and Los Angeles campaigned to keep the project alive, and State Senator Adam Schiff pushed through a bill that created the Pasadena Blue Line Construction Authority (PBLA) in 1999 that created a stand-alone construction agency charged with the completion of the project. The PBLA completed construction of the line to Pasadena in 2003, on time and

under budget, at which time they transferred ownership and operational duties to LACMTA.²⁵

Design Features

The Gold Line mainly occupies the former BNSF right-of-way including a small portion of street running. Five miles with three stations—Lake, Allen, and Sierra Madre Villa—are located in the median of the eight-lane Foothills Freeway (I-10). The freeway and LRT line run in trench alignments through Pasadena.

Stations

Center-island stations are located in the freeway median. Each station is uniquely designed. For example, at the Lake Station, large scale black-and-white photo portraits of people are laminated within glass at the mezzanine level. At the Allen Station, paper cutouts and metal grillworks enhance the station entry. At the Sierra Madre Villa Station, the line’s current northern terminus, large-scale photo portraits of porcelain enamel street panels are suspended above the stairway access to platform areas.

About 5,000 parking spaces are provided along the Gold Line of which 3,000 are at Union Station. Along the I-210 multi-modal section, there are 950 spaces at the Sierra Madre Villa Station and 100 at the Lake Station. Each of the three stations has connecting bus service. An intermodal transportation hub at the Sierra Madre Station is connected to the parking area and trains.

Operations

The Gold Line uses about 25 articulated light-rail vehicles. Each train car seats 76 passengers and has a rush-hour schedule design capacity of 144 passengers, including standees. The line operates three-car trains. Service operates from about 4 A.M. to 2 A.M. the next day. Trains run at 10-minute intervals during rush hours, 12-minute intervals midday, and 15- to 20-minute intervals during evening hours. One-way running time for the 13.7 mile trip is 36 minutes. Speeds average 23 miles per hour.

Patronage

- 21,500 average weekday boardings (estimated for study corridor) on the Gold Line.
- State Route 210:
 - 186,000 vehicles per weekday (estimated for study corridor) on State Route 210.
 - 241,800 vehicles per weekday (estimated for study corridor) on State Route 210.

²⁵<http://www.publicartinla.com/Metroart/GoldLine/history.pdf>

Benefits

The Gold Line provides convenient and reliable access to many destinations en route. To build the Gold Line and capitalize on the benefits it has brought, the Pasadena Construction Authority was created. The Authority hopes to recoup roughly \$30 million of the costs of building the line by developing excess land acquired during construction.²⁶ A number of TOD projects have been proposed or built since this line's opening, including Avenue 57 and Del Mar, in station areas within the City of Pasadena.²⁷

Los Angeles El Monte Busway/San Bernardino (I-10) Freeway Corridor

Limits

From: El Monte Bus Terminal
To: Union Station

Context and Project Development History

The I-10 (San Bernardino) Freeway corridor largely occupies former Pacific Electric Interurban rail right-of-way between El Monte and downtown Los Angeles. The busway has one-way bus lanes built in the median strip or alongside the freeway, which are separated from the general-purpose traffic lanes by concrete barriers or a buffer lane with traffic posts. Downtown distribution is provided via city streets—Broadway inbound and the Spring Street contra-flow bus lane outbound.

The busway was jointly developed by the Southern California Rapid Transit District (SCRTD) (now the Los Angeles County MTA) and the California Department of Transportation in conjunction with the widening of the freeway. The 11-mile busway opened as a bus-only facility in 1972; its development costs were \$57 million. A one-mile, \$18-million extension into downtown Los Angeles opened in 1989. The busway was originally intended for bus-only operations and operated as such from 1973 to 1974, but was opened to vehicles with three or more occupants during the 68-day 1974 SCRTD strike. In 1976, the facility was opened to authorized carpools of three or more occupants from 6–10 A.M. and 3–7 P.M. After the strike ended, the use by carpools continued.²⁸

In 1999, the State Legislature revised the state's vehicle code to provide for an 18-month experiment that allowed two-

person carpools. The reduction was in effect from January 1, 2000, to June 30, 2001. As a direct result, the number of people moved on the busway dropped. Many carpools previously forced to triple up moved to two-person carpools. This increased traffic on the roadway and substantially increased congestion. As a result of the congestion, speeds on the busway dropped from 65 mph (105 km/h) before the experiment to 20 mph (32 km/h) during the experiment, while speeds in the mixed-flow lanes did not change significantly paradoxically making the busway slower than the regular lanes.^{29, 30} As a result of public outrage, Assembly Bill 769 was passed in July 2000 that was an emergency measure to terminate the experiment during peak hours. After June 30, 2001, carpools again required a minimum 3 occupants per vehicle.

Design Features

The busway, when built, was the most complete busway in the United States with on-line stations, park-and-ride facilities, and feeder bus lanes. It includes a 5-mile barrier-separated segment and a 7-mile segment with a 10.5-foot-wide striped pavement buffer.

The 6.6-mile section between El Monte and the Long Beach Freeway is located in the freeway median. A 20-foot railroad track and opening is maintained in the median and flanked by a median walk, a 17-foot busway, a 3-foot flexible post every 50 feet, a 10-foot common shoulder, and then four freeway lanes.

A 3.8-mile section adjacent to the freeway between Mission Road and the Long Beach Freeway consists of a 54-foot two-way busway with 12-foot lanes, an 8-foot right shoulder, and a 4-foot left shoulder in each direction separated by a barrier.

Contra-flow lanes exist west of the California State University, Los Angeles, to the Santa Ana/San Bernardino Freeway interchange. The transposed operations facilitates access to and from the busway and allows common station platforms.

Stations

Three major on-line bus stations are located at El Monte, the university, and a large hospital complex. Five park-and-ride lots along the busway provide 2,425 spaces. The 2,100 space El Monte Station park-and-ride, the largest facility, is connected to the transitway by a bus-only ramp. A circular island platform provides convenient transfer between express and local (feeder) bus lines.

²⁶Cervero, R., S. Murphy, C. Ferrell, N. Goguts, and Y. Tsai. Transit Oriented Development in America: Experiences, Challenges, and Prospects. Transit Cooperative Research Program, Report No. 102., p. 333.

²⁷Ibid, p. 413.

²⁸http://en.wikipedia.org/wiki/El_Monte_Busway

²⁹http://en.wikipedia.org/wiki/El_Monte_Busway

³⁰Turnbull, K. "Effects of Changing HOV Lane Occupancy Requirements: El Monte Busway Case Study," FHWA-OP-03-002, June 2002. http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/13692.html

LACMTA and Foothills Transit buses operate on the transitway. Seven express bus routes make 200 weekday trips along the 12-mile (19 km) transitway. One-way bus running time is 17 minutes resulting in operating speeds of more than 40 miles per hour.

Patronage

- 7,000 average weekday boardings (estimated for study corridor) on the transitway.
- Interstate 10:
 - 221,000 vehicles per weekday (estimated for study corridor) on Interstate 10.
 - 287,300 person-trips per weekday (estimated for study corridor) on Interstate 10.

The San Bernardino (I-10) Freeway Transitway was initially restricted to buses only when it opened in 1973. The number of buses using the lanes and the ridership increased significantly during the first few years of operation and then grew slowly. Ridership increased from 1,000 to 14,500 passengers during the initial bus-only operating period; between 50 and 70 percent of the riders during this period previously drove alone³¹. The average daily bus ridership was 18,000 in 1994 and 19,400 in 1996, despite the introduction of Metrolink Rail service into the corridor. MTA reports daily boardings of 18,000 (as of 2001). The park-and-ride facility at the El Monte terminal was filled to capacity in the first few years, and the lack of parking space appears to have inhibited bus ridership growth.

The number of peak-hour buses increased from 76 in 1998 to 84 in 2000³²; buses carried 2,750 passengers and 2,950 passengers, respectively³³. These numbers exceed the people carried per general occupancy lane. As a result during the peak hour (as of 1998), buses accounted for 17 percent of the total person movement, carpools 26 percent, and the remaining 57 percent were single-occupant cars in the four general purpose freeway lanes. This is contrasted with daily patronage estimates listed above that suggest a more modest 2 percent bus mode share of person-trips in this corridor.

Benefits

Busway users (with 3 or more person carpools) experience a significant speed advantage over travelers using the mixed-

flow freeway lanes during peak periods. A 12-mile peak-hour trip required 48 minutes using mixed-flow lanes as compared with 17 minutes by a three-person car pool or bus trip.

Denver Region

Denver is the major center of the Rocky Mountain area with an urbanized area population of more than two million. Its central business district employment approximates 120,000, and CBD floor space approximates 24 million square feet. I-25, the major North-South expressway, has a major spur, I-225 to Aurora.

Much commercial and residential development has located along both these interstate routes in southeast and eastern Denver, including the Denver Tech Center with an employment that exceeds 50,000. Their junction has been reported as one of the busiest in the United States.

RTD light rail began revenue service on October 7, 1994. RTD's first light rail line, the Central Corridor, runs from 30th Avenue and Downing through the Five Points Business District and downtown Denver, by the Aurora campus, then along railroad right-of-way to I-25 and Broadway. There are three park-and-rides on the Central Corridor light rail line. The I-25 and Broadway Station Park-and-Ride provides 1,050 parking spaces. Alameda Station Park-and-Ride opened in August 1996 and has 287 spaces. The adjacent Broadway/Marketplace provides 221 spaces. The 30th and Downing Station Park-and-Ride has 27 parking spaces.³⁴

Denver T-REX/I-25 Corridor

Limits

From: Lincoln Station
To: I-25/Broadway Station

Context and Project Development History

The Southeast Transportation Expansion Project (T-REX) line extends along the west side of reconstructed I-25 to Lincoln, with a short spur in the median of I-225 to Aurora (see Figure D-2). LRT lines to Union Station and to 16th Street in the eastern part of the CBD link both trunk lines with the City Center. These are viewed as the Central Corridor.

The multimodal segment of this corridor consists of roughly 17 miles of a 19-mile line completed in 2006 for a cost of \$1.67 billion. The project was delivered ahead of schedule and has had over a full year of operation.

³¹Levinson H. S., Zimmerman S., et al, TCRP 90 Bus Rapid Transit, Vol. 1 Case Studies in Bus Rapid Transit Appendix C (CD), Transportation Research Board, Washington, D.C. 2003.

³²St. Jacques K., and Levinson H. S., TRCP Report 26 Operational Analysis of Bus Lanes on Arterials, Transportation Research Board, Washington D.C., 1991.

³³Turnbull K. F., Levinson H. S., Pratt R. H., TCRP 95 Traveler Response to Transportation System Changes, Chapter 2—HOV Facilities, Transportation Research Board, Washington, D.C., 2006.

³⁴www.rtd-denver.com/Projects/Fact_Sheets/CCLRT_Facts.pdf



Source: Colorado Department of Transportation, T-REX Fact Book.

Figure D-2. The T-REX Corridor looking north toward the Tech Center and Downtown Denver.

The T-REX project includes park-and-ride facilities at all the stations and RTD operates feeder bus service throughout the station areas as well. Six distinct light rail lines use portions of the segment; these provide limited service over some portions.

The Denver region had been considering fixed guideway transit since the 1970s. Prior to the development of light rail, Denver's downtown had declined over time and LRT could be seen as both an effort to reduce congestion and provide increased capacity to stimulate growth in the downtown. Anecdotal observations indicate that today, downtown Denver has been revitalized and is flourishing, suggesting that the value of T-REX and its predecessor light rail projects should be evaluated not just in terms of how well they have competed with nearby freeways and mitigated congestion, but also as a tool for encouraging the growth of downtown.

The beginnings of the T-REX project can be traced to a 1992 study by the Denver Regional Council of Governments (DRCOG) that found that congestion levels on the freeway would soon bring gridlock most of the day. Specifically, the study found that local bus service travel times were about twice that of cars in the corridor, while express bus travel

times were closer to cars. Local buses were subject to the same congestion as cars and were further delayed by frequent passenger stops. The study also voiced the concerns of the corridor's employers who said that the inadequacy of effective and affordable transportation services there made it difficult to recruit and retain employees.³⁵ This was in contrast to the projections of planners that 150,000 new jobs would be added in the downtown area and the huge Denver Tech Center over the next 20 years, further increasing the prospects for gridlock. The study recommended two capacity enhancements to accommodate this anticipated growth: the widening of the corridor's freeways and the development of a high-capacity transit line along the freeway's alignment.³⁶

In April 1995, The Colorado Department of Transportation, Denver's Regional Transit District, and DRCOG commissioned the Southeast Corridor Major Investment Study (MIS), which sought the best solutions to the corridor's congestion problems.³⁷ The study included partners with interests in the corridor, including Arapahoe and Douglas counties along with the cities of Denver, Aurora, and Greenwood Village. Perhaps due in part to this wide variety of interests involved in the study, the initial MIS was largely transit-oriented in its recommendations, which included light rail, pedestrian/bicycle facility improvements, enhanced Transportation Demand Management (TDM) measures, intelligent transportation system (ITS) measures, and relatively minor highway improvements such as acceleration and deceleration lanes and wider shoulders. Somewhat to the disappointment of the Federal Highway Administration (FHWA) and CDOT, no highway-widening measures were recommended and the four lead agencies agreed that the MIS placed too much emphasis on transit.³⁸ According to Cal Marsalla, RTD's director, "We looked at ways to break down the highway vs. transit rivalry and started looking at mobility," and, "Let's look at highway and transit as coordinated pieces of a comprehensive strategy to maximize mobility in a project with limited available right of way. We set our sights on a project that was a win-win (proposition) for both transit and highway. What emerged was the T-REX project."³⁹

³⁵Metro Denver/Colorado, T-REX Fact Book, http://www.metrodenver.org/files/documents/transportation-infrastructure/highways/Trans_HWY_T-REX_FactBook.pdf

³⁶Accessed 8/27/09, http://en.wikipedia.org/wiki/Colorado_T-REX_Project_%28Transportation_EXPansion%29

³⁷Civil Engineering News- Spotlight on Building The Future-T-REX project, <http://www.cenews.com/article.asp?id=1314>

³⁸Civil Engineering News- Spotlight on Building The Future-T-REX project, <http://www.cenews.com/article.asp?id=1314>

³⁹US Department of Transportation, Environmental Review Toolkit, 'Transportation Expansion (T-REX) Multi-Modal Transportation Project' <http://www.environment.fhwa.dot.gov/stmlng/casestudies/co.asp>

The persistence of this partnership team paid off many times throughout the history of this project. In 1997, a small sales tax increase put on the ballot by RTD to finance construction of six new rail lines failed, despite the passage of a similar measure the year before. Lauren Martens, an environmental organizer who helped lead a successful 2004 ballot initiative, suggested two reasons why the 1997 transit plan and its associated sales tax measure failed to pass. First, she said the 1997 transit plan was not clear about the proposed projects' costs and planned routes. Second, a politically prominent, libertarian, free-market RTD board member opposed the 1997 proposal, which Mr. Martens said confused voters. The project partners learned from this setback and concluded that future efforts needed to be based on a detailed set of project plans with costs and line routes clearly stated in combination with a vigorous public outreach campaign. Transit advocates also worked to elect RTD board members who would support light rail and other mass transit improvements, and the following year (1998), they were successful in electing a transit-friendly board. The business community was also an active project partner. In 1999, the Denver Chamber of Commerce led the effort to form a grassroots coalition of civic groups and elected leaders known as the Transit Alliance—an organization that would play a critical role in building the political support for future transit funding initiatives. It did this by recruiting local elected leaders from more than 30 communities to endorse the plan, recruiting thousands of volunteers, convening hundreds of public meetings, and distributing informational materials to metro Denver residents.⁴⁰

These efforts to bridge the gap between highway and transit interests also yielded a revised Major Investment Study that combined highway widening (with up to seven lanes in each direction) with fixed rail transit improvements—a mix that all the project partners could support. This cross-agency collaborative structure and the multimodal, widely supported plans that it produced would yield additional benefits in June 1999 when the state's voters passed Referendum A, allowing CDOT to borrow money based on federal funds for the T-REX project that the state had not yet approved.⁴¹ These partnering efforts only intensified as time went on. CDOT, RTD, FHWA and the Federal Transit Administration (FTA) signed a "Partnering Agreement" to work on the project. The agreement established four primary goals:

- Minimize inconvenience to the community, motorists, and public.

- Meet or beat the total program budget of \$1.67 billion.
- Provide a quality project.
- Meet or beat the project's operational deadline of June 30, 2008.

Collaboration among the partners was further institutionalized by the formation of a Policy committee and a Technical committee, staffed by citizens from the jurisdictions within the project corridor with appropriate policy and technical backgrounds. The Policy Committee monitored project progress relative to the overall public agency decision-making processes. The Technical Committee monitored the project's planning, engineering, and environmental issues and helped develop the project alternatives.⁴²

Design Features

Stations are uniquely designed; their canopies are simple, functional, and attractive. Covered pedestrian bridges connect stations with parking facilities and adjacent developments. The most unique design feature is the integration of an LRT flying junction with the SR4 freeway interchanges between I-25 and I-225.

Stations

There are eleven center island stations along I-25 and two along I-225. The stations will eventually accommodate four-car trains. Parking facilities are provided at all stations. The largest parking structure at the Lincoln (terminal) station contains 1,734 spaces. The RTD also operates feeder bus service to most stations.

Operations

In the service plan for Denver's six initial lines, Routes C and D link Union Station and 16th Street in downtown Denver with Littleton. T-REX Lines E and F connect the city center with Lincoln. Line H connects downtown Denver with Nine-Mile Road. Line G connects Lincoln with Nine-Mile Road. Eighty-foot articulated LRT cars—at a cost of \$2.4 million per car, which can hold 120 people each—run in one to three car trains.

North of the flying junction there are 10 trains and 28 cars per hour. On I-25 south of this junction there are 6 trains and 17 cars. Speeds average up to 30 mph between 16th Street in downtown Denver and the outer terminals. Since this involves several miles of street running, the actual speeds along I-25 and I-225 are considerably higher.

⁴⁰Denver University Colorado Economic Futures Panel 'Paying for Transportation', http://www.du.edu/economicpanel/article/five_033005.html

⁴¹Denver University Colorado Economic Futures Panel 'Paying for Transportation', http://www.du.edu/economicpanel/article/five_033005.html

⁴²US Department of Transportation, Environmental Review Toolkit, 'Transportation Expansion (T-REX) Multi-Modal Transportation Project' <http://www.environment.fhwa.dot.gov/strmlng/casestudies/co.asp>

Patronage

- Light Rail Line:
 - 22,500 average weekday boardings (estimated for study corridor) on the light rail line
 - 2,602 riders peak-hour direction.
- Interstate 25:
 - 208,000 vehicles per weekday (estimated for study corridor) on Interstate 25
 - 270,400 person-trips per weekday (estimated for study corridor) on Interstate 25

Trains carry about 18 percent of the 12,427 peak-hour passengers in this corridor. However, on a per-lane basis, the trains actually carry more people.

Benefits

The multimodal corridor has dramatically reduced congestion and improved mobility in Southeast Denver. It has also given travelers a viable choice of mode. While the freeway lanes are operating at about 75 percent of capacity during peak hours, there is a much greater capacity reserve on the LRT lines. The project has dramatically shortened travel times over the whole length of the corridor. While traffic was stop-and-go all day before the project, the corridor has not reverted to a more typical A.M. and P.M. peaking pattern. The harsh winter weather Denver experiences has turned out to work to the advantage of the light rail line in this corridor, since the train offers better travel time reliability than the highway.⁴³

“What we’ve built so far already has influenced where businesses locate, where housing is built, where people decide to live and how they get to work,” said Joe Blake, the president of the Metro Denver Chamber of Commerce.⁴⁴ The City of Denver has taken bold steps to encourage transit-oriented development around its rail stations. Blueprint Denver provides a new transit mixed use (TMU-30) zoning designation that allows FARs of up to 5-to-1, and parking requirements for areas close to light-rail stations are slashed 25 percent.⁴⁵ TOD zoning policies such as these were first adopted by the City of Denver along the northern part of the T-REX corridor, but now have been adopted by cities up and down the line.⁴⁶ The expansion of Denver’s light rail system has brought substantial benefits to downtown Denver, with office rents along the transit mall leasing at a premium of 8 to 16 percent higher than those off the mall during the early 2000s.⁴⁷ Several

station areas in the T-REX corridor have also benefited from TOD development, including Dry Creek Station, where a pedestrian bridge east of the station is encouraging the development of new high-density residential developments, and the Arapahoe Station Office Project, which was completed in 2008.⁴⁸

The simultaneous construction of the roadway and LRT facilities reportedly saved \$300 to \$500 million in construction costs.⁴⁹

Denver Central/I-25 Corridor

Limits

From: I-25/Broadway Station
To: Union Station

Context and Project Development History

The Central Corridor line runs parallel to I-25 from its junction with I-225, south of downtown Denver. The line runs along a pre-existing freight rail line, and there are generally very few direct street connections to the freeway’s interchanges. The stations will eventually accommodate four-car trains. Parking facilities are provided at all stations. The largest parking structure at the Lincoln (terminal) station contains 1,734 spaces. The RTD also operates feeder bus service to most stations.

Cost

\$116.5 million⁵⁰

Design Features

Stations are uniquely designed; their canopies are simple, functional, and attractive. Covered pedestrian bridges connect stations with parking facilities and adjacent developments.

Stations

There are three park-and-ride lots on the Central Corridor light rail line. The I-25 & Broadway Station park-and-ride provides 1,050 parking spaces and serves as a major intermodal transfer station. Alameda Station’s park-and-ride lot opened in August 1996 and has 287 spaces. The adjacent Broadway/Marketplace provides 221 spaces. The 30th and Downing Station park-and-ride has 27 parking spaces.⁵¹

⁴³Interview with Larry Warner, CDOT, December 15, 2008.

⁴⁴Denver University Colorado Economic Futures Panel ‘Paying for Transportation’, http://www.du.edu/economicpanel/article/five_033005.html

⁴⁵Ibid Cervero et al., p. 69.

⁴⁶Interview with Larry Warner, CDOT, December 15, 2008.

⁴⁷Ibid, p. 163.

⁴⁸Interview with Larry Warner, CDOT, December 15, 2008.

⁴⁹Public Roads, September, October, 2007.

⁵⁰http://www.rtd-denver.com/Projects/Fact_Sheets/CCLRT_Facts.pdf

⁵¹http://www.rtd-denver.com/Projects/Fact_Sheets/CCLRT_Facts.pdf

Operations

North of the I-225/I-25 interchange there are 10 trains and 28 cars per hour. On I-25 south of this junction there are six trains and 17 cars.

Speeds average up to 30 mph between 16th Street in downtown Denver and the outer terminals. Since this involves several miles of street running, the actual speeds along I-25 and I-225 are considerably higher.

Patronage

- Light Rail Line:
 - 17,900 average weekday boardings (estimated for study corridor) on the Central Line.
 - 3,853 peak-hour direction on the Central Line.
- Interstate 25:
 - 208,000 vehicles per weekday (estimated for study corridor) on Interstate 25.
 - 270,400 person-trips per weekday (estimated for study corridor) on Interstate 25.

San Francisco Bay Area

The San Francisco urbanized area, has a population that exceeds 3,000,000. Employment is concentrated in downtown San Francisco (340,000) and Oakland (65,000). The area is served by Bay Area Rapid Transit (BART) that links San Francisco with the East Bay areas. BART routes from Richmond, Pittsburgh/Bay Point Dublin/Pleasanton and Fremont converge in Oakland, and a single line through the transbay tunnel connects them with San Francisco, Daly City and Millbrae (Figure D-3). Sections of each line are within or adjacent to freeway corridors.

The 104-mile, 43-station BART system began operation September 18, 1972, and has been progressively expanded since then. The present weekday system ridership approximates 350,000. There are more than 47,000 parking spaces at BART stations. Many stations are served by AC Transit and other bus systems.

Key design features for the BART system include the following:

Track Gauge	5-feet 6-inches
Maximum Speed	80 mph
Maximum Gradient	4%
Minimum Curve Radius	394 feet
Maximum Train	10 cars
Station Platform Length	700-feet
Car Dimensions	75-feet± by 10-feet 4-inches
Passenger Capacity per car	About 64–72 seats, 150 crush load



Source: Courtesy of the Bay Area Rapid Transit District.

Figure D-3. San Francisco BART's system map.

San Francisco Daly City Line/I-280 Corridor

Limits

From: Daly City Station
 To: Glen Park Station

Context and Project Development History

The trunk line including the subway under Market Street in San Francisco was opened to Daly City in 1972. By 2002, it was extended to the San Francisco International Airport (although this section is not part of our study corridor).

The heart of the BART system—the most important link in binding the Bay Area as a cohesive, urban region—is the underwater transbay tube. The idea was first proposed in the early 1900s by Francis “Borax” Smith—the builder of the region’s first interurban transit network known as the Key System. This early twentieth century transit network connected by ferry transfer to downtown San Francisco prior to the construction of the San Francisco Bay Bridge and once the bridge was complete, the Key System had regular trans-bay trains running across the lower deck of the Bay Bridge. This system is credited with helping to develop San Francisco’s East Bay counties (Alameda and Contra Costa) into an urban and suburban outgrowth of San Francisco. But, by the 1950s the entire system had been dismantled in favor of automobiles and buses and the explosive growth of highway construction. It is no coincidence that much of BART’s current coverage

area was once served by the Key System's streetcar and inter-urban trains.⁵²

After World War II, the San Francisco Bay Area experienced a population boom. While the Bay Area had developed largely along a network of transit lines and interconnected ferries, the construction of the region's bridge system (i.e., the Golden Gate, San Francisco-Oakland, and Richmond-San Rafael bridges) in the pre-war period set the stage for the rapid expansion of the region's urban footprint, facilitated by the automobile. The Bay Area Rapid Transit (BART) system was an idea born from informal gatherings of business and civic leaders from around the Bay Area. In 1946, the region's leaders could already see the day rapidly approaching where growth would outstrip the capacity of the current bridge system. Congestion was already mounting. An Army-Navy review board concluded in 1947 that additional capacity would soon be needed in the San Francisco-Oakland Bay Bridge corridor. They recommended an underwater tube exclusively carrying high-speed trains—the very idea that would be built for the BART system.⁵³

The Army-Navy recommendations were quickly adopted and expanded on by the region's leaders. This process was distinguished by its “grassroots” public participation. Hundreds of meetings were held around the Bay Area to encourage local citizens to participate in the planning of BART system routes and station locations. Meanwhile, on the technical side of the project, engineers were designing a system that would revolutionize rapid transit in the United States, ushering in an era where trains would be designed to compete head-to-head with the automobile, often paralleling freeway rights-of-way. With wide station spacings in suburban areas where BART would compete directly with freeways, the system's electric trains would run on grade-separated right-of-ways, reaching maximum speeds of 75–80 mph, and average 45 mph. The California State Legislature formed the San Francisco Bay Area Rapid Transit District in 1957, which included San Francisco, Alameda, Contra Costa, Marin, and San Mateo counties. Interestingly, because Santa Clara County opted instead to first concentrate on developing its expressway system, they opted out of the BART system. This decision would set the stage for the automobile-led development of the South Bay Area—a pattern that Santa Clara's leaders would try to reverse 20 years later with the development of their own light rail system, largely parallel to and competing with their freeways and expressways.⁵⁴ The final plan was completed

and submitted to the supervisors of the five BART district counties for approval by 1961, which included a line running through the Daly City study corridor, extending south into San Mateo County and terminating in Palo Alto.⁵⁵ However, San Mateo's supervisors (representing the county directly south of San Francisco) chose to withdraw from the district, citing the high costs of a new system and their concerns that BART would compete directly with their existing Southern Pacific commuter trains. Marin County followed soon thereafter. As a result, the Daly City Line would terminate at the San Francisco-San Mateo County border until the 1990s when it was extended south to Colma and eventually (in 2003) to the San Francisco International Airport (in San Mateo County). The BART plans were finally approved by the voters of the three remaining participating counties in November 1962.⁵⁶

The following criticisms of the BART system and its design have been leveled:

1. **BART Originally Seen as a Low-Cost Alternative to Freeways:** The system's original planners and designers underestimated the costs of the system.
2. **Direct Competition with Automobiles and the Freeway System:** The system was designed to provide high-speed, high-comfort, high-style, and direct service to downtown destinations that would provide it a competitive edge compared to the automobile and the freeway system. These design goals led to a series of tradeoffs that have led to BART's underperformance in ridership. Some of the key tradeoffs made were a design with long station spacings, emphasizing line-haul speed over accessibility to and from local stations, right-of-way alignments along major (often freeway) travel corridors, which sacrificed direct access to activity centers, a heavy/fixed-rail design that was extremely expensive, and no capacity to bypass stations preventing express service trains, among others.
3. **An Emphasis on In-Vehicle and In-Station Comfort as Opposed to Ease of Station Access:** Station design and quality of in-vehicle service are high, but studies have shown that the rider experiences ease of station access as far more important than time spent in the stations or vehicles.⁵⁷

⁵²Accessed 08/29/09, http://en.wikipedia.org/wiki/History_of_the_Bay_Area_Rapid_Transit

⁵³Accessed 08/29/09, <http://www.bart.gov/about/history/index.aspx>

⁵⁴Accessed 08/29/09, http://en.wikipedia.org/wiki/History_of_the_Bay_Area_Rapid_Transit

⁵⁵Accessed 08/29/09, http://en.wikipedia.org/wiki/History_of_the_Bay_Area_Rapid_Transit

⁵⁶Accessed 08/29/09, <http://www.bart.gov/about/history/index.aspx>

⁵⁷Webber, M., *The BART Experience—What Have We Learned?*, October 1976, No. 26, Institute of Urban and Regional Development and the Institute of Transportation Studies, University of California, Berkeley.

Operations

The service pattern is more complex than those in other multimodal corridors. The section of line from Daly City to downtown San Francisco and West Oakland has weekday trains to and from Pittsburg, Dublin, Richmond, and Fremont. On weekday nights and weekends the Richmond and Fremont trains do not operate. During rush hours, 20 trains per hour operate each way. During weekdays, 16 trains per hour operate each way. During weeknights, six trains per hour operate each way. Some trains begin or end at Daly City, others at the San Francisco-Oakland International Airport or Millbrae. Travel time to Embarcadero from Daly City is 18 minutes.

Patronage

- 50,900 average weekday boardings on the Daly City Line.
- Interstate 280:
 - 194,000 vehicles per weekday on Interstate 280.
 - 252,200 person-trips per weekday on Interstate 280.

Benefits

The Daly City Line provides direct service from the San Francisco International Airport to downtown San Francisco, downtown Oakland, and many East Bay destinations. According to research on BART's impacts on regional and local urban form, land use changes associated with BART have been largely limited to downtown San Francisco and Oakland and a handful of suburban stations. In this study corridor, few land use changes have occurred.⁵⁸

San Francisco East Bay (BART) Pittsburg/ Bay Point Line/S.R. 24 Corridor

Limits

From: Pleasant Hill Station
To: MacArthur Station

Context and Project Development History

The East Bay BART line runs from north of downtown Oakland to the suburban community of Pittsburg. Service from MacArthur BART to Concord BART stations commenced in May of 1973. In 1996 service was extended to Pittsburg Bay Point. The line runs for roughly 17 miles in the median of State Route 24 and Interstate 980 (see Figure D-3).

This line provides a commuter alternative to I-680 between Pleasant Hill and Walnut Creek and an alternative to State Route 24 (the parallel freeway in this study corridor) to cross the east bay hills to State Route 24 which is capacity-constrained by the Caldecott Tunnel. East Bay traffic destined for San Francisco can travel through Oakland and use the San Francisco Bay BART tube as an alternative to the Bay Bridge.

Operations

Service is provided from Pittsburg/Bay Point to Oakland, downtown San Francisco, and the San Francisco International Airport. Trains run from about 4 A.M. to midnight. Service is at 15-minute intervals 6 A.M. to 7 P.M., and at 20-minute intervals at other times. Additional trains run every 15 minutes between Pleasant Hill and San Francisco for 2 hours in the morning rush-hour period and 2 hours during the evening rush. This translates into a 7.5 minute headway south of Pleasant Hill. Travel times to the Embarcadero in San Francisco are about 38 minutes from Pleasant Hill and 53 minutes from Walnut Creek.

Patronage

- 57,100 average weekday boardings (estimated for study corridor) on the Pittsburg/Bay Point Line.
- State Route 24:
 - 157,000 vehicles per weekday (estimated for study corridor) on State Route 24.
 - 204,100 person-trips per weekday (estimated for study corridor) on State Route 24.

Benefits

This line provides an attractive commuter alternative to I-680 between Pleasant Hill and Walnut Creek and an alternative means to cross the East Bay hills to State Route 24, the parallel freeway route, which is capacity-constrained by the Caldecott Tunnel. East Bay traffic destined for San Francisco can travel through Oakland and use the San Francisco BART Transbay Tube as an alternative to the Bay Bridge.

San Francisco East Bay (BART) Dublin Line/ I-580 Corridor

Limits

From: Dublin Station
To: Bay Fair Station

Context and Project Development History

The 12.5-mile Dublin BART line was opened as a branch of the Pleasanton Fremont Line in 1997 to provide a tran-

⁵⁸Cervero, R. & J. Landis. Transportation Research Part A: Policy and Practice Volume 31, Issue 4, July 1997, Pages 309–333.

sit alternative for commuters traveling between the Bay Area and the Tri-Valley Area as well as communities east of the Altamont Pass. Large-scale planned developments including East Dublin and the Hacienda Business Park were developed in coordination with longstanding plans for the extension of BART.

The Dublin Corridor consists of three stations along the Dublin/Pleasanton Line. Two of the stations are situated in the median of Interstate 580. The rail line was extended east from the existing Fremont/Richmond line and began operation in 1997.

Currently the Dublin/Pleasanton Line provides direct service to downtown San Francisco and the San Francisco International Airport (SFO), and to downtown Oakland via transfer. The terminal station at Dublin/Pleasanton was planned for mixed-use development at the time of construction and has since become the focus for concentrated residential and retail uses. This station accounts for 49 percent of the station entries along the corridor with virtually all of the traffic on the corridor segment originating at or destined for locations beyond the segment.

Design Features

The Dublin Line meets the Richmond-Fremont Line at the Bay Fair transfer station. Two stations—one at Castro Valley, and another at Dublin/Pleasanton—are located within the median of I-80.

Stations

Each of the two stations has a single center island platform. The terminal station at Dublin was planned for mixed-use development at the time of construction and has since become the focus for concentrated residential and retail uses. This station accounts for 49 percent of the station entries along the corridor with virtually all of the traffic on the corridor segment originating at or destined for locations beyond the segment.

Operations

The Dublin/Pleasanton Line provides direct service to San Francisco and Daly City, and to downtown Oakland and the San Francisco International Airport on the Peninsula via transfer. Service operates from about 4 A.M. to midnight. Weekday trains run every 15 minutes from about 5 A.M. to 7 P.M. and about 20 minutes at other times. Travel time from Dublin to the Embarcadero Station in downtown San Francisco is 45 minutes. Running time for the 12.5 miles between the Dublin/Pleasanton and Bay Fair stations (the beginning and end-points of our study corridor) is 15 minutes. This translates into a 50-mph speed.

Patronage

- 19,900 average weekday boardings (estimated for study corridor) on the Dublin/Pleasanton Line.
- Interstate 580:
 - 198,000 vehicles per weekday (estimated for study corridor) on Interstate 580.
 - 257,400 person-trips per weekday (estimated for study corridor) on Interstate 580.

Benefits

The Dublin/Pleasanton Line brings the physically separated East Bay communities into a reasonable commuting time to major East Bay and downtown San Francisco employment centers. It has also fostered development in the Dublin/Pleasanton area.

San Jose Guadalupe/S.R. 87 & 85 Corridor

Limits

From: Santa Teresa Station
To: St. James Station

Context and Project Development History

The Santa Clara Valley Transportation Authority operates a 42-mile, 62-station system. The system, which has two main routes and a two-station spur serves an urbanized area population that exceeds 1.5 million and a central business district employment of about 52,000 (Figure D-4). LRT speeds average 20 miles per hour.

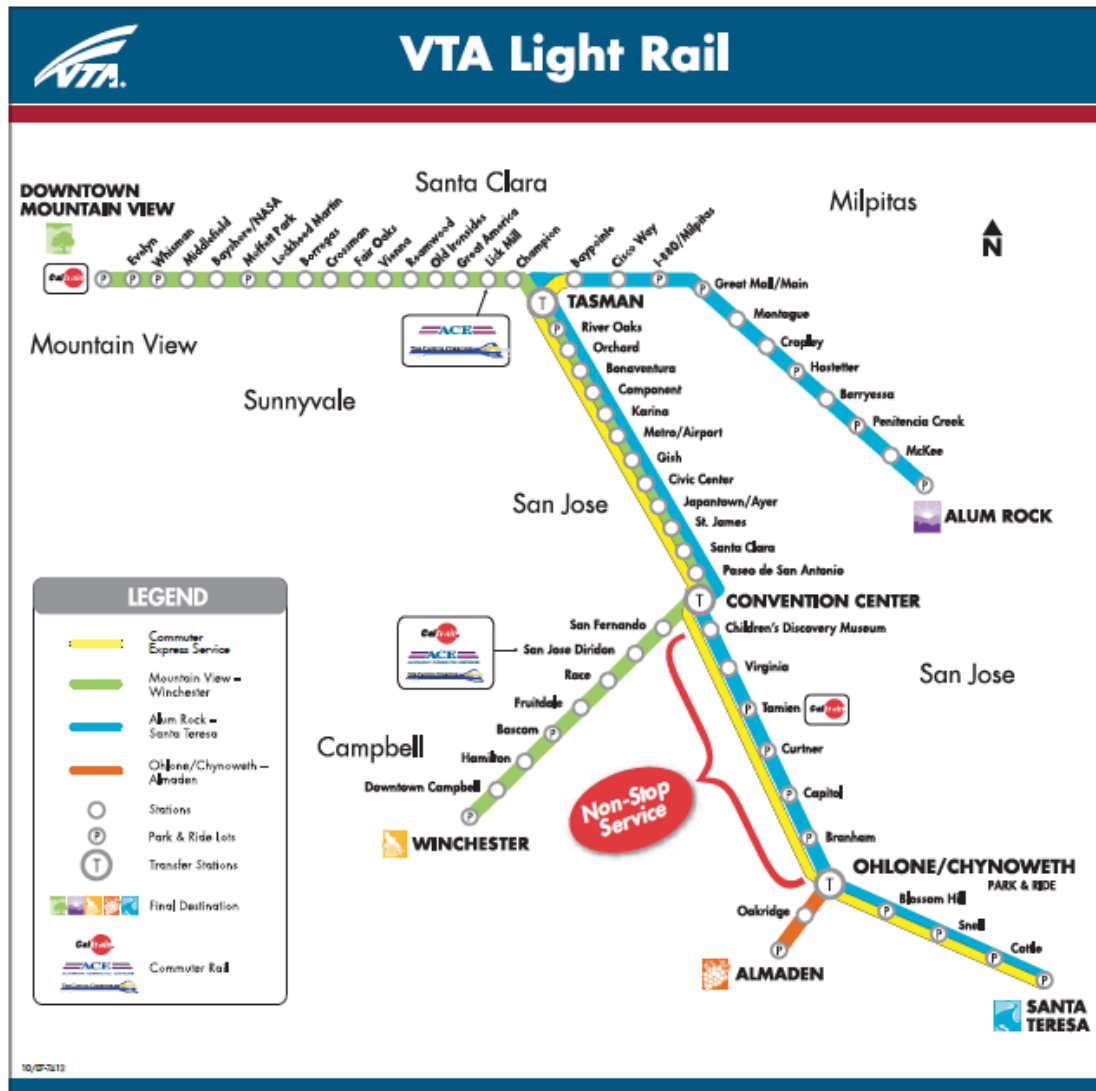
Line 900 is the three-stop Almaden-Ohlone/Chynoweth shuttle. It runs in the Almaden Expressway.

Line 401 runs from the Alum Rock Transportation Center in East San Jose to Santa Teresa. It operates about 10 miles in the median of California Routes 87 and 85. There are 36 stops.

Line 902 runs from the Mountain View multimodal transit center to Winchester. It uses a portion of the Southwest Expressway.

The Guadalupe Corridor consists of a portion of the Santa Clara VTA Light Rail line 901 that runs from Alum Rock Station through the downtown and on to Santa Teresa Station. Service from the downtown to Tasman Station was included from the initial opening of the LRT system in 1987. The corridor includes about 10 miles and 10 stations in the freeway median.

A Guadalupe Parkway (State Route 87) connection between Downtown San Jose and the present day US 101 was first built as an arterial road in the 1960s. In the 1970s, gradual conversion of this surface roadway to a grade-separated



Source: Courtesy Santa Clara Valley Transportation Authority

Figure D-4. San Jose/Santa Clara Valley light rail system map.

freeway facility was undertaken and continued for the next 30 years. The four-level interchange of 87 with I-280 built in the early 1970s was the first step in this conversion and the structure replaced an old downtown neighborhood in the process. The freeway was extended north to Taylor Street (at the northern edge of San Jose's downtown) and completed in the 1980s. The southern part, from I-280 to Highway 85, was opened to Almaden Expressway in 1992 and to Highway 85 in 1993. This segment—the longest section of the route's freeway—was built in tandem with the parallel Guadalupe light rail line. The rest of the highway's freeway section was built over the next 15 years, with its northern terminus at Highway 101 completed in 1992, and the replacement of all grade-level intersections with freeway grade separations and six lanes completed in

the northern section in 2004 and the final ramps at the Skyport interchange opening in 2005. The widening of the southern segment, from Taylor Street to Highway 85, to six lanes was completed in 2007.

The Guadalupe light rail line was first opened in 1987, with the extension to south San Jose (in the study corridor) opening in 1991—99 days ahead of schedule.⁵⁹ The system has been expanded since its opening in 1987.

⁵⁹Bertini, R. L. and Doña, R. D. "Light Rail Transit Design in a Changing Economy: Adversity and Opportunity in Santa Clara County." Compendium of Technical Papers, Institute of Transportation Engineers, District 6 Annual Meeting, Portland, Oregon, 1994, pp. 269–274.

Design Features

The Guadalupe corridor is double-tracked and primarily runs down the center-median of S.R. 87 and S.R.85, where trains reach a top speed of 55 mph. However, as it approaches and enters downtown San Jose, it transitions to a surface street alignment, parallel to the freeway and speeds drop to 10 mph in the downtown transit mall and a maximum of 35 mph along city streets. Trackways are fully grade-separated from vehicular and pedestrian traffic.⁶⁰

Stations

Low-floor articulated cars are used to provide level boarding. This involved reconstructing stations on the Guadalupe (Alum Rock-Santa Teresa) Line and all three stations on the Almaden line during 2008. Island stations are provided in freeway medians. They are served by three sets of doors on each LRV.

Operations

Service operates 7 days each week from roughly 4 A.M. to 1 A.M. Service frequencies are as follows: 15 minutes during peak periods; 30 minutes otherwise.

Patronage

- 6,600 average weekday boardings (estimated for study corridor) on the Guadalupe Corridor Line.
- State Route 87:
 - 140,000 vehicles per weekday (estimated for study corridor) on State Route 87.
 - 182,000 person-trips per weekday (estimated for study corridor) on State Route 87.

In 2007, there were 6,600 boardings along the multimodal section, and 21,000 along the entire Alum Rock-Santa Teresa Line. A 2006 survey of VTA's riders found that 39 percent of the riders made one-way trips also using a bus or train, 81 percent of these riders did not use more than 2 buses or trains, and 62 percent of the riders had no other means of travel. Other key findings were as follows:

- 48% of weekday trips were made during rush hours, 44% midday, 6% evenings, and the remainder late nights.
- 65% of the riders (2006) had no car available, 19% had an automobile available, and 16% had an automobile, but found it inconvenient.

⁶⁰Ibid, Bertini, R. L. and Doña, R. D.

Table D-2. Station access/egress by mode for VTA riders.

Mode	To Station	From Station
Walk	71%	73%
Bus	12%	13%
LRT	6%	4%
Drive	4%	3%
Bike	3%	3%
CalTrain	1%	1%
Other/unknown	3%	3%
Total	100%	100%

Source: Santa Clara Valley Transportation Authority, "2005-2006 On-Board Passenger Survey: Final Report," October 2006.

- 46% of the residents lived in an apartment or condominium.
- The trip purposes were work (36%), school or college (15%), shopping (11%), and other (19%).

Riders of the VTA system accessed the light rail system's stations by the modes shown in Table D-2.

Excluding the downtown stations, boardings are weighted toward Santa Teresa Station, which had 1,296 boardings per day compared to a median of 438 boardings for the other (non downtown) stations on the line. This reflects the considerable A.M. peak park-and-ride traffic at the end points of the line.

Benefits

The multimodal corridor was reported to have about 60,000 jobs within walking distance of stations and 150,000 residents when the line first opened.

Portland MAX Airport/I-84 Red Line Corridor

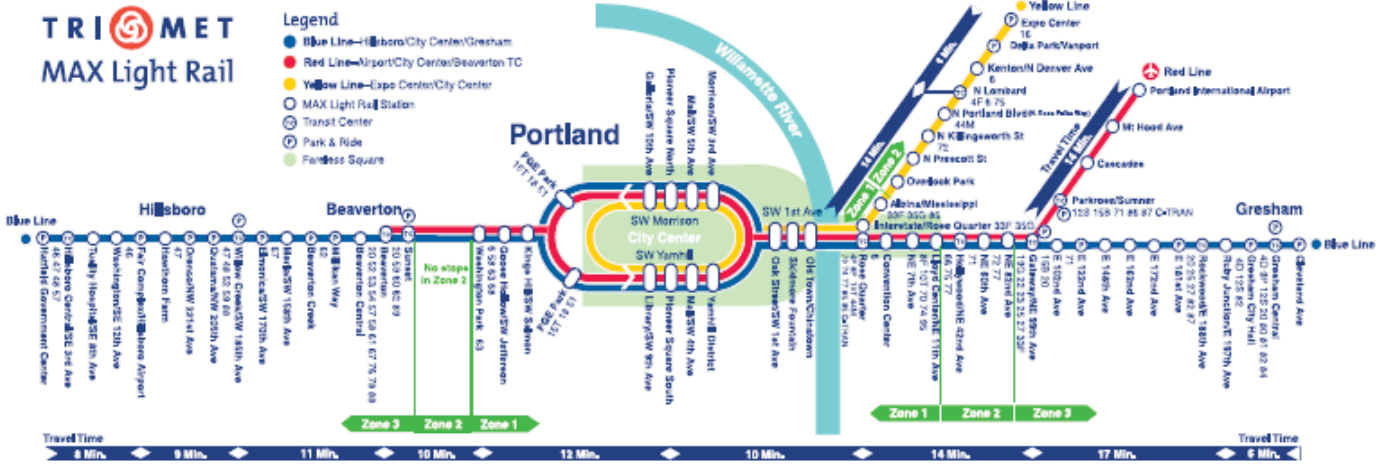
Limits

From: Cascades MAX Station
To: Rose Quarter TC MAX Station

Context and Project Development History

Portland's 43-mile, three-route MAX light rail system serves an urbanized area population of over 1.6 million and a downtown employment of 105,000. Weekday ridership exceeds 80,000. The MAX Red Line runs from the Portland International Airport to downtown Portland and Beaverton. This line overlaps the Blue Line between the Beaverton and the Gateway Stations (see Figure D-5).

The initial segment of the Blue Line opened in 1986 and was developed in conjunction with the widening of I-84.



Source: Courtesy TriMet.

Figure D-5. Portland MAX system map.

A four-mile section of the Blue Line is located on the north side of the freeway (see Figure D-6).

Except for a short segment that cuts through an industrial area along the Columbia River, the corridor sustains a band of mixed and commercial uses as it winds through a predominantly residential grid from the airport to the downtown.

The Portland MAX Red Line runs from the Portland International Airport to Downtown Portland. The extension to



Source: Photo by “Cacophony”

Figure D-6. Portland’s Red Line runs adjacent to Interstate 84 (Banfield Freeway).

the airport, including a 2.5-mile segment along or within the median of I-205, opened in September 2001. On both the Red and Blue Lines, park-and-ride facilities are provided at two stations—the Parkrose/Sumner Transit Center and the Northeast Gateway/99th Street Transit Center. Except for a short segment that cuts through an industrial area along the Columbia River, the corridor sustains a band of mixed and commercial uses as it winds through a predominantly residential grid from the airport to the Downtown.

The Banfield Expressway, later to become Interstate 84, was planned and built in 1955 as the first link in a Portland region freeway network. It was Oregon’s first freeway and it runs east-west, from Portland to Troutdale.⁶¹

The Mt. Hood Freeway was planned as an extension to I-84 running from the Willamette River to SE 122nd Street. This plan called for the freeway to cut through established city neighborhoods and triggered a “freeway revolt” in Portland in the late 1960s and early 1970s, leading to its eventual cancellation. Politicians and light rail advocates fought for and won the right to use the funds for these freeway projects on other projects, including the construction of the MAX Light Rail system.⁶²

The Oregon Department of Transportation’s (ODOT’s) role in developing Portland’s MAX light rail system is emblematic of pressures and conflicts for DOTs to change their roles and approaches to transportation planning, both within these agencies and from outside. For the first time in its history, ODOT appointed a citizens’ advisory

⁶¹http://en.wikipedia.org/wiki/Interstate_84_%28Oregon%29
⁶²http://en.wikipedia.org/wiki/Mount_Hood_Freeway

committee for a regional transportation project—the Banfield corridor study (the corridor that would become the MAX Blue and Red Lines). ODOT appointed several citizen activists to the committee, showing that a progressive approach to multimodal and multi-stakeholder planning was beginning to take hold within the agency. But as the preliminary engineering study evaluating alternatives for the Banfield Corridor was nearly complete in 1976, the light rail option was dropped from consideration, citing ridership forecasts that said the bus alternatives would attract more riders than light rail. Many of the Portland-area’s pro-transit supporters continued to press for consideration of light rail as an alternative to widening and extending the freeway.

As 1976 came to a close, ODOT’s citizens’ advisory committee and others successfully negotiated to reinstate light rail as an official alternative.⁶³

Costs

- Original Blue Line Cost: \$214 million
- Widening I-84 Cost: \$107 million

Design Features

The combined Blue-Red Line between the Northeast Gateway and Beaverton Station is double tracked, except for the one-way operations on Morrison and Yamhill Streets in downtown Portland. There is a single-track loop flyover to the Blue Line and the I-84–I-205 Westbound ramp. There is also a single track on the approach to the Airport Station. Trains run both alongside and within the median of I-205; the median reservation was provided when the freeway was built. Both single-tracked sections are designed to allow 10-minute headways when needed.

Stations

The Gateway-99th Street Station, located in the environs of the I-84 and I-205 interchange, is designed to facilitate transfers between the Red and Blue Lines. The station has three tracks and three platforms. The eastern track (with both a side and a center island platform) serves trains heading to downtown Portland. The center track serves Red Line trains heading to the airport. A side platform serves eastbound trains to Gresham. The Green Line along I-205 to

Clackamas County, scheduled to open in September 2009, will also use this station.

Operations

Tri-Met’s MAX system uses 90-ft articulated low-floor cars. LRVs run in two-car trains because of the short 200-foot blocks in downtown Portland. Service is provided from about 4 A.M. to midnight. Red Line trains run every 15 minutes. Blue Line trains run in 5- to 6-minute intervals in the rush hours, every 15 minutes at other times. During rush hours, about 15 trains run each way along I-84 to the west of the Gateway-99th Street Station.

Red Line travel times from the airport to the Gateway-99th Street Station are 18 minutes. Travel times to Pioneer Square in downtown Portland are 38 minutes.

Patronage

- 7,100 average weekday boardings (estimated for study corridor) on the Red Line.
- Interstate 84:
 - 150,000 vehicles per weekday (estimated for study corridor) on Interstate 84.
 - 195,000 person-trips per weekday (estimated for study corridor) on Interstate 84.

Benefits

The Red Line brings the airport within easy reach of a large part of the Portland Area. Some have indicated that the East Side LRT Lines have spawned \$2 billion in development or redevelopment.⁶⁴

Houston Northwest/U.S. 290 Corridor

Limits

From: Northwest Station
To: Northwest Transit Center

Context and Project Development History

The Houston urbanized area has a population of approximately three million people, of which about 1.8 million live in the city. In 1999, the central business district (CBD) employed approximately 150,000 and about 28 percent of the CBD employees used public transport during peak periods.

The Metropolitan Transit Authority of Harris County (METRO) has a bus fleet of about 1,400 vehicles. Systemwide

⁶³Thompson, G. L., “How Portland’s Power Brokers Accommodated the Anti-Freeway Movement of the Early 1970s: The Decision to Build Light Rail,” *Business and Economic History: On-Line*, Vol. 3, 2005, <http://www.thebhc.org/publications/BEHonline/2005/thompson.pdf>

⁶⁴http://en.wikipedia.org/wiki/Eastside_MAX

average weekday ridership (July, 2001) was about 330,000. The metropolitan area is characterized by the low-density development that is typical of most southwestern cities. The area has flat terrain and there are relatively few barriers to travel. An extensive radial-circumferential freeway system has been developed and progressively improved over the years.

The Houston High-Occupancy Vehicle (HOV) system is shown in Figure D-7. It is the longest barrier-separated HOV system in the United States. The lanes operate on four freeways: the Gulf (I-45) South, Southwest (US-59 South), North (US-59 North) and Northwest (US-290 West). The existing system comprises almost 100 miles. The HOV lanes operate weekdays in the inbound direction between 5 A.M. and 11 A.M., and in the outbound direction between 2 and 8 P.M. During the “peak of the peak period,” carpools have been limited to 3+ occupants on several of the freeways. Houston

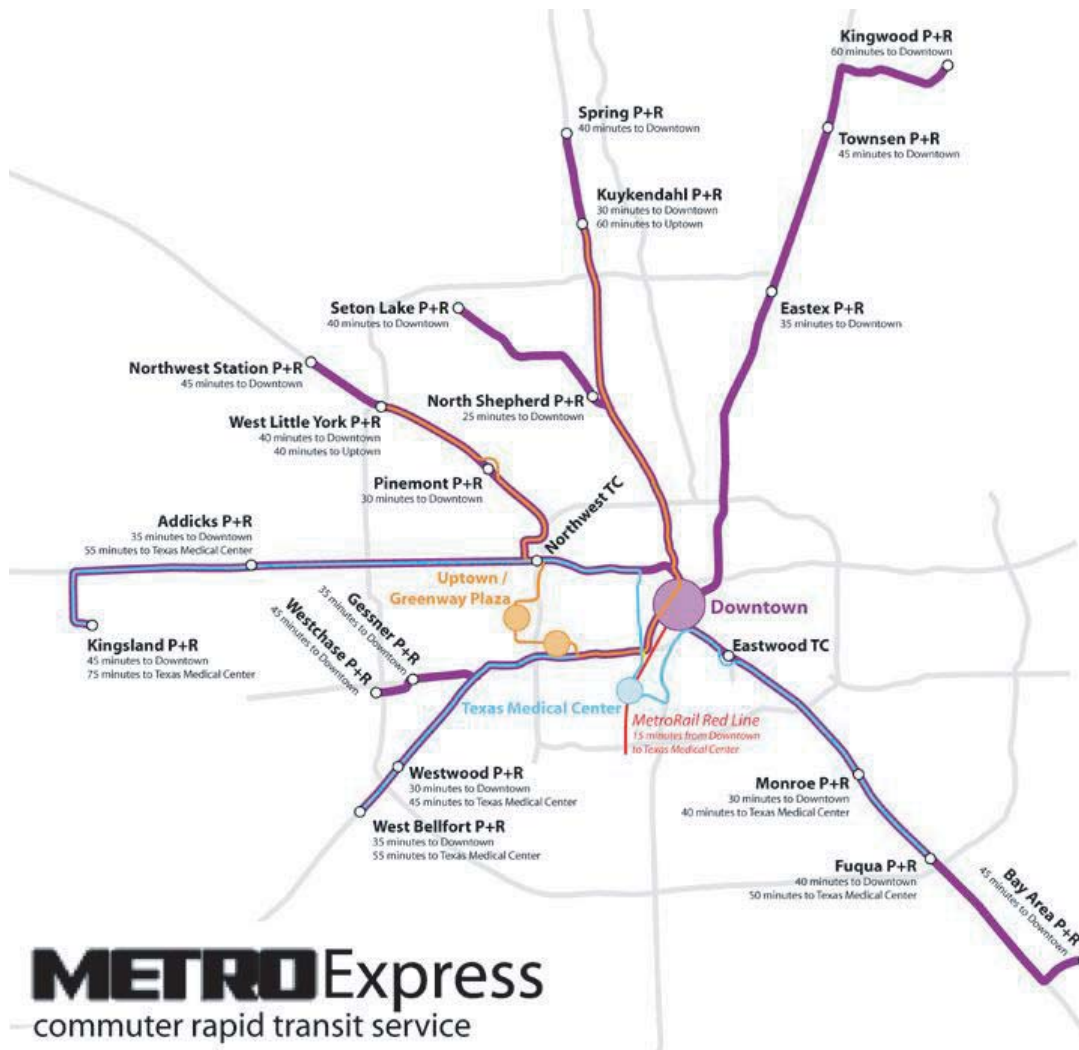
Metro provides express bus service in these lanes during the peak periods.

Collectively, the region’s six HOV facilities serve about 140,000 people each weekday. During the morning peak hour, they carry about 25,000 people, and of these about 10,500 (40 percent) are bus passengers.

The HOV lanes are supported by an extensive system of park-and-ride lots and transit centers. Four transit centers have been established with direct access to five HOV lanes. All transit centers and 10 of the 32 park-and-ride lots have direct, grade-separated connectors to an HOV lane. Collectively, the lots provide more than 30,000 spaces.

Access to and from the ramps is provided by

- Slip ramps connecting with the freeway main lines
- “Wishbone” ramps connecting with freeway frontage roads



Source: Courtesy of Christof Spieler and CTC METRO.

Figure D-7. Houston’s HOV and BRT System map.

- “T-ramps” connecting with park-and-ride lots
- Standard ramps connecting with surface streets
- Special bus/HOV ramps connecting with downtown streets

TranStar, a high-tech traffic and emergency management center (a State, County, City, and Metro joint facility) controls the HOV lanes through a series of variable message signs. TranStar is linked by fiber-optic cable to closed-circuit television cameras (CCTV) monitoring the freeways for traffic flow, as well as being linked to the computerized traffic signals on arterial roadways and freeway feeder streets. METRO’s buses feed traffic information to TranStar, while getting congestion updates in return.

The 290 Corridor consists of a dedicated busway in the median of U.S. 290. It is one of six designated HOV corridors serving downtown Houston. Each of the three stations outside the downtown are served by park-and-ride lots. Four bus routes serve the corridor, with substantial differences in schedule and frequency and minor difference in the path of travel through the downtown. The 290 Corridor extends about 13.5 miles.⁶⁵

In the early 1970s, Houston’s private transit operator was purchased by a newly formed public transit authority. To gain public support and funding for the new agency, a long-range transit plan was developed. The plan proposed an extensive regional rail and HOV system. In 1973, a ballot measure was put forward to the voters to establish the Houston Area Rapid Transit Authority, using the long-range transit plan as its primary selling point. Even though the Houston City Council and an array of community leaders supported the measure, it was defeated at the polls, sending the City back to the drawing board. In 1974, the City purchased the ailing private bus company and established the Office of Public Transportation (OPT) as its new home. While the rail alternatives did not garner enough support, the City and the OPT were confident of the public’s support of the bus system and initiated efforts to upgrade it.

To fill the high-capacity, rapid transit needs identified in the long-range plan, the OPT began working closely with the State’s Highway Department (THD, later to be renamed, TxDOT). The expressed goal of this partnership was to explore and implement congestion-reducing projects, particularly those involving the greater use of buses, vanpools, and carpools. THD wanted to improve travel conditions on the region’s freeways while OPT wanted to rebuild the image of the bus system by finding methods to move buses through congested traffic. This HOV/BRT-focused partnership gave OPT the

opportunity to quickly implement an improved transit system for the area and start to build a reputation as an effective agency. Moreover, OPT was able to establish a positive image with the public by working with THD and quickly implementing a set of popular HOV/BRT proposals while distancing themselves in the public’s mind from their previously expressed desire to develop a regional rail transit system. Meanwhile, OPT (and its successor agency, METRO) continued to push for a rail system, but with limited success.⁶⁶

The partnership focused early on the potential for freeway HOV lanes to achieve these goals—a relatively new idea at the time. They obtained a federal Service and Methods Demonstration (SMD) grant to study this option. The study recommended a contraflow lane demonstration project on the North (I-45 North) Freeway, a corridor with high levels of peak-period, peak-direction congestion. While this proposal planned to take away a freeway lane of travel the contraflow lane was created by taking the inside lane from the off-peak direction of travel. In this way—taking away a lane during the peak period from the excess capacity in the non-peak direction—the demonstration project avoided public criticism.⁶⁷

Once the demonstration project got underway, use of the contraflow lane exceeded projections. Roughly 8,000 people (bus riders and vanpoolers) used the lane every day during the first year—a performance level that nearly exceeded the number of people in the two adjacent mixed-flow freeway lanes. Later, in 1981, a 3.3-mile concurrent flow lane section was added upstream from the entrance to the contraflow lane. With this improvement, patronage on the HOV lane increased to 15,000 a day.⁶⁸

Following these successful pilot tests, the THD and OPT partnership went on to develop a comprehensive network of bus rapid transit HOV lanes around the Houston region, including the U.S. 290 corridor. The development and operation of this network was guided by and dependent on a series of formal and informal agreements between the two agencies. These agreements set out clear and balanced responsibilities for each of the partners. The THD was responsible for construction management, engineering, and inspection of the facilities while OPT administered the funds

⁶⁶In 1973, voters defeated the initial HARTA referendum, which included development of a significant heavy rail system. A subsequent bond referendum, which also included a major rail element, was defeated in 1983. A 1988 plan, which included rail, an expanded HOV system, local bus service, and a general mobility program to fund roadway improvements, was approved. The rail component never moved forward, however., Turnbull, p. 30.

⁶⁷Turnbull, K. F., “Houston Managed Lanes Case Study: The Evolution of the Houston HOV System,” Texas Transportation Institute, Texas A&M University, 2003, p. 7.

⁶⁸Turnbull, K. F., “Houston Managed Lanes Case Study: The Evolution of the Houston HOV System,” Texas Transportation Institute, Texas A&M University, 2003, p. 8.

⁶⁵Turnbull K. F., Levinson H. S., Pratt R. H., TCRP 95 Traveler Response to Transportation System Changes, Chapter 2—HOV Facilities, Transportation Research Board, Washington, D.C., 2006.

for contractor payments and reimbursement of THD. Following on the demonstration project successes, the voters approved a measure to create the Metropolitan Transit Authority of Harris County (METRO) and dedicated a 1% local sales tax to fund it. This success, in stark contrast to the previous ballot measure that failed in 1973, was in part due to the new Regional Transit Plan that identified the projects METRO would pursue using its new funding source. This plan included HOV facilities in most freeway corridors as well as rail transit.⁶⁹

The institutional arrangements that governed the design, construction, and operations of Houston's HOV/bus rapid transit network evolved over time. After the successful demonstration project and the establishment of METRO as OPT's successor agency, subsequent HOV/BRT projects were guided by formal agreements between METRO and TxDOT. These agreements and the subsequent projects were initially established using a two-stage process. Once a project was ready to be scheduled, a construction agreement was developed that spelled out each agency's share of the design and construction costs, the contracting agency, and the responsibilities for construction management, engineering, and inspections. For the first few projects, these construction agreements were detailed and comprehensive, not only spelling out construction phase responsibilities, but also detailing maintenance and operational roles. While this approach may have helped build confidence in the partnership for the member agencies, including operational and maintenance agreements in the construction documents forced the partnership to maintain these bulky construction documents as active files well after construction was complete—an administrative headache. As time progressed and different personnel became involved in developing these construction, maintenance and operations agreements, each new agreement brought changes and improvements.

While these improvements speak well of the partnership's flexibility and willingness to improve, the aging and complicated construction documents resulted in confusion within the partnership as to their roles and responsibilities for HOV/BRT segments built at different times. As a result, periodic reviews were necessary to determine which partner was responsible for operations and maintenance for different segments.⁷⁰ These problems were eventually solved by the development of a Master Operation and Maintenance Agree-

ment for all HOV/BRT segments in 1988. This agreement superseded all previous agreements and established a consistent set of roles and responsibilities for the partners across all HOV/BRT segments in the Houston area. The Master Agreement also changed the roles of the two partner agencies. While previous agreements made METRO responsible for signs, control devices, and electrical power on the HOV/BRT rights-of-way while TxDOT was responsible for maintaining pavement, barriers, and supporting structures, the Master Agreement gave METRO a greater role in day-to-day operations, making them responsible for all aspects of operations, enforcement, eligibility and safety on the HOV/BRT facilities. This greater role for METRO allowed TxDOT to step back from day-to-day operations while maintaining its policy and administrative partnership in running the system. To facilitate this policy-level partnership, the Master Agreement created a formal Management Team, composed of TxDOT and METRO staff responsible for preparing rules, regulations, operating manuals, and operational plans. The Management Team meets monthly.⁷¹

Just as important are the informal arrangements between the project partners. Strong working relationships between individual staff members are based on trust and respect. These relationships have led to the ongoing use of informal working groups with staff from both agencies. These informal ties have helped smooth the coordination of the design, development, and operations of the HOV/BRT system and have led to a more efficient and effective partnership.⁷²

In response to peak-period traffic congestion on the freeway system, and right-of-way restrictions in many corridors, a system of HOV lanes, with peak-period express bus service, has been implemented over the last three decades. In September, 2008, four HOV lanes (two in each direction) opened on the Katy Freeway. The lanes are separated by a barrier median and operate at all times. They are the first high-occupancy toll lanes on Houston's radial freeways.

Design Features

The HOV lane in the Northwest Freeway—like other one-lane, barrier-separated reversible lanes—is about 20.5 feet wide to allow passing of disabled vehicles. The HOV lane (and its continuation via the Katy Freeway) provides direct access to downtown Houston.

⁶⁹Turnbull, K. F., "Houston Managed Lanes Case Study: The Evolution of the Houston HOV System," Texas Transportation Institute, Texas A&M University, 2003, p. 8.

⁷⁰Turnbull, K. F., "Houston Managed Lanes Case Study: The Evolution of the Houston HOV System," Texas Transportation Institute, Texas A&M University, 2003, p. 27.

⁷¹Turnbull, K. F., "Houston Managed Lanes Case Study: The Evolution of the Houston HOV System," Texas Transportation Institute, Texas A&M University, 2003, pp. 27–28.

⁷²Turnbull, K. F., "Houston Managed Lanes Case Study: The Evolution of the Houston HOV System," Texas Transportation Institute, Texas A&M University, 2003, p. 28.

Table D-3. Summary of before and after A.M. peak-direction Houston Northwest Freeway and HOV lane data.

	Bus Passenger Boardings			Total Passenger-Boardings		
	Pre-HOV (1987)	Post-HOV (1996)	% Increase	Pre-HOV (1987)	Post-HOV (1996)	% Increase
Peak-Hour	270	850	251%	6,140	9,538	55%
Peak-Period	605	1,545	155%	17,450	23,962	37%

Source: Turnbull, K.F., et al., TCRP 95 Traveler Response to Transportation System Changes, p. 2-13.

Stations

There are four stations along the Transitway with almost 4,000 parking spaces. The stations are off line and are connected by special T ramps to the Transitway.

Operations

Four express bus routes serve the corridor. Each route runs express from the Houston CBD to an off-line station where it terminates. There are substantial differences in schedule and frequency, and minor differences in paths of travel through downtown.

Service is provided by 45-foot, 57-seat over-the-road coaches. These coaches provide a high degree of comfort. However, single-door operation and on-board fare collection slow passenger boarding in downtown Houston during the evening peak period.

The HOV lane substantially reduced travel times for buses and car/vanpools. While freeway travel averages 24 mph during most morning and evening rush hours, HOV lane traffic operates between 50 and 55 mph, saving those who use the lane anywhere from 12 to 22 minutes per trip.

The travel time savings have been 14 minutes for a 13.5 mile trip—about 1 minute per mile.

Patronage

- 6,400 average weekday boardings (estimated for study corridor) on the busway.
 - A.M. Peak Period: 2,350 passengers
 - P.M. Peak Period: 2,500 passengers
- U.S. 290:
 - 243,000 vehicles per weekday (estimated for study corridor) on U.S. 290.
 - 315,900 person-trips per weekday (estimated for study corridor) on U.S. 290.⁷³

Benefits

Before and after usage comparisons for the Northwest Freeway are shown in Table D-3. Although the total number

of transit riders is very low, there were substantial increases in the number of bus trips, bus riders, and total persons moved in the corridors in percentage terms.

Sacramento North Line/ S.R. 160 & I-80 Corridor

Limits

From: Watt/I-80 Station

To: Globe Avenue Station

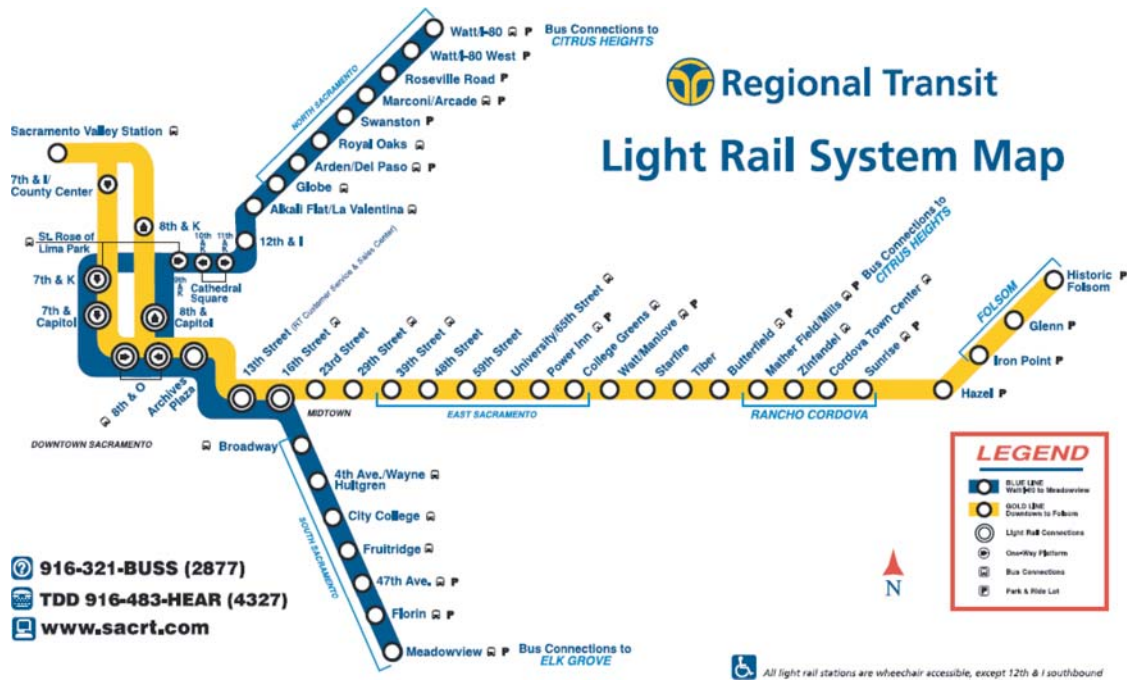
Context and Project Development History

The 42-mile Sacramento Regional Transit District Light Rail system serves the northern, eastern, and southern suburbs (see Figure D-8). The system serves an urbanized area of population of about 1.4 million and a central business district of 65,000. The system uses a broad variety of alignments, including freeway medians, abandoned railroad rights-of-way, and street running in the central area. Weekday daily boardings are approximately 50,000. There are about 7,500 park-and-ride spaces along the three lines.

The Sacramento North light rail line forms a multimodal corridor between the central area and Watt/I-80 station. It is located in the median of the State Route 160 Bridge over the American River for roughly 0.4 miles. It then occupies about 4.5 miles that were made available by the withdrawal and relocation of the Interstate 80 freeway. The next 1.2 miles run in the median of Interstate 80 for three stations as it proceeds northeast of downtown. Service on the light rail line began in 1987. The corridor extends through residential areas east of downtown. Park-and-ride lots are provided at all study corridor stations except Globe and Royal Oak. The balance of the I-80 median between the Watt/I-80 and Watt/I-80 West stations that is not dedicated to the rail tracks and platforms provides park-and-ride parking. About 2,000 parking spaces are available along the multimodal corridor.

Sacramento's North Line (sometimes known as the Gold Line) was the first light rail line to be built in Sacramento and opened in 1987. This segment was an 18.3 mile route between

⁷³Turnbull K. F., Levinson H. S., Pratt R. H., TCRP 95 Traveler Response to Transportation System Changes, Chapter 2—HOV Facilities, Transportation Research Board, Washington, D.C., 2006.



Source: Courtesy Sacramento Regional Transit District

Figure D-8. Sacramento Regional Transit District's Light Rail system map.

Watt/I-80 Station and downtown Sacramento. Built at a cost of \$176 million (in 1987-equivalent dollars), including the cost of vehicles and maintenance and storage facilities, much of the line was originally single-tracked, though in the 1990s, nearly all of its length was converted to double-track. While the line was built mostly within an existing railroad right-of-way, it also used structures of the abandoned I-80 freeway bypass projects—the highway facilities the North Line effectively replaced after a citizen's “freeway revolt” halted these projects.⁷⁴

And just as citizen activism brought these I-80 bypass projects to a halt, the light rail system was built in part as a result of advocates encouraging their elected leaders and government agency staff to consider, plan, and then build the system. One prominent organizer pushed politicians to get behind the idea and get it funded. Following directly on the successes of the “freeway revolt” in Orangevale which successfully stopped the freeway bypass construction plans, pro-transit supporters organized the first meeting of the Sacramento chapter of the Modern Transit Society in 1975, with the proposal to pursue a light rail project as a prominent item on the agenda. During the same period, the City and County of Sacramento formed a joint Northeast Area Transportation Task Force to study the alternatives for using the I-80 bypass corridors, now that the freeway alternatives had been abandoned. At that same time, a federal law—passed in response

to the “freeway revolts” taking place around the country—changed the financing picture for the light rail project by allowing areas affected by proposed freeway projects to veto those projects and propose alternative transportation projects that would use those funds.⁷⁵

Other non-governmental stakeholders provided key impetus to the light rail project, including the local chapter of the American Lung Association, which worked with transit advocates to organize the earliest public meetings of the newly formed, Northeast Area Transportation Task Force.⁷⁶

Planning and public outreach for the light rail option continued through the late 1970s, and culminated in County Measure “C,” a 1979 Regional Transit District-sponsored ballot measure to raise funds for transit operations (¼ cent from the State gas tax). Perhaps due partially to the economic and political times, and perhaps due in part to a lack of consensus in the region on the future of light rail, Measure C failed with only 44 percent of the vote. A second measure was placed on the ballot in November of the same year—a funding mechanism for the projects identified in the Northeast Corridor Study. These transit-oriented projects included the official withdrawal from the I-80

⁷⁵Hultgren, R. “How It Happened: The Development of Sacramento's Light Rail,” 1982, <http://www.friendsoflightrail.org/history/documents/How%20It%20Happened.pdf>

⁷⁶Hultgren, R. “How It Happened: The Development of Sacramento's Light Rail, 1982, <http://www.friendsoflightrail.org/history/documents/How%20It%20Happened.pdf>”

⁷⁴http://en.wikipedia.org/wiki/Blue_Line_%28Sacramento_RT%29

freeway bypass projects, a set of transit improvements, and a series of multimodal transit centers.⁷⁷

A shake-up at the Regional Transit District led to the replacement of the general manager and all but one of the agency's Board of Directors. The new board hired a new general manager, widely perceived as pro-light rail. Encouraged by these changes, MTS conducted a community petition campaign for light rail. This campaign attracted wide-ranging support from forty-six community organizations.⁷⁸

By 1981, the Sacramento City Council voted eight-to-one in favor of light rail for the Folsom Corridor and the Northeast Corridors. After a parallel effort by local congressional representatives as well as Sacramento's mayor and other legislators, the U.S. Department of Transportation and the State of California approved funding for the project. Shortly thereafter, a Joint Powers Agreement between Sacramento City, Sacramento County, Regional Transit, and Caltrans created the Sacramento Transit Development Agency (STDA) as the agency tasked to build the light rail system.⁷⁹

Once completed and operational, the line became very popular, and in response, RT built two new stations at 39th and 48th streets that opened in 1995. In 1998, a 2.3-mile extension to the Mather Field/Mills station was opened and in 2004, a further extension to Sunrise station was opened.⁸⁰

Design Features

Many sections of the line and other lines are single track with passing siding. The line is double-track where it occupies the abandoned freeway right-of-way; it uses several structures that were built for the abandoned freeway. A passing siding is provided at the Globe Station⁸¹. Trains operate on-street through central Sacramento. Most private rights-of-way, including all single-track sections, have three-aspect (red, yellow, and green) automatic block signals.

Stations

Low-platform stations are provided. Double-track sections on private rights-of-way use island platforms. Sta-

tions are 320 feet long and can accommodate four-car 80-ft-long trains. Almost all stations have senior/disabled platforms that are accessed by ramps or lifts. Each station is equipped with at least one fare vending machine. All stations have telephones and most have lighted shelters⁸². Other amenities include comfortable seating, landscaping, bicycle racks, lockers, and information kiosks. There are 700 parking spaces provided at the two northern stations—Watt/I-80 West and Watt I-80. Many stations have bus access.

Operations

Service is provided daily from about 4 A.M. to midnight. The North Line is routed via the South Line to Meadowview, as the "Blue Line." Trains run via a one-way street couplet through downtown Sacramento.

Trains run at 15-minute intervals throughout the day, and at 30-minute intervals during evenings and weekends. Three-to four-car trains run during rush hours. Single-car trains operate during late evenings and mornings on Sunday. The large number of single-track operations (which are gradually being reduced) limits intervals between trains to at least 15 minutes. Each two-direction car can seat 64 people. The 79-foot 6-inch cars can carry 80 standees, and the 84-foot cars can carry 113 standing passengers. The maximum speeds are 55 miles per hour. The travel time between Watt—I-80 and Meadowview is 38 minutes each way. A proof-of-payment fare structure is used.

Patronage

- 6,400 average weekday boardings (estimated for study corridor) on the North Line.
 - There are almost 5,000 daily boardings and alightings at the Watt I-80 terminal station.
- Interstate 80:
 - 146,000 vehicles per weekday (estimated for study corridor) on Interstate 80.
 - 189,900 person-trips per weekday (estimated for study corridor) on Interstate 80.

Benefits

The LRT Line has substantially reduced travel times. It is estimated that the travel times between Watt—I-80 and Meadowview have been reduced from roughly 60 to 38 minutes. Partly as a result of system expansion, LRT ridership has grown substantially.

⁷⁷Hultgren, R. "How It Happened: The Development of Sacramento's Light Rail, 1982, <http://www.friendsoflightrail.org/history/documents/How%20It%20Happened.pdf>"

⁷⁸Hultgren, R. "How It Happened: The Development of Sacramento's Light Rail, 1982, <http://www.friendsoflightrail.org/history/documents/How%20It%20Happened.pdf>"

⁷⁹Hultgren, R. "How It Happened: The Development of Sacramento's Light Rail, 1982, <http://www.friendsoflightrail.org/history/documents/How%20It%20Happened.pdf>"

⁸⁰http://en.wikipedia.org/wiki/Blue_Line_%28Sacramento_RT%29

⁸¹Matoff, T. G., "Regional Rail in a Low-Density Center", Transportation research Record No. 1433, Public Transit, Transportation Research Board, Washington, D.C., 1994.

⁸²<http://www.sacrt.com/lightrail.stm>

**Atlanta North-South Line/
Route 400 Corridor**

Limits

From: Medical Center Station
To: Civic Center Station

Context and Project Development History

The Atlanta urbanized area has a population of about four million and continues to grow rapidly. Its central business district has over 16 million square feet of commercial office space. I-70 and I-75 converge into a common north-south freeway on each side of the central area, where it interchanges with I-20. The Metropolitan Atlanta Rapid Transit Authority (MARTA) operates north-south and east-west rapid transit

lines that cross at Five Points in the heart of downtown Atlanta. The 48-mile, 38-station system shown in Figure D-9 serves more than a quarter-million passengers each weekday. A 3-mile section of the North Line centered on the Buckhead station is located in the median of six-lane Georgia 400—a toll freeway that opened in 1993.

Atlanta’s North Line is the longest branch of the MARTA rail system extending 15.1 miles from Five Points to North Springs. The overall Atlanta Route 400/North-South Line study corridor includes sections of State Route 400 and Interstate 84 that run parallel to MARTA’s North-South Line. The study segment begins at the north side of downtown Atlanta at the Civic Center Station where Peachtree Street crosses I-85. It ends at the Medical Center Station, just south of the Route 400/Route 19 interchange—a total distance of roughly 11.4 miles. Route 400 north of the study corridor



Source: Public Domain, Courtesy Metropolitan Atlanta Rapid Transit Authority

Figure D-9. Atlanta’s rail system map.

(north of I-285) was completed in 1979 and the connection south of I-285 connecting to I-85 was completed in 1993. The North-South Line—including the stations along the study corridor segment—opened during the period from 1982 to 1984. The section north of Buckhead is the newest part of the system. The Buckhead, Medical Center, and Dunwoody stations opened in June 1996, the Sandy Springs and North Springs stations opened in December 2000. The corridor includes Lindbergh station—the second busiest station in the MARTA system—a transit-oriented development on a 47-acre site combining office towers, retail, restaurants, and parking structures constructed on MARTA-owned land.

For the length of the study corridor, the rail line runs in the median of or directly adjacent to the corridor freeway for roughly half the corridor distance and is off set (within 0.5 mile) from the freeway for the other half.

Following right on the heels of San Francisco's BART initiative, Atlanta's rapid transit proposals first surfaced in the early 1950s with the publication of a series of regional planning reports. Initiated by Atlanta's Metropolitan Planning Commission (MPC), these reports primarily focused on freeway planning to accommodate the rapid post-war expansion of the Atlanta metro area. But these early reports also openly questioned whether increased highway construction could ever meet future transportation demands in the region. With this, MPC began to study the potential for a regional rapid transit system, while the Georgia Highway Department continued to assert that highways would be an adequate solution.⁸³

Momentum continued to build through the 1960s, as three additional planning reports—including MPC's regional comprehensive plan—pushed for a 60-mile rapid transit system serving five counties at a cost of roughly \$215 million. Like the vision for BART and the San Francisco Bay Area, two of these three reports saw rapid transit as a tool for shaping the future urban form of the Atlanta region and promoting the region as the premier urban region in the southeastern United States. The third report was more modest in its ambitions and called for a \$59 million first phase of a regional system with a 16-mile starter-line. This report would find support from Atlanta's business community and in 1961 the Atlanta Chamber of Commerce established a rapid transit steering committee, including the president of the Atlanta Transit System. This group worked with the MPC to publicize and advocate for this proposal with the public. Civic organizations and business groups met to discuss the initiative. Meanwhile, Atlanta mayor William Hartsfield appointed a rapid transit committee to work with the MPC to lobby members of the Georgia General Assembly on behalf of the project. This two-pronged approach—the Chamber of

Commerce working with public outreach, and the Rapid Transit Committee/MPC team building support among politicians—paid off in 1962 when the Georgia legislature created the Metropolitan Atlanta Transit Study Commission (MATSC).⁸⁴

But this was one step short of a full-fledged, regional rapid transit agency, something that would be needed if planning, financing, engineering and construction were to ever get started—something that would require a state constitutional amendment. In 1962, this amendment went before the state's voters, and while DeKalb and Fulton counties (in the Atlanta metro area) approved it, the rest of the state's counties voted against it. In retrospect, it appears that the amendment was written too broadly. For example, the amendment did not specify the composition of the agency or whom it would be answerable to, but rather, stated the general nature of its powers (taxing, eminent domain, and expenditure of public funds). As a result, it appears that the state's voters feared they were being asked to pay for Atlanta's rail system. Opposition also appeared from the pro-highway lobby within the state, particularly the trucking industry that sought to maintain funding for the currently planned highway system.⁸⁵

During this time, MATSC had not been idle. At the end of 1962, they published a regional rapid transit plan that called for a 66-mile system with 42 stations, with an emphasis on feeder buses and park-and-ride facilities for five counties in the Atlanta metro area. They quickly kicked off a publicity campaign for the plan, forming a committee with the mandate to build support for financing the proposed rapid rail system. Meanwhile, campaigning at the state level continued as well, and in 1964 a measure to form a regional transit agency was put before the voters—this time, only in the five metropolitan Atlanta counties where the system would operate. This measure passed and in 1965 the Metropolitan Atlanta Rapid Transit Authority (MARTA) Act was approved by the state legislature. MARTA was officially formed in January 1966.⁸⁶

MARTA published their own plan for the regional rapid rail system in 1967, and while it was slightly smaller than the planned MATSC system (54- instead of 66-miles) it was also estimated to cost \$190 million more. This gave an opening to anti-MARTA forces, and Robert Somerville—the head of the Atlanta Transit System and a former member of the Chamber of Commerce's rapid transit steering committee—put forth a counterproposal. Instead of the proposed rapid rail system, he planned a 32-mile regional rapid bus system estimated to cost

⁸³http://en.wikipedia.org/wiki/Metropolitan_Atlanta_Rapid_Transit_Authority_history

⁸⁴http://en.wikipedia.org/wiki/Metropolitan_Atlanta_Rapid_Transit_Authority_history

⁸⁵http://en.wikipedia.org/wiki/Metropolitan_Atlanta_Rapid_Transit_Authority_history

⁸⁶http://en.wikipedia.org/wiki/Metropolitan_Atlanta_Rapid_Transit_Authority_history

\$52 million. This plan gained political popularity and momentum and soon became a viable alternative in the public eye.⁸⁷

MARTA moved quickly to reduce the size and costs of their proposed rail system to meet this challenge. In 1968 they proposed a 40-mile system, but the plan was published only a few months before a referendum to fund MARTA's capital programs went before the voters. There are several reasons why it failed, but some of the more prominent explanations include

- The continuing controversy over the choice of rail or bus rapid transit;
- The lack of guaranteed federal funding for the system gave conservatives a reason to claim the plan was financially irresponsible;
- The proposed use of property taxes to fund MARTA alienated low income and suburban voters;
- A perception by suburban voters that the system would be a greater benefit to the city of Atlanta;
- Complaints that local officials and Atlanta's black community had not been included in the planning and would not receive adequate service; and
- MARTA's publicity for the plan had been too rushed and poorly executed.⁸⁸

After the referendum went down, MARTA regrouped and worked to address these issues directly and build greater political support for the proposed system. They worked to enlist support from organized labor, sought out local and African-American representatives to participate in planning the system, modified service plans to provide better service to African American communities, and changed the property tax funding proposal to a 1% sales tax.⁸⁹

A second funding referendum went before the voters in 1971, this time including rapid busways in key corridors to attract those who supported the rapid bus plan. While voters in DeKalb and Fulton counties approved the referendum, Clayton and Gwinnett counties voted it down by substantial margins (only 23% and 21% voted in favor, respectively). It was thought that voters in these counties were reacting negatively to the plan since it only included nine miles of rail line in both counties, total.⁹⁰

In 1971 MARTA purchased the Atlanta Transit System for \$12.8 million, and in 1975, the Urban Mass Transportation

⁸⁷http://en.wikipedia.org/wiki/Metropolitan_Atlanta_Rapid_Transit_Authority_history

⁸⁸http://en.wikipedia.org/wiki/Metropolitan_Atlanta_Rapid_Transit_Authority_history

⁸⁹http://en.wikipedia.org/wiki/Metropolitan_Atlanta_Rapid_Transit_Authority_history

⁹⁰http://en.wikipedia.org/wiki/Metropolitan_Atlanta_Rapid_Transit_Authority_history

Administration allocated \$600 million to MARTA for the system's construction. Groundbreaking took place that same year.⁹¹ In 1981, the North-South Line opened from Garnett to North Avenue, followed by the opening of the expansion to the Arts Center in 1982 and the section between Lindbergh Center and Brookhaven opened in 1984. Finally, the section between Buckhead and Dunwoody stations (including a stretch in the Georgia 400 freeway median) opened in 1996.⁹²

Design Features

Horizontal and vertical alignments are designed for 70 mph maximum train speeds.

Stations

Center island stations are attractively designed. The enclosed portion of the Lindbergh Center station has colored glass panels in the ceiling, which cause interesting lighting effects in the morning. Vertical access is ADA compliant, and direct access is provided to nearby developments and parking facilities. A large parking garage at the North Springs terminal station has its own access ramps to and from the Route 400 Expressway.

Benefits

The North corridor has experienced considerable land development as a result of market forces and the improved road and rail access. Major commercial developments include those found in the vicinity of the Lindbergh and Buckhead Stations.

Washington D.C. Orange Line/I-66 Corridor

Limits

From: Vienna/GMU Station

To: Foggy Bottom Station

Context and Project Development History

The Washington D.C. Urbanized Area has a population that exceeds four million and a central area employment of more than 300,000. The region is served by a five-route Metro rail system that carries 600,000 people each day. It is also served by the Shirley (I-395) HOV reversible median roadway that serves large numbers of express bus passengers. The Metro Orange Line linking downtown DC to Northern Virginia

⁹¹http://en.wikipedia.org/wiki/Metropolitan_Atlanta_Rapid_Transit_Authority_history

⁹²http://en.wikipedia.org/wiki/Metropolitan_Atlanta_Rapid_Transit_Authority_history

was completed and opened in June, 1986. It runs along the median of I-66 for the portion serving Fairfax county and half of its stretch through Arlington County. In Arlington, I-66 carries commuter traffic and also provides the connection to Virginia 267, the Dulles Airport Access Road.

Along the line, Vienna/Fairfax-GMU serves as the access point for 9,900 morning entries while Foggy Bottom has 10,000 A.M. exits. Rosslyn station immediately west of the Potomac has balanced A.M. entries and exits with 4,800 entering and 6,800 exiting in the morning.

The rapid post-war suburbanization of metropolitan Washington D.C. created a host of interstate transit service challenges. Like many regions, its automobile-dependent suburbs were increasingly hard to serve with transit. However, in and around DC, the difficulties of regional transit service were compounded by the many private transit companies serving DC, Virginia, and Maryland that were regulated by separate public utilities commissions while inter-jurisdictional trips were regulated by the federal Interstate Commerce Commission. This patchwork of regulatory control meant that suburban commuters often faced an uncoordinated set of schedules, fares, and routes.⁹³ So while other regions considering regional rapid rail systems—San Francisco and Atlanta—faced similar problems of serving dispersed suburbs and uncoordinated transit service providers, the DC region developed an ambitious plan to create a unified transit agency that would cross state lines.

During the 1950s, when Eisenhower's Federal-Aid Highway Act (1956) set the stage for the automobile to play the leading role in shaping urban form across the nation, these policies were echoed by Congress's National Planning Commission's Mass Transportation Plan for DC, calling for a network of 329 miles of highways to carry the bulk of the region's traffic. And while this network included a rapid rail network as well, the 33-miles planned for this system was small in comparison to the emphasis placed on highways—priorities that encouraged DC's own freeway revolt. John F. Kennedy's election in 1960 gave further impetus to the pro-transit supporters, when he replaced the national experts who had been in charge of planning DC's freeway expansions with local transit advocates who had opposed the highway-oriented plan. When he assumed office, Kennedy established a new planning agency—the National Capital Transportation Agency (NCTA)—for the region. The NCTA worked through much of the 1960s to expand the size and role of the planned rapid rail system in regional transportation. In 1967, partially as a result of President Lyndon B. Johnson's emphasis on locally driven planning, local officials convinced Congress to turn over DC

metro planning to a locally run agency—the Washington Metropolitan Area Transit Authority (WMATA), which would develop plans for a 98-mile regional system, estimated to cost \$1.828 billion. When adjusted for inflation, the system would eventually cost \$3.8 billion, drawing recent criticisms as an example of a “mega-project” that subjected tax-payers to cost-overruns and underperformance. Counter-arguments point out that WMATA's metro system is incredibly successful at attracting ridership and has been effective as a replacement to the freeway “mega-project” originally planned by Congress.⁹⁴

The I-66/Orange Line corridor provides a microcosm of the larger highway versus transit debate in the Washington D.C. region and the rest of the country during the 1950s, 60s, and 70s. Prior to World War II, Arlington County, through which the corridor runs just west of the District, served primarily as a bedroom community. But the National Capital Planning Commission (NCPC) published a plan that set the stage for a comprehensive transformation of the corridor in 1961—a plan that called for dense developments along major transportation corridors, reserving wedges between those corridors for less dense development. The Orange Line Corridor was one such area designated for dense employment and residential growth.⁹⁵ A 1962 NCTA report provided the vision for these changes where rapid rail in the corridor would be the transportation glue that would bind the corridor together and attract NCPC's planned growth.

NCTA's report also set the design specifics for the rapid rail system as a whole that would eventually come to fruition in this and several other of the region's corridors—minimizing costs by routing suburban extensions as surface lines along freeway rights-of-way.⁹⁶ And it appears that if the plan was carried out to the letter, then the Orange Line would have been routed along I-66 in its entirety, but the government of Arlington County had plans for dense residential and commercial development roughly a mile to the south of I-66. By 1966, the County and NCTA had agreed to route the first few miles of the Orange line along Wilson Boulevard (where the high-density commercial and apartment developments were planned) instead of the low-density residential areas along I-66. Once the line was west of this planned high-density area, the Orange Line would rejoin I-66 to reduce costs of alignment as it ran into Fairfax County.⁹⁷ However, in the District, stakeholders were often split in terms of geography, with suburban Virginia and Maryland residents favoring the freeway-

⁹³Schrag, Z. M. “The Great Society Subway: A History of the Washington Metro,” Baltimore, MD: The Johns Hopkins University Press, 2006, p. 96.

⁹⁴Schrag, Z. M. “Thinking Big: Lessons from the Washington Metro,” Transportation Research News, March-April 2007, National Academies, pp. 18–20.

⁹⁵Schrag, Z. M. “The Great Society Subway: A History of the Washington Metro,” Baltimore, MD: The Johns Hopkins University Press, 2006, p. 222.

⁹⁶Schrag, Z. M. “The Great Society Subway: A History of the Washington Metro,” Baltimore, MD: The Johns Hopkins University Press, 2006, p. 223.

⁹⁷Schrag, Z. M. “The Great Society Subway: A History of the Washington Metro,” Baltimore, MD: The Johns Hopkins University Press, 2006, p. 224.

heavy plan, and District residents favoring the plan for rapid rail that would replace many of the freeway system's links.

As the 1960s progressed, it became clear that a compromise was needed since the District was not going to allow freeways within its borders and the suburban freeways would be cut off from the region's core employment center. In 1968, WMATA publicly stated that the philosophy that transit could substitute for highways was unworkable. The agency's general manager stated for the record that WMATA, "has consistently maintained that rapid rail transit is a supplement to and not a substitute for alternative modes of transportation," promising that the vast majority of the system's passengers would access its stations via bus or car.⁹⁸ This appears to have helped to circumvent the suburban/urban political impasse. In 1968, WMATA put forth a bond initiative on the ballot to fund the construction of the rail system. Voters in both states approved the funding by a 72 percent landslide. Federal funding for WMATA's construction was secured in 1969 from Congress. The corridor would be developed as a multimodal facility, with Metrorail running in the median of a reduced, four-lane I-66 freeway.⁹⁹

Service on the Orange Line began on November 20, 1978 (temporarily), between National Airport and New Carrollton. When the line from Rosslyn to Ballston-MU was completed a year later, trains began following its current route rather than going south to National Airport. The line was completed on June 7, 1986, when it was extended by four stations to Vienna/Fairfax-GMU.¹⁰⁰

Design Features

The Orange Line is designed for 70 mph top speeds. With an average spacing of 3 miles between stations, trains speeds are high. The space occupied by the tracks, stations, and buffers is about 65-foot wide.

Interstate 66 is designated as an HOV-2-only facility between the Washington, DC, Beltway and the Theodore Roosevelt Bridge during peak periods. The entire eastbound (inbound) roadway is HOV-2 during the AM peak period, and the entire westbound (outbound) roadway is reserved for HOV-2 during the PM peak.

Stations

Center island stations are located within a right-of-way of about 65 feet. The stations can accommodate eight-car 75-foot trains. Metro Bus and Fairfax County buses serve the stations, and special areas are provided for passenger boarding and

alighting. The 9,600 parking spaces located at stations in the multimodal corridor account for an average of 4.5 passenger boardings per space.

Operations

Orange Line trains run at frequent intervals from early morning to late evening. There is no overnight service. The trains join the Blue Line between the Rosslyn and Stadium-Armory stations and then proceed to New Carrollton. About 300 cars operate across the Potomac River from Virginia during the 6:30–9:30 morning peak period. Occupancy averages 90 percent. Travel times from Vienna to Ballston (the station East of East Falls Church) are 15 minutes. The average speed is 36 mph.

Patronage

- 139,400 average weekday boardings (estimated for study corridor) on the Orange Line.
- Interstate 66:
 - 98,000 vehicles per weekday (estimated for study corridor) on Interstate 66.
 - 127,400 person-trips per weekday (estimated for study corridor) on Interstate 66.

The Vienna/Fairfax terminal station serves as the access point for 9,900 morning entries. Rosslyn Station on the combined Orange and Blue Lines, immediately west of the Potomac River has balanced entries and exits; 4,800 enter, and 6,800 exit in the morning. Foggy Bottom has 10,000 A.M. exits.

Benefits

The multimodal corridor carries roughly 8,800 people in the AM and PM peak hour directions across the Capital Beltway. Metro Rail carries slightly more people than the freeway lanes. The use of the rail line is more than three times as productive as the freeway on a per lane basis. The Arlington County zoning ordinance encourages commercial and high-density residential development around stations between Rosslyn and Ballston. In recent years, development has begun to occur around stations in the multimodal corridor.

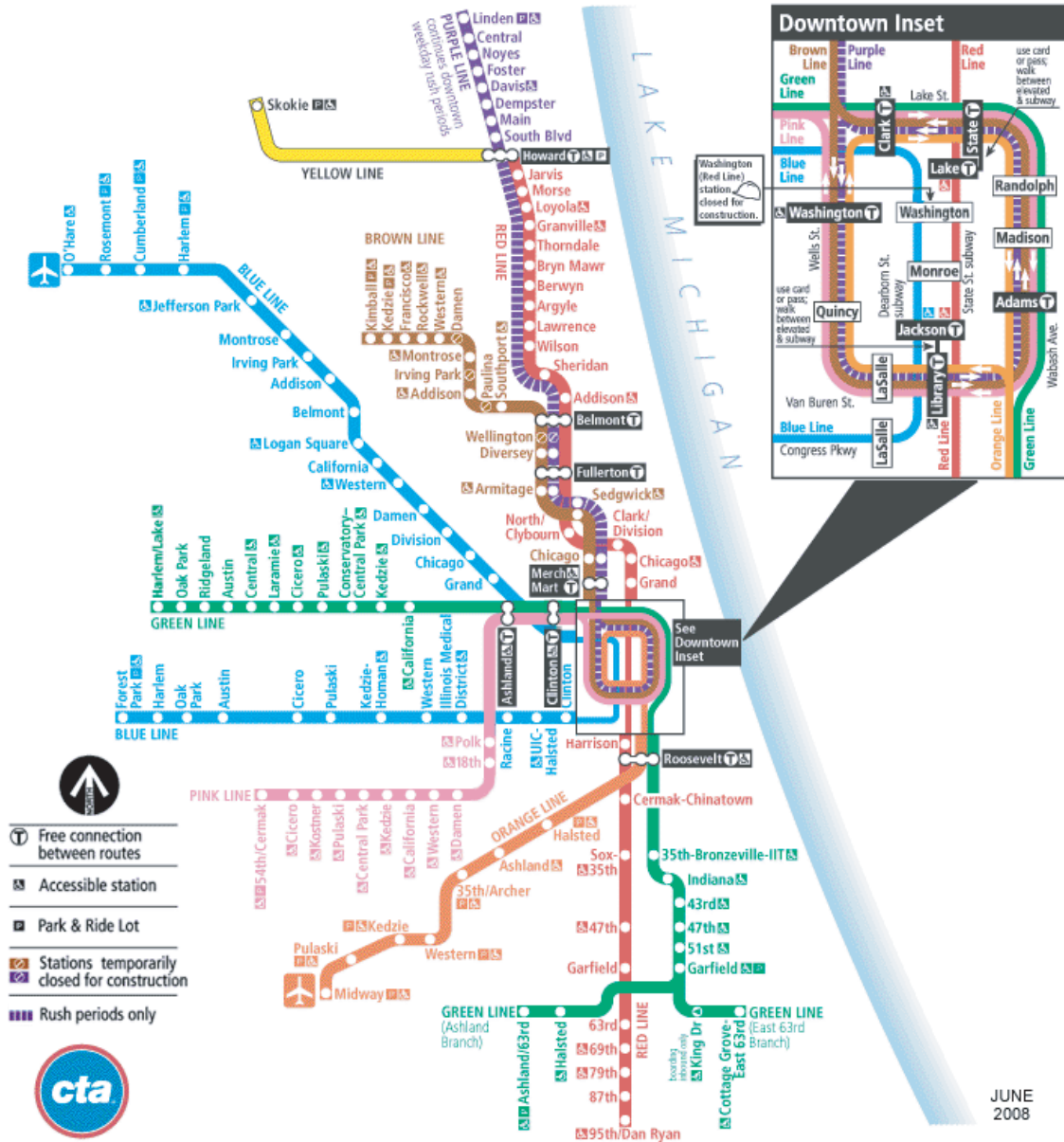
Chicago Region

The Chicago Urbanized Area—one of the nation's largest—has more than 8.5 million residents. The City's central business district (the Loop) has over 120 million square feet of commercial floor space, and its employment exceeds 350,000. It is served by an extensive commuter rail system, and a 90-mile 138-station rail rapid transit (heavy rail) system (Figure D-10).

⁹⁸Schrag, Z. M. "The Great Society Subway: A History of the Washington Metro," Baltimore, MD: The Johns Hopkins University Press, 2006.

⁹⁹http://en.wikipedia.org/wiki/Interstate_66

¹⁰⁰http://en.wikipedia.org/wiki/Orange_Line_%28Washington_Metro%29



Source: Courtesy Chicago Transit Authority

Figure D-10. Chicago's rail transit system map.

The City of Chicago and the Chicago Transit Authority pioneered the development of multimodal freeway-rapid transit corridors. There are rail lines in the Eisenhower, Ryan, and Kennedy Expressways.

Chicago Blue Line/Eisenhower Expressway Corridor

Limits

- From: Forest Park Station
- To: LaSalle Station

Context and Project Development History

The I-290 Eisenhower Expressway multimodal corridor extends from the Chicago Center business district to Forest

Park. The Blue Line opened on June 22, 1958, replacing the former Garfield Park elevated that had operated since 1905. The rapid transit line connects with the Congress-Dearborn-Milwaukee subway through the Loop, and with the rapid transit line to Logan Square, Jefferson Park, and O'Hare International Airport. The first 6 miles are located in the median of the eight-lane freeway, and the next 3 miles are located along the south side of the (6-lane) freeway. There are 11 stations in this multimodal corridor.

Construction of the Blue (Congress) route and its connection to the subway was financed by the City of Chicago. About \$2 million was derived from the sale of revenue bonds being serviced by subway rental paid by the Chicago Transit Authority. An additional \$25 million came from a general obligation



Source: Courtesy of Jeremiah Cox/SubwayNut.com

Figure D-11. Chicago's Eisenhower Expressway and the Blue Line at Racine Station.

issue¹⁰¹. The city made \$12 million available for equipment, to be repaid by the CTA. The city's opening brochure indicates that "the use of the median strip has made possible construction cost distribution of one-fifth for the transit to four-fifths for expressway facilities."¹⁰²

Design Features

The expressway and transit line are located below grade for about the first 6 miles. They are flanked by continuous frontage roads that provide local access. North-south streets cross over the freeway at about quarter-mile intervals (see Figure D-11).

The median is wide enough to allow future expansion to four tracks for the first 4.5 miles, and to three tracks for the rest of the route. The initial design provided a ramp from the median to connect with the Douglas Park (now Pink) line that was used for many years. There is also a third track for switching trains in the eastern section of the rail line.

Stations

Center Island station platforms are 600 feet long and canopied. Access to each station is from the middle of cross-street bridges by a gently sloping ramp. The major stations are located between two cross street bridges one quarter mile apart, with an access ramp from each street bridge. An entrance building (about 42 by 21 feet) at each cross-street bridge contains fare collection equipment. Access to stations is provided

¹⁰¹Chicago Transit—History and Progress, Chicago Transit Authority, Public Information Department, Chicago, Illinois, Undated.

¹⁰²Krambles, G. and Peterson, A., CTA at 45, George Krambles Scholarship Fund, Chicago, Illinois 1993.

by intersecting CTA and suburban bus routes. There are more than 1,000 parking spaces at the Forest Park terminal.

Operations

The initial operating plan had alternate trains serving the Douglas (Pink) and Congress (Blue) branches. As ridership patterns changed, the Pink Line trains were rerouted to the nearby Lake Street elevated structure, and a single Blue Line service runs to the Forest Park Terminal. Because the O'Hare Line has heavy ridership, alternate trains are terminated in the CBD during rush hours. Trains run in the subway in the central area and continue to O'Hare International Airport.

The CTA provides 24-hour service. Trains run every 7 to 8 minutes from about 6 A.M. to midnight, with longer headways during overnight hours. Trains have eight cars between 6 A.M. and 6 P.M. and four cars at other times. Cars are 48 feet long; they are 8 feet and 9 inches wide at platform level, and 9 feet and 4 inches wide at waist level.

Patronage

A 1960 study of the passenger use of the Blue Line showed that trains accounted for 28 percent of the peak-hour peak-direction passenger flow west of the Douglas junction and 57 percent east of the junction. Corresponding figures were 18 and 36 percent for a 24-hour period¹⁰³.

- 20,000 average weekday boardings (estimated for study corridor) on the Blue Line.
- Interstate 290:
 - 196,100 vehicles per weekday (estimated for study corridor) on Interstate 290.
 - 254,900 person-trips per weekday (estimated for study corridor) on Interstate 290.

Weekday station boardings in 2008 for the Blue Line are shown in Table D-4

Benefits

While it is difficult to identify a direct causal relationship between the transit line's presence and land development activities in the corridor, several notable trip attractors have continued to expand during the period of this line's operation. The Chicago Circle Campus of the University of Illinois is located along the Blue Line, a short distance to the east of the multimodal corridor. The Cook County Medical Center, located near the line, continues to expand.

¹⁰³Source: Chicago Transit Authority, also Gunlock, V. E.; Chicago's Rail Rapid Transit Line in the Congress Expressway. Presented at the annual convention of the American Society of Civil Engineers, Boston, Massachusetts, November 1960.

Table D-4. Average station boardings Eisenhower (Congress) Blue Line average—January–September 2008.

Station	Passengers
Forest Park	4,535
Oak Park	1,807
Austin	2,026
Cicero	1,241
Pulaski	1,527
Kedzie-Homan	1,908
Western	1,430
Medical Center	2,761
Racine	1,656
Total along Expressway	19,952
U.I.C. Halsted	3,674
Clinton	2,926
Blue Line Total	26,552

Source: Chicago Transit Authority.

Chicago Red Line/Dan Ryan Expressway Corridor

Limits

From: 95th Street Station

To: Cermak/Chinatown Station

Context and Project Development History

Figure D-10 shows the relationship of this multimodal corridor to the rest of Chicago's rapid transit system. The Dan Ryan Expressway opened in 1962. The rail line opened in the median in 1969.

The expressway (I-90/I-94) has 14 express lanes along with continuous frontage roads between 27th and 65th streets. It provides eight lanes south of 67th Street.

The total cost of the expressway has been cited as \$300 million. Total cost of the rapid transit line was reported to be about \$38 million plus another \$19.5 million for new cars. The rapid transit line opened September 1969. Two-thirds of the construction costs were covered by a federal grant. The line was built to relieve the then-overlooked Jackson Park and Englewood lines and to extend 4 miles further south. There are nine stations along the 10.5-mile-long line.

The Chicago Transit Authority Red Line is located in the median of I-90, the Dan Ryan Expressway from south of Cermack/Chinatown Station to its terminus at 95th Street station. The Dan Ryan Expressway was completed to 95th Street in 1962. The section of the Red Line to 95th street opened in 1969.

A plurality of station entries (13,449) takes place at the end point of the line at 95th Street. The median number of entries is 3,722. This indicates the line has a strong role in serving park-and-ride traffic and a strong automobile orientation overall. The land use along the line is varied, with several stations surrounded by transitional uses. Comiskey Park, the

home of the Chicago White Sox, is located at the 35th Street/Sox station.

Design Features

The Dan Ryan Expressway and rapid transit lines are below street grade. The rail line connects with both the South Side Elevated and the State Street subway. A storage yard is located south of 95th Street within the interchange area between I-94 and I-57 to the south of 95th Street. Trains run on continuously welded rails supported by reinforced concrete ties, with the rails cushioned by stone ballast.

Stations

Wide visibility and a high level of illumination characterize station areas. Fare collection equipment and turnstiles are of stainless steel. Escalators supplement stairs. Use of steel and glass affords maximum visibility from adjacent streets and highways. Self-service infrared radiant heaters are located at windbreaks on the platforms. Patron conveniences include high illumination lighting and a translucent canopy. Boarding platforms accommodate eight-car trains.

Off-street bus transfer facilities are provided at the 95th Street terminal and at the 69th Street station; there are bus bridges at each station over the expressway traffic lanes. Both are heavily used stations. An off-street bus loop is also provided at the Cermak Road station.

Operations

Dan Ryan trains operated between 95th Street and the Harlem-Lake Station from 1969 through 1993. Trains ran on the east (Wabash) and north (Lake Street) sides of the downtown Loop. However, the ridership imbalance between the heavy (Ryan) and light (Lake) lines, and between the heavy (Howard) and light (Englewood-Jackson) lines became increasingly pronounced. Therefore, since February, 1993, the Dan Ryan trains have been through routed via the State Street subway to Howard Street on the city's north side.

Trains run 24 hours daily and consists of eight cars from about 5 AM to 11 PM and four cars at other times. Trains run every 4 to 5 minutes during rush periods and every 7 to 8 minutes during midday and early evening. Service is at 15-minute intervals overnight. Running times were initially cited as 26 minutes between 95th Street and downtown Chicago. Current schedules show running times of about 25 minutes for the 10.5-mile distance.

Patronage

- 42,500 average weekday boardings (estimated for study corridor) on the Red Line.
- Dan Ryan Expressway:

- 239,100 vehicles per weekday (estimated for study corridor) on the Dan Ryan Expressway.
- 311,700 person-trips per weekday (estimated for study corridor) on the Dan Ryan Expressway.

Benefits

The Ryan Line has dramatically reduced travel times. A rebuilt Comiskey Park, the home of the Chicago White Sox, is located at the 35th Street Sox Station. The Dan Ryan Red Line has carried as many as 16,000 people through the maximum load point in a single hour on a single track. In 1987, almost 11,000 people per hour were carried. 2008 figures suggest 7,300. These numbers vastly exceed the number of people carried per general-purpose travel lane.

Chicago Blue Line/Kennedy Expressway (I-90) Corridor

Limits

From: O'Hare Station
To: Grand-Blue Station

Context and Project Development History

The John Fitzgerald Kennedy Expressway, opened in 1962, connects downtown Chicago with the Illinois Toll Road on the northwest side of the urban area. The southern section, which carries both I-90 and I-94, was located along Metro's northwest rail line to minimize community impacts. It has four travel lanes each way, plus two reversible lanes within the median area. The western (I-90) section has three lanes in each direction; a short spur (I-190) connects with O'Hare International Airport.

The long-established Milwaukee Avenue elevated and subway line on Chicago's northwest side was initially extended from its Logan Square terminal to Jefferson Park. The 5-mile extension, which includes a short subway and operates in the center of the expressway, opened in 1970. It cost about \$50 million (excluding the costs for 150 new cars). The rapid transit line was subsequently extended to River Road February 1983; a three-track terminal at O'Hare International airport opened in September 1984. The median operation includes about 11 miles of route with eight stations.

The Kennedy Corridor runs along a historical rail right-of-way along I-90 to the northwest of Chicago. This corridor provides the most direct link between O'Hare International Airport and downtown Chicago. The corridor is co-aligned with the METRA Northwest Union Pacific suburban rail line that runs adjacent to the Freeway. The portion of the Blue Line, which is offset from I-90, runs along North Milwaukee Avenue, a commercial and mixed-use

strip that cuts across the predominantly residential grid of Northwest Chicago.

Design Features

The southern parts of the rapid transit line and freeway are on an elevated embankment. The section west of I-94 is below grade. There is a short tunnel into the O'Hare International Airport. The two-track line has a third track in the median to the west of the initial terminus at Jefferson Park. This track was used for storage of up to 108 cars, plus a two-track inspection facility when the line was extended to O'Hare, a 12-car Rosemont inspection stop and 260-car capacity yard were fitted into previously unused segments between expressway ramps.

Stations

Center island stations are located about 1 mile apart on the initial section. Stations on the extension to O'Hare are spaced about 2 miles apart; these stations have stairways, elevators, and escalators and comply with ADA standards. Bus routes were revised to connect with the stations. At the Jefferson Park station, there is an off-street bus terminal.

A pedestrian way connects this terminal with the rapid transit station and the adjacent METRA commuter rail station. Off-street parking facilities are provided at three outlying stations. There are about 800 spaces at the Rosemont station, 1,636 at the Cumberland station, and 50 at the Harlem station. Daytime rates range from \$2.00 to \$3.00.

Operations

Blue Line trains operate between O'Hare and downtown Chicago 24 hours a day. They are through-routed with the Eisenhower service. During rush periods, alternate trains terminate in downtown. Trains are eight cars long from about 5:00 A.M. to 7:00 P.M., and four cars long at other times. They run every 3 to 5 minutes during the rush hours, and 7 to 8 minutes at other times. Overnight service is less frequent. The major portion of the new line is designed for speeds of 70 miles per hour. The actual maximum operating speed is 58 miles per hour. The running time between O'Hare and the Loop is 44 to 48 minutes.

Patronage

- 74,358 average weekday boardings (estimated for study corridor) on the Blue Line.
- Kennedy Expressway:
 - 292,000 vehicles per weekday (estimated for study corridor) on the Kennedy Expressway.
 - 379,600 person-trips per weekday (estimated for study corridor) on the Kennedy Expressway.

The maximum load point on the Blue Line (September 2008) approximated 12,000 people per hour in the busiest direction. It is estimated that the maximum load point (one-way) in the multimodal section is 4,000 people per hour.

Benefits

The Blue Line operating in the median dramatically reduced transit travel times to O'Hare International Airport. The 45-minute time to the Loop during rush hours is competitive with driving. It also provides convenient travel for airport workers. The line to O'Hare was CTA's first extension into relatively undeveloped land in more than half a century. It has resulted in commercial development at the Cumberland and Rosemont stations.

New Haven Line/I-95 Corridor

Limits

From: New Haven Station

To: New Rochelle Station

Context and Project Development History

The I-95 New Haven Corridor consists of Interstate 95 and the Metro North Railroad New Haven Line and runs along roughly 60 miles of a historical rail right-of-way that has extended from New York City to Boston for more than 150 years. (Passenger service along portions of this line is also provided by the Shoreline East Line and Amtrak, but the service characteristics of those operations are not included here.)

Although running on a legacy right-of-way, the Metro North Railroad (which includes the New Haven line) is at its peak in terms of service, providing a record 80 million trips in 2007.

The I-95 New Haven Corridor is a regional system, as there are distinct business districts in New Haven, Bridgeport, and Stamford in addition to New York City. Bridgeport station includes access to the ferry terminal serving Long Island.

Design Features

The New Haven Line generally has four tracks between New Haven and Grand Central Terminal in New York City. It is fully grade-separated from all crossroads and streets. The railroad is electrified by 11,000-volt alternating current between New Haven, Connecticut, and Pelham, New York, and by 650-volt direct current between Pelham and Grand Central Terminal. Most service is provided by multiple-unit trains. Amtrak leaves the New Haven Line at New Rochelle and reaches Pennsylvania Station, New York City, via the Hell Gate Bridge.

Stations

There are 30 stations along the New Haven main line. Most stations have side platforms that serve the outer two tracks. The Stamford, New Haven, and New York City's Grand Central and Harlem stations have multiple platforms. Overhead or below-track pedestrian connections are provided. Major stations have bus access. More than 20,000 off-street parking spaces are provided at or near stations.

Operations

Metro North trains on the New Haven Line operate on a "zone express" basis during peak hours. Three tracks are often provided in the heavy direction of travel. During off-peak hours, local trains between Stamford and New York City alternate with New Haven to New York trains that run express between Stamford and New York City, each on an hourly basis. Each weekday, 115 westbound trains enter Grand Central Terminal, and 60 westbound trains enter Stamford. During the 8 A.M. to 9 A.M. rush hour, 21 westbound trains enter Grand Central and about 11 enter Stamford. Faster trains average 40 to 45 mph. Frequently they pass motorists on I-95 in the heavy direction of travel during rush hours.

Patronage

- 86,500 average weekday boardings (estimated for study corridor) on the New Haven Line.
- Interstate 95:
 - 152,100 vehicles per weekday (estimated for study corridor) on Interstate 95.
 - 197,700 person-trips per weekday (estimated for study corridor) on Interstate 95.

Benefits

The combined rail and road access in this multimodal corridor have contributed to increased office development in Stamford, Greenwich, and several other towns. Stamford has emerged as the major office center of Connecticut.

Multimodal Corridors Outside the United States

Auckland (New Zealand) Northern Busway/Northern Motorway (SH 1) Corridor

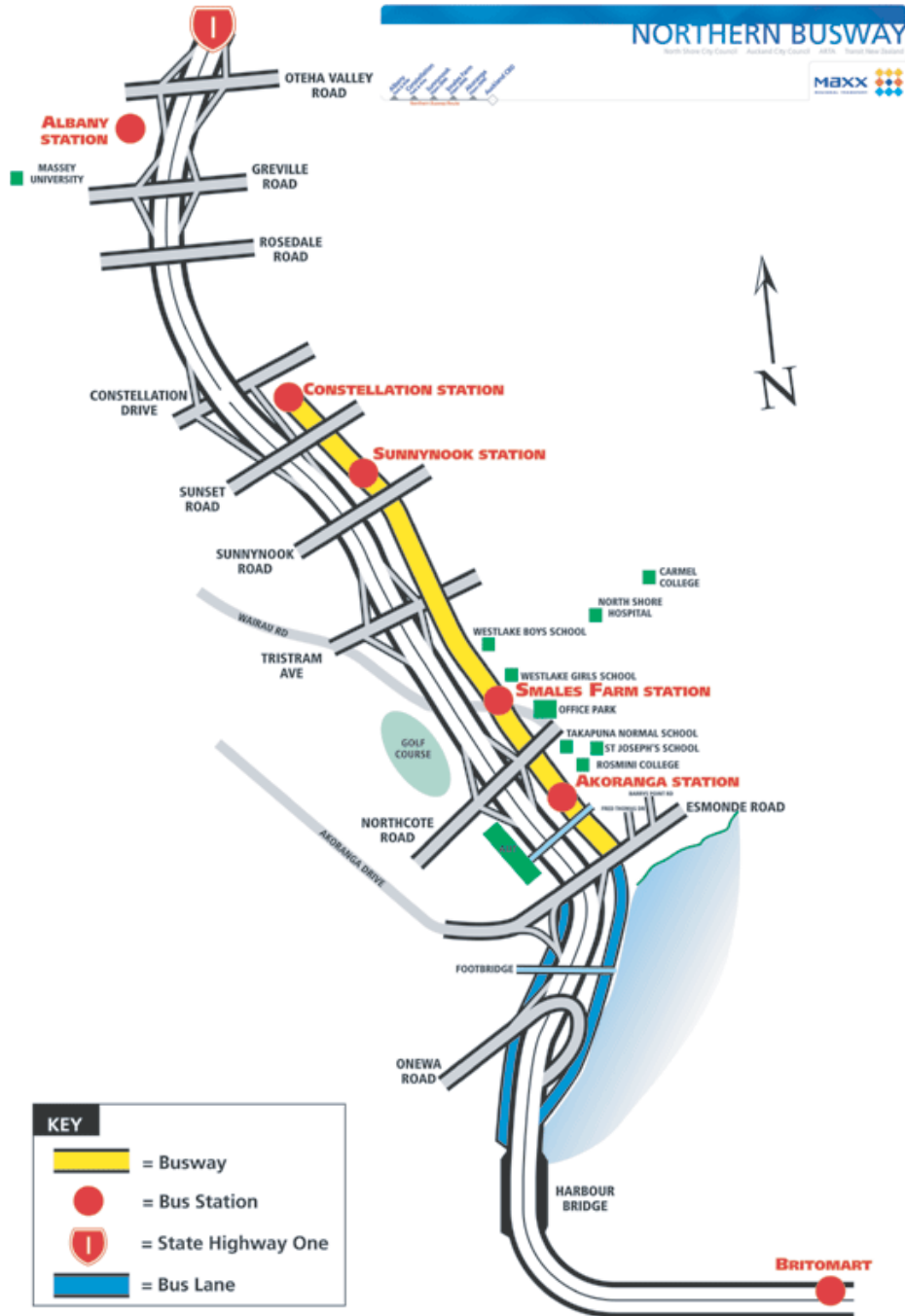
Limits

From: Akoranga Station

To: Albany Station Park-and-Ride

Context and Project Development History

Auckland's 6.8-mile five-station Northern Busway system links the North Shore with the center of Auckland (Fig-



Source: Courtesy New Zealand Transport Agency

Figure D-12. Auckland, New Zealand’s Northern Busway map.

ure D-12). The busway, opened in February 2008, is a cooperative venture of the Auckland Regional Transit Authority and the North Shore and Auckland City Council. It is the first step of a planned improved bus transit system that links the urban population of 368,000 with the City Center. The 1.67 square mile central business district has 65,000 jobs and, 10,000 residents; there are 73,000 entrants during the A.M. peak hours. The cost of the busway has been estimated at NZ

\$290 to 294 million—NZ \$210 million for the busway construction and NZ \$84 million for stations.

Design Features

The two-lane busway runs roughly 4 miles along the east side of the Northern Motorway. Bus-only lanes connect the busway to the Harbour Bridge (see Figure D-13). The new Esmonde Interchange facilitates the transition from the busway



Source: Courtesy Scoop.co.nz and Transit New Zealand.

Figure D-13. Auckland, New Zealand's Northern Busway parallels the Northern Motorway (SH 1).

to bus lanes. The busway is designed for possible future conversion to light rail transit.

Stations

Four of the five stations are located along the busway. The busway system includes elevators, electronic signs, audio assistance posts, and 24-hour video monitoring. Many park-and-ride spaces are provided at the Albany and Constellation stations.

Operations

Initially, there will be a bus at a station about every 3 minutes.

Patronage

The busway is forecast to carry 250 buses an hour and take an estimated 2,400 cars off the road during peak periods.

Benefits

It is anticipated that the busway will reduce peak-hour travel times from about 1 hour to 30 minutes.

Beijing (China) Southern Axis Busway Corridor

Limits

From: Demaozhuang Station
To: Qianmen Station



Source: Courtesy The Energy Foundation.

Figure D-14. Beijing's Southern Axis BRT.

Context and Project Development History

Beijing, China's capital, has a population of about 14 million. The urban area and its surroundings are served by a growing number of rail transit and BRT lines. As Beijing continues to expand at a rapid pace, residents are increasingly settling in the suburbs, leaving their city-center neighborhoods and their walkable, bikeable commutes behind as well. While most of Beijing's transportation improvement investments have been focused on expanding roads and parking lots for cars, most of the people remain dependent on public transportation. BRT is seen as a cost-effective solution to these challenges.

Design Features

Beijing's 10-mile, 17-station BRT line in the center of the Southern Axis Freeway opened in 2006 (Figure D-14). It links eight residential areas with a total population of 200,000 and four commercial areas in the city's southern districts.

The 59-foot-long buses are equipped with an electronic stop announcement system and air conditioning, which most regular city buses do not have. The buses' low entry step allows access for wheelchairs, a feature that Beijing only recently began incorporating into city transport.

Stations

Stations are located in the median of the road where the busway runs. Stations are connected to the sidewalks at the road's outer edges via overpasses and cross-street intersections.¹⁰⁴

¹⁰⁴Matsumoto, N. "Analysis of policy processes to introduce Bus Rapid Transit systems in Asian cities from the perspective of lesson-drawing: cases of Jakarta, Seoul, and Beijing", <http://www.docstoc.com/docs/2370895/Analysis-of-policy-processes-to-introduce-Bus-Rapid-Transit>.

Operations

Service is provided by 59-foot-long articulated buses equipped with low entry steps, electronic stop announcements, and air conditioning. Fare collection is done at a ticket counter at the entrance to each station. Tickets are sold manually by salesclerks, instead of through salesclerks. One ticket costs a flat rate of two Yuan (25 cents)—roughly two-thirds the cost of a subway ticket.¹⁰⁵

Patronage

In its first 2 months in service, this BRT line attracted overwhelming ridership, with an average of about 80,000 daily passengers. While officials originally expected a peak flow of roughly 150,000 daily passengers to occur in 2007, passengers neared 130,000 on the third day of operations.¹⁰⁶

Benefits

One-way travel times are reported as 37 minutes compared to the previous 1-hour journey.

Brisbane (Australia) South East Busway

Context and Project Development History

Brisbane's 10.5-mile-long South East Busway system is perhaps the first side-running rapid transit facility along an urban freeway. It complements an extensive commuter rail system in serving the 1.8 million people living in the Brisbane metropolitan area, of which half reside in the city. Brisbane's central business district employment is about 60,000.

The South East Busway opened between September 2000 and mid-2001 after 5 years of planning, design, and community liaison. It is a key component of Queensland Transport's plan for a fully integrated multimodal transport system. The Inner Northern Busway connects with the South East Busway at the central Queen Street bus station. The Northern, Eastern, and Boggs Road busways are under development.

The South East Busway extends from the Brisbane CBD to the southern suburb of Eight Mile Plain, adjacent to the South East Freeway. Some 8 miles with six stations are alongside the South East Expressway. The A\$400 million busway includes 10 attractively designed stations and a bus operations center that employs modern ITS technology. It traverses a highly developed urban area in a constrained corridor. Over half of Brisbane Transport bus routes use some part of the busway.

¹⁰⁵Matsumoto, N. "Analysis of policy processes to introduce Bus Rapid Transit systems in Asian cities from the perspective of lesson-drawing: cases of Jakarta, Seoul, and Beijing", <http://www.docstoc.com/docs/2370895/Analysis-of-policy-processes-to-introduce-Bus-Rapid-Transit>.

¹⁰⁶<http://peopleandplanet.net/doc.php?id=2690>

The busway includes surface and tunnel operations on exclusive rights-of-way. Users include Brisbane Transit and suburban bus operators who are under the bus operations center control. Priority lanes connect with the southern busway terminus.

Design Features

The two-lane busway is located along one side of the six-lane South East Freeway, through much of the corridor. The cross section between stations consists of two 11.5-foot-wide travel lanes. Bypass lanes are provided at stations to enable express buses to pass buses making stops. A 1.6-foot-wide barrier with a fence separates two 11.5-foot-wide travel lanes. These lanes are flanked by two 9.8-foot-wide lanes for stopped buses. The entire Busway envelope, including station platforms, occupies 69 feet right-of-way. There are 6,560 feet of elevated roadway and 5,345 feet of tunnel. There are 140 security cameras are linked to CCTV monitors at the busway operations center.

Stations

The ten attractively designed busway stations at key nodes (six are located along the freeway) serve major activity centers; they allow buses to serve low-density communities, collect passengers on local roads, and then join the busway for a congestion-free trip to the city center.

The stations have extensive monitoring surveillance and communications capability and provide real-time information. Each station provides the visual "signature" for the bus rapid transit service. Stations are unattended and are open 24-hours each day.

Each station provides facilities for passengers to safely access buses arriving and departing from two platforms. Pedestrian overpasses enable passengers from between station platforms to cross the busway, and fences preclude at-grade crossings of the busway.

Busway station design is a key component of the Busway system. Each station forms a significant part of the adjacent landscape. The strong horizontal lines of station elements (that is, roof structures) and an emphasis on slender steel detailing and sizes produces sensitive structures and minimized visual and environmental impacts on surrounding areas.

Operations

Busway service is provided to two separate areas in the Central Business District (CBD). City Expresses serve the South Bank Cultural Centre and Queen Street. The Rockets serve Queen Street and Riverside. Overlaid on these BRT services is a complex array of services that make various stops along the Busway. More than 100 scheduled routes and 2,300 individual bus services use a portion of the Busway on a typical weekday morning. Service frequencies range from 1 to 6 minutes during peak hours, 5 to 15 minutes on weekdays, 5 to 30 minutes on Sundays, and 10 to 60 minutes after 8:00 P.M.

Patronage

Busway ridership for the core services between the CBD and Eight Mile Plains increased 42 percent between May and October 2001—the first 6 months that the complete busway was open. During this period, some 9.6 million passengers were carried. The first entire year it carried 17.7 million passengers, excluding special events and the opening weekend. Daily boardings are approximately 60,000. The City of Brisbane indicates that the busway can carry 11,000 people per hour in each direction during the peak hour. Reported peak direction volumes were up to 9,500 per hour just outside the central area. The busway carries more people in the peak hour than the adjacent general-purpose freeway travel lanes.

Benefits

The South East Busway is an extension of the rapid transit system provided by City Train. It links major destinations, improves bus-rail and bus-bus transfers, and results in transit travel times that are more competitive with driving, particularly during peak hours. The South East Busway is a showplace of state-of-the-art technology and modern architecture. Some 375,000 (annual) private vehicle trips were converted to public transport.

Property values have increased as much as 20 percent in some communities located near the Busway. Research suggests that property values increased two to three times as much in communities located within 6 miles of the Busway as compared with those located at greater distances.

APPENDIX E

Glossary of Terms

Multimodal Facilities: The combination of physical facilities for highways, public transit, pedestrians and bicycles. (Multimodal Facilities = Highways + Transit + Pedestrians + Bicycles).

Corridor: The combination of multimodal facilities and the land uses surrounding them. (Corridor = Multimodal Facilities + Surrounding Land Uses). The interaction of multimodal facilities and land uses can take many forms, but can generally be described as ranging from auto-oriented to transit-oriented corridors. These two polarities are described in greater detail below.

Multimodal Corridor “New Paradigm”: Optimized combinations of multimodal facilities and land uses.

Physical Context: Refers to the characteristics of the land use, urban design (street and block characteristics), social, economic, demographic, and so on surrounding the existing or future transportation facilities.

Institutional Context: Refers to the institutional arrangements for physical design, highway operations, other modal operations, and land development decisions along and near the corridor. This also includes institutional arrangements for providing access to the corridor from the area served by the corridor as well as the policies, regulations, and other transportation management actions that help determine corridor operations.

Intermodal Facilities/Station: A station or node where transfers between travel modes are facilitated.

System Access: Refers to the characteristics of how the transportation facility is accessed, including transit stations, bus stops, on- and off-ramps-and so on

Central Business District (CBD): The CBD is the central district of a city, usually typified by a concentration of retail and commercial buildings.¹

¹http://en.wikipedia.org/wiki/Central_business_district

Transit Mode Terminology:

- **Local Bus:** The most common form of public transit in the United States, it is distinguished by single bus vehicles operating with a capacity of 35 to 50 seated passengers, operated along fixed routes, running in mixed-flow traffic along surface streets. Since they run in mixed traffic, buses are typically slower than other forms of transit, and because they follow fixed routes with frequent stops, they typically travel at slower speeds than auto traffic in the same corridor.
- **Express/Rapid Bus:** Generally distinguished from local bus service by the limited number of stops made along a fixed route. The route can be in a surface street in mixed-flow traffic lanes either on a local surface street or a freeway. Fewer stops mean fewer opportunities to attract passengers, so this mode is best suited to serve a large destination such as a central business district paired with either a system of widely spaced intermodal transfer stations (for example, park-and-ride lots surrounding stations) or dense residential clusters. Also called rapid or transit-priority buses, express buses can be fitted with signal priority technology to increase running speeds. Other route improvements include queue jump lanes, bus stop “bulb-outs,” and exclusive bus lanes. These improvements are also associated with BRT (see description below), but unless most or all of these elements are in place and in use, the route is generally considered express or rapid bus, not a full BRT system. Express bus service with park-and-ride lots around their stations can serve at relatively low corridor residential densities of four dwelling units per acre and CBDs as small as 20 million square feet because this configuration draws on a large commuter shed. Pedestrian access stations require higher corridor residential densities of 15 dwelling units per acre or more and a CBD of at least 50 million square feet.² Express buses are also very flexible. An express

²Pushkarev, B. & J. Zupan, Public Transportation and Land Use Policy. Indiana University Press, Bloomington, IN, 1977. p. 187.

bus—such as AC Transit’s Transbay routes from the East Bay to downtown San Francisco—can run as a local service in a collector mode, then as an express bus to the destination.

- *Bus Rapid Transit (BRT)*: The most important feature of BRT is that it runs on a dedicated, exclusive lane of travel, giving it a high level of service reliability (since it does not compete for right-of-way with other modes) and speed. Bus priority technologies (such as signal prioritization) are often used to improve travel times and provide a competitive edge to BRT vis-à-vis other modes. Off-bus fare collections as well as platform boarding and alighting are frequently used to reduce dwell times at stops.² In addition to operational improvements, the cost of a BRT system can be about one-third that of a light rail system.³ This makes BRT feasible for somewhat less dense and smaller CBD corridors than more capital-intensive rail systems. As a rule of thumb, minimum CBD size for a BRT system to generate adequate ridership is around 25 million square feet.⁴
- *Light Rail Transit (LRT)*: Light rail vehicles run singly or in short trains on tracks in a variety of right-of-way environments, including mixed-flow surface streets, dedicated lanes with grade crossings, and fully grade-separated dedicated facilities.² Compared to BRT, LRT offers and requires more fixed capital investments and, as such, is thought to be more attractive to riders and developers.⁵ Another advantage of LRT, particularly in comparison to heavy or commuter rail, is its operating flexibility. LRT can operate in mixed traffic and exclusive rights-of-way conditions, all along the same line.² This is important because many freeway right-of-ways do not penetrate downtown areas, and LRT can do so on city streets at a relatively low cost compared to heavy or commuter rail (see below).⁶ Therefore, for multimodal corridors where transit is being retrofitted into an existing freeway right-of-way, the freeway need not run directly to the activity center that the transit system will serve. Rather, the LRT system can take advantage of the opportunities for colocating its tracks along an available freeway right-of-way for most of the route, then veer away to run on surface streets to reach the CBD. Minimum CBD size for an LRT system is around 35 million square feet, but for lines that can be built along existing rights-of-way (such as a freeway), CBDs as small as 20 million square feet may

be financially feasible. Minimum corridor residential densities for LRT range from 9 to 12 dwelling units per acre.²

- *Heavy Rail/Rapid Transit (HRT)*: Heavy rail transit provides intraurban service running on exclusive, dedicated, fully grade-separated rights-of-way. Called “heavy” because of its large passenger capacity, HRT can generally carry up to 400 passengers per track per hour at high speeds and excellent service reliability. Cars are generally designed to carry 90 to 150 people each in comfort, and up to double that in “crush load” conditions. The trains are typically very long compared to LRT, up to 8 to 11 cars depending on their size. To reduce dwell times and increase service speeds, HRT systems have fare collections in the stations, as well as high-level station platforms and more doors per car than other vehicles to speed boarding and alighting.² Express HRT service is sometimes provided via additional, parallel tracks to allow skip-stop trains.⁷ HRT is generally thought to be financially infeasible for corridors with CBDs less than 50 million square feet and corridor residential densities less than 12 dwelling units per acre.²
- *Commuter Rail*: Commuter rail provides service between a metropolitan area’s suburban areas and its main CBD. It usually shares tracks with other railroad traffic (freight and intercity passenger) and so can suffer from delays due to these competing uses. Usually, its power source is on-vehicle (locomotive) versus off-track (for example, overhead wires and middle third rail). Commuter rail almost always runs at grade since locomotives are too heavy for aerial or subways, and they typically have stub-end stations at the periphery of downtowns. Suburban stations almost always have surface parking. Typically, commuter trains run less frequently than other forms of rail transit, often only during peak periods. In this way, they tend to cater to “choice” riders who prefer public transport because of speed, reliability, and avoidance of traffic congestion and parking problems. To compete with auto traffic travel times, commuter trains are often scheduled to skip stops, resulting in express and local services in the same corridor. Compared to intercity rail service, commuter rail has more frequent stops and seating densities. This requires train equipment with high acceleration and deceleration as well as seating and door configurations that allow rapid loading and unloading. In these ways, commuter rail equipment and system design are comparable to HRT or LRT, but the route distances are often longer, ranging between 15 and 30 miles. Because of these design features, there are few commuter

³Leal, Monica T. & Robert L. Bertini, Bus Rapid Transit: An Alternative For Developing Countries, <http://web.pdx.edu/~bertini/brt.pdf>

⁴TCRP Report 90, Volume 2, page 2-4.

⁵Diaz, Roderick B., Impacts Of Rail Transit On Property Values. <http://www.apta.com/research/info/briefings/documents/diaz.pdf>

⁶Examples of LRT systems traveling on city streets through central business districts include Boston, Edmonton, Philadelphia, Pittsburgh and San Jose.

⁷Examples of HRT systems providing express service include Chicago, New York City, and Philadelphia.

rail station area TODs. Where development densities provide an adequate ridership market, commuter lines are electrified and the stations have platforms and automatic doors. Where corridor market densities are lower, slower speeds are acceptable and diesel-pulled trains with low-level station platforms are frequently used.² Commuter

rail is generally thought to be financially infeasible for corridors with CBDs less than 50 million square feet. The CBD should have a pre-existing rail line serving it, and the service corridor residential densities should be no less than 1 to 2 dwelling units per acre² with good transit and auto feeder access to corridor stations.

Abbreviations and acronyms used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI-NA	Airports Council International-North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation