International Journal of Innovative Inventions in Social Science and Humanities

ISSN (print): 3050-6921, ISSN (online): 3050-693X

Volume 02 Issue 06 June 2025

DOI: 10.58806/ijiissh.2025.v2i6n01

Page No: 45-65

Revisiting Bus Transit-Oriented Development (BTOD): A New Sustainable Development Pattern

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ABSTRACT

Achieving a successful and sustainable Bus Transit-Oriented Development (BTOD) pattern remains a significant challenge. This paper, based on a review and synthesis of relevant literature, proposes a set of adaptive transit and land use strategies to address this issue. On the transit side, adaptive transit aims to enhance bus transit's role in BTOD by improving operational performance, strengthening public perception, and better serving riders. This can be accomplished through taking strategic bus transit planning measures, with the implementation of Bus Rapid Transit (BRT), which is emerging as a particularly promising technology, for future BTOD. On the land use side, an effective coordination between bus transit and land use planning is essential to creating transit-supportive developments near bus stations. Establishing an adaptive land use pattern encourages greater integration of transit and surrounding infrastructure. Additionally, fostering public-private partnerships and engaging communities through making outreach efforts are crucial for securing participation from private developers and the general public. Lastly, this paper briefly introduces selected BTOD planning practices in the United States, offering insights into their implementation and impact.

KEYWORDS: Bus Transit-Oriented Development (BTOD); adaptive transit; adaptive land use; Bus Rapid Transit (BRT)

ARTICLE DETAILS

Published On:
10 June 2025

Available on:
https://ijiissh.com/

INTRODUCTION

Compared to Rail Transit-Oriented Development (RTOD), Bus Transit-Oriented Development (BTOD) remains a minor component in the TOD system (Currie, 2006). This is especially true in the United States (US). In contrast, BTOD seems to be more appropriate than rail-based TOD systems (RTODs) in the Australian context due to its low-density requirement and low cost (Nawaz et al., 2017). It was estimated that only 7.8% of TOD initiatives in the US were bus-based, primarily located in smaller or suburban communities (Cervero, 2004). This is unsurprising, as bus transit - particularly regular bus service - tends to attract less development investment around its stops compared to rail transit. Additionally, bus transit generally has a weaker influence on land use and urban form (Vuchic, 2007). Even though Bus Rapid Transit (BRT) has recently gained a development momentum, mostly in cities of Latin America, Asia, and North America, some people still question the city-shaping potential of BRT (Deng & Nelson, 2011; Nelson & Ganning, 2015; Suzuki et al., 2013; Vergel-Tovar, 2023), in part due to a belief that it delivers fewer regional accessibility benefits than rail, but also to the social stigma some assign to bus-based forms of mass mobility (Cervero, 2014). As a result, BTOD remains more of a concept than a widespread reality.

Despite these perceptions and challenges, expanding BTOD in the US is essential for several key reasons.

First, buses are the most widely used transit mode in the US in terms of ridership share. In 2021 alone, of the 4.493 billion unlinked passenger trips taken nationwide, 51.79% were by bus, 35.77% by heavy rail, and 12.44% by all other modes combined (APTA, 2023). Given its dominant role in public transit, bus transit has a strong potential to attract more riders and encourage a shift from automobile use.

Second, it is worth noting that emerging bus technologies are quickly transforming public transportation, focusing on efficiency, sustainability, and safety. Key advancements include bus signal priority, advanced public transit system, electric buses, fuel cell buses, autonomous driving systems (e.g., iBus), smart connectivity, and others. These new bus technologies will generate significant benefits on multiple fronts. For example, fuel cell buses are a type of bus powered by hydrogen fuel cells, which convert hydrogen into electricity to power electric motors. Unlike traditional buses, fuel cell buses produce only water vapor as exhaust and offer the potential for zero emissions, reduced noise, and a longer range than battery-electric buses. They also refuel faster than battery-electric buses, offering a more continuous operation schedule.

Third, TODs exist within a hierarchy corresponding to different transit modes, allowing BTOD to establish its niche, even in lower-density or suburban settings. In particular, after overcoming some regular bus limitations, Bus Rapid Transit-Oriented Development (BRT-OD) is poised to become a more competitive and viable option.

Fourth, buses do not always compete with rail; under certain circumstances, they may complement it. When a bus line serves as a feeder to a rail system, BTOD along the feeder route and RTOD along the trunk line mutually reinforce each other's ridership. Additionally, the integration of bus services and terminals at major rail stations has been shown to support RTOD development (Porter, 1997).

Recognizing the aforementioned BTOD importance and yet lack of its related study in existing literature motivates the writing of this paper.

Following this introduction, the paper contains five sections. The literature review section focuses on describing TOD, TOD typologies, BTOD, RTOD, and their comparative advantages and disadvantages. The research methodology is outlined to guide the rest of this study. The following section proposes adaptive transit and land use improvement strategies. Selected BTOD planning practices in the US are described later. The last section summarizes key research findings, recognizes limitations, and draws preliminary conclusions.

LITERATURE REVIEW

To provide the context of this BTOD study, a brief literature review is provided below.

Definition of TOD

Transit-Oriented Development (TOD) has been defined at a number of levels and a variety of scales. So far, there is no consensus in the literature on just what constitutes TOD.

Nevertheless, TOD is generally seen as an alternative to sprawl, as a mixed-use transit-friendly community, and as a specific development type. In essence, TOD is a type of urban planning and design that focuses on creating compact, walkable communities centered around high-quality public transportation systems. The goal is to make it convenient for people to live, work, shop, and play without relying heavily on personal vehicles.

The TOD concept was not introduced by a single individual but rather evolved over time, with significant contributions from several urban planners and theorists.

However, Peter Calthorpe, an American architect and urban designer, is widely credited with popularizing and formalizing the TOD concept in the early 1990s. Peter Calthorpe published the book entitled "The Next American Metropolis: Ecology, Community, and the American Dream" in 1993, where he laid out the principles of TOD as a strategy to combat suburban sprawl. He defined TOD as compact, walkable, mixed-use communities centered around high-quality public transit systems (Calthorpe, 1993).

Key principles of TOD in Calthorpe's book include:

- **Walkability**: Streets are pedestrian-friendly, with safe sidewalks, street furniture, and human-scale design.
- **Mixed-Use Development**: Residences, offices, shops, schools, and services are located close together.
- **Density**: Higher residential and commercial density near transit stations to support ridership and local business.
- **Transit Accessibility**: Development is concentrated within a 5–10-minute walk (about 0.25 to 0.5 miles) of a transit stop or station.
- **Reduced Car Dependency**: The design encourages the use of public transit, biking, and walking over private car use.
- **Public Spaces**: Parks, plazas, and community gathering places are often integrated into the development.

A TOD project integrates both transit and land use components. The term "TOD degree" was coined to measure the extent to which development concentrates in or around transit stations and along transit corridors (Papa & Bertolini, 2015). Unfortunately, so far, few have quantitatively examined TOD degree and its correlates (Zhou & Yang, 2021). Recognizing the symbiotic relationship existing between transit and urban form (Black, 1995), Cervero introduced concepts such as adaptive cities, adaptive transit, strong-core cities, and hybrids (Cervero, 1998). Cervero observed that combining flexible bus-based services with mixed-use development along busway corridors led to high per capita transit ridership in cities like Ottawa and Curitiba.

Typologies of TOD

There are different typologies of TOD. For example:

Based on urbanity, we can distinguish "Urban TOD" from "Neighborhood TOD." Urban TODs are typically located on the Trunk Line Network at heavy or light rail stations or express bus stops. These TODs, situated near the regional transit system's main spine, have a higher potential for generating jobs and are often developed with higher commercial intensities and residential densities. Due to their substantial employment base, urban TODs generally have higher trip attractions than trip productions. In contrast, neighborhood TODs are located on high-frequency bus routes or feeder bus lines within a 10-minute travel time from light rail stops or bus transfer stations. These TODs rely on frequent, medium-capacity transit services to attract development, with a focus on residential and locally-serving commercial uses. As a result, neighborhood TODs tend to have higher trip productions than trip attractions. Calthorpe also noted that not all transit stops will develop into TODs; some may become park-and-ride lots or be located in low-density industrial areas (Calthorpe Associates, 1992).

Based on transit modes, we can identify Rail TOD (RTOD) and Bus TOD (BTOD) (Cervero, 2004). Bus TOD refers to urban planning and development strategies that center around bus stations rather than rail. It promotes compact, walkable, and mixed-use communities within a close proximity to bus transit hubs or corridors. The goal is to reduce dependence on cars, improve transit accessibility, and support sustainable urban growth. In contrast, Rail TOD is a type of urban development that focuses on creating compact, walkable, mixed-use communities around rail stations, including subways, light rail, commuter rail, or streetcars. It's designed to maximize access to public transit and reduce car dependency.

Based on the spatial configuration of transit stations, there are three types of TOD: 1) single-node TOD (most common); 2) multi-node TOD; and 3) corridor TOD.

From a combination of transit modes and geographical locations, we have TODs located in urban downtown, urban neighborhood, suburban center, suburban neighborhood, neighborhood transit zone, commuter town center (Dittmar & Ohland, 2004).

In Latin American cities, one study identified 10 types of BRT stops: 1) Mixed-use Corridor; 2) Downtown City Center (Quito); 3) Urban Center; 4) Institutional Use Corridor; 5) BRT-oriented Satellite Center; 6) Nexus; 7) Guatemala City Corridor; 8) Community Center; 9) Neighborhood Center; and 10) Green Area (Rodriguez & Vergel-Tovar, 2013).

Different TODs correspond to different transit modes, transit service levels, land use densities, and development patterns. This paper only focuses on a subset of TOD: BTOD, whose comparison with RTOD is given below.

BTOD, RTOD: A Comparison

The 2002 California TOD study compared BTOD's advantages and disadvantages, which are compiled in Table 1 (Parker et al., 2002).

Table 1. Bus TOD and Rail TOD

Bus TOD	**Rail TOD**
Pros:	
Can increase ridership	Can increase ridership
More efficient service provision	More efficient service provision
More ubiquitous and flexible than rail	Fixed and better identity
Large number of bus stops along a transit corridor	Permanent stops provide less risks for investment
Urban and suburban service market	More culturally accepted than bus
	The construction process provides more opportunities for joint development
	Proven track record
	Higher income and choice riders
	More influential constituencies
Cons:	
Lack of fixity decreases investment at traction	More expensive than bus
Stigmatized as second-rate transportation	Fewer stops along a transit corridor
The construction process provides fewer opportunities for joint development	Only urban service markets

Few successful examples	
Low-income riders	
Less influential constituencies	

According to Table 2, rail transit has a stronger identity (strength) but comes with higher costs (weakness). In contrast, bus transit is more flexible (strength) but suffers from a poorer public image (weakness). These trade-offs are evident. One Australian empirical research also analyzed the strengths and weaknesses of BTOD in comparison to RTOD (Currie, 2006). His findings are summarized in Table 2.

Table 2. BTOD Strengths and Weaknesses

BTOD Strengths	Strength Rating	BTOD Weaknesses	Weakness Rating
Complementarity and Ubiquitousness	High	Permanence, Magnitude, Development Risk	High
Flexibility-Choice	Moderate	Newness	Low to Medium
Flexibility-Adaptiveness to Change	Moderate	Different Markets	Low to Questionable
Cost effectiveness	High	Park and Ride	Unclear
Service Frequency	High	Industry TOD Capabilities	High
Transfers	Low to Medium	Pedestrian Access	Moderate
		Parking restraint	High
		Urban Density	Moderate to High
		Scale Dilution	Unimportant to Low
		Noise and Pollution	Moderate to High
		Frequency and Speed	Moderate to High
		Bus Stigmatization	High
		Track Record	Moderate to High

From Currie's perspective, the key challenges for effective BTOD include the limited capabilities of the bus industry, the noise and pollution impacts of buses, and their generally poor track record. He concluded that Bus Rapid Transit (BRT) has more advantages than local buses. With a thoughtful design, BRT can mitigate many of these challenges and, in some cases, offer net advantages over rail transit.

As a result, it seems that BTOD has more weaknesses than strengths, while RTOD has more strengths than weaknesses. This helps explain why RTODs far outnumber BTODs in the US and around the world. However, this situation could change if we implement effective improvement strategies to reverse the trend.

RESEARCH METHODOLOGY

Research Diagram

Figure 1 is a schematic diagram depicting the symbiotic relationship between adaptive transit and adaptive land use elements in TOD.

Adaptive transit refers to transit systems that are designed to be flexible and responsive to changes in land use, population density, travel patterns, and user needs within TOD environments. A transit system consists of several components: vehicles, right-of-ways, stations, controls, etc. Development of an adaptive transit system is influenced by many complex factors, including transit planning, infrastructure investment, etc.

Adaptive land use refers to planning and designing land use in a way that is flexible, responsive, and evolves with changing demographics, economic conditions, transportation patterns, and environmental goals, all centered around a transit hub. Different transit modes require different land use densities and patterns. Formation of an adaptive land use is also affected by such factors as land use planning, land development, etc.

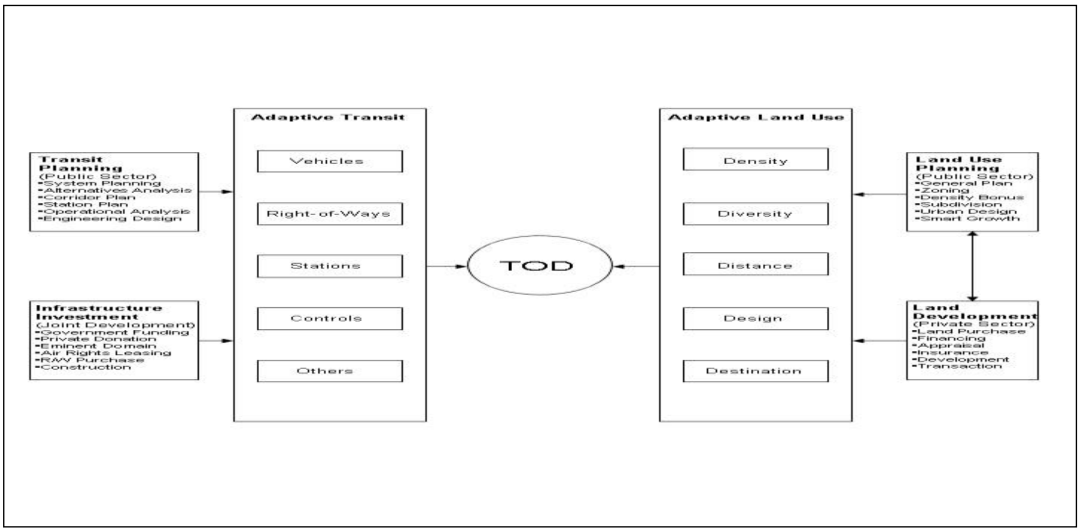

Figure 1. TOD Research Diagram

The TODs of different transit modes have different features and investment requirements. The capital costs of different transit modes vary significantly, with rail systems generally having higher costs per mile than bus or light rail systems. Bus rapid transit (BRT) typically has lower capital costs than light rail, while heavy rail (HRT) systems are the most expensive. Factors like land acquisition, guideway construction, and station costs contribute to these differences.

Guided by the above TOD diagram, this study proposes two research hypotheses.

RESEARCH HYPOTHESES

Hypothesis #1: Developing an adaptive transit system supporting BTOD requires improvement be made at three levels:

- **System Level:** Through transit planning and infrastructure investment, establish a tiered, hub-and-spoke transit network in urban areas to minimize transfers and make transit more car-like.
- **Route Level:** Upgrade regular bus service to Bus Rapid Transit (BRT) with specially designed vehicle types, level boarding stations, exclusive busways, and other more rail-like features.
- **Station Level:** Optimize station and nearby area design to enhance accessibility to transit stations (e.g., walkability, bikeability, etc.) and reduce conflicts between pedestrians and vehicles. One main factor that affects TOD performance is accessibility to transit and connectivity between several modes of transport (Tamakloe et al., 2021). For example, the transit village around the El Monte, California, bus station (EMBS) would have little impact on the surrounding community without improvements in pedestrian access to the EMBS (Cottrell, 2006).

The core idea behind an adaptive transit strategy is to make bus transit as flexible, convenient, and efficient as cars while incorporating the permanence and strong public image associated with rail systems. BRT-oriented development seems to be the long-term development goal.

Hypothesis #2: Developing an adaptive land use strategy supporting BTOD also requires improvements at least at three levels:

- **Intersectoral Level:** Coordinate land use planning with bus transit planning in the vicinity of transit stations through imposing appropriate zoning controls.
- **Intrasectoral Level:** Foster public-private partnerships in land development.
- **External Outreach Level:** Strengthen public participation and community engagement.

An adaptive land use pattern should ideally adhere to TOD's 7D principles:

- **Density** – Increase development density around bus transit stations. The closer to the stations, the higher the densities.
- **Diversity** – Promote mixed-use developments to reduce vehicle dependency and encourage pedestrian activity.
- **Design** – Improve urban, neighborhood, and station design to enhance walkability and cycling infrastructure.
- **Destination Accessibility**– Enhance accessibility to key local destinations.
- **Distance to Transit** – Ensure major land uses are within walking distance (approximately a quarter-mile radius) of transit stations.
- **Demand Management** – Strategies should be implemented to encourage transit use and reduce reliance on private vehicles, such as parking restrictions and carpooling incentives.
- **Dissonance -** The design and development of the TOD area should minimize the visual and functional "dissonance" between the station area and the surrounding neighborhood.

Achieving an adaptive land use pattern requires a strong collaboration between government agencies, the private sector, and the general public.

Data Collection

The data collection of this paper heavily relies on literature review. Data sources include online search, journal articles, planning reports, census data, local employment information, data on housing and transportation affordability, National Transit Database (NTD), etc.

BTOD IMPLEMENTATION STRATEGIES

Guided by the TOD diagram (shown in Figure 1) and the research hypotheses proposed in Research Methodology Section, this paper details two sets of implementation strategies to address the BTOD weaknesses identified earlier: 1) adaptive transit strategies and 2) adaptive land use strategies.

Many factors are considered in the process of recommending these strategies:

First, BTOD projects are primarily located in urban areas rather than in rural areas. Compared to rural areas, urban areas typically have higher population densities and higher transit demand.

Second, BTOD’s transit-side planning involves different geographic scales: system (network) level, route level, and station level. The bottom line is to have a car-like transit system while possessing attributes of rail permanence.

Third, BTOD’s land use-side planning involves multi-sector coordination.

Due to the symbiosis between transit and land use, adaptive transit strategies and adaptive land use strategies are intertwined and must be considered as a whole.

Adaptive Transit Strategies

This set of adaptive transit strategies includes three levels of measures for urban areas:

Level 1: Build a Tiered Transit System in the urban area

This tiered transit system can adopt a hub-and-spoke model, similar to that used in airline industry, to reorganize the transit network. Transit hubs - such as the Central Business District and major population and employment centers - would be connected by trunk lines (e.g., BRT routes, metro rail, and other high-capacity routes), with local bus lines serving as feeders to these trunk lines. Figure 2 illustrates the difference between point-to-point and hub-and-spoke networks.

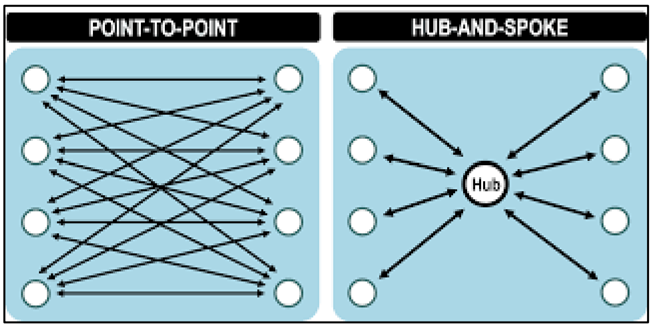

Figure 2. Point-to-Point (Left) versus Hub-and-Spoke (Right) Networks
(Source: https://transportgeography.org/contents/chapter2/geography-of-transportation-networks/point-to-point-versus-hub-and-spoke-network/)

For example, Los Angeles County's transit system consists of multiple components, including Metro Rail (Tier 1), Metro Busway (Tier 2), and Regional Connector (Tier 3).

In addition, this transit network should also contain transfer hubs to facilitate seamless, timed intermodal transfers.

Level 2: Upgrade Regular Bus to Bus Rapid Transit

Upgrading the bus transit mode from regular bus service to Bus Rapid Transit (BRT) is a critical step toward making BTOD more successful and sustainable. See Figure 3 for a photo of Bus Rapid Transit in Richmond, Virginia.

Figure 3. Bus Rapid Transit Photo
(Source: https://www.google.com/search?sca_esv=dde5d8e9a1f0dd6b&q=Bus+Rapid+Transit&udm=2&fbs=AEQNm0Aa4sjWe7Rqy32pFwRj0UkWd8nbOJfsBGGB5IQQO6L3JzWreY9LW7LdGrLDAFqYDH2woUsp5q8yOe1Ezp2_yrNmR3SpMLBW2m9pijhRidUVljMe6s385gLbwtoseHGE3PirdtBa7R2n6ot3cd6KRCLlzIXSDqsBw0NRktcJbKsDrfaLwFlF9i9YBKgL7HwCAlasi2ImQI9hSR0CPdsggmI_DuFfjg&sa=X&ved=2ahUKEwiEudjd8s6KAxXAle4BHUqjL70QtKgLegQIEhAB&biw=1024&bih=402&dpr=1.88)

BRT can overcome several key weaknesses of BTOD:

- BRT typically involves exclusive busways, which enhance the system’s permanence, identity, image, and reliability. This, in turn, can attract more development and investment around stations.
- BRT features a new exterior design, color scheme, and station layout, giving it a modern look that can boost public perception and increase ridership.
- BRT offers significantly better operating performance compared to regular buses, with faster speeds, more frequent service, no transfers between feeder and trunk lines, fewer stops, and greater comfort. These improvements make BRT more competitive than regular buses and, in some cases, even more competitive than light rail, especially given its lower capital costs.
- Since BRT carries fewer stigmas than regular buses, it is more attractive to higher-income riders and can facilitate a modal shift from cars to transit.

BRT Systems have many positive land development benefits, as shown in Table 3 (Levinson et al., 2003).

Table 3. Land Development Benefits of BRT Systems

Busway System	Land Development Benefits
Pittsburgh East Busway (9.1 miles)	59 new developments within a 1500-ft radius of station. $302 million in land development benefits, of which $275 million was new construction. 80% is clustered at station.

Ottawa Transitway System (19.3 miles)	$1 billion in Canadian dollars ($C) in new construction at Transitway stations
Adelaide Guided Busway (7.5 miles)	Tea Tree Gully area is becoming an urban village.
Brisbane South East Busway (10.25 miles)	Up to 20% gain in property values near busway. Property values in areas within 6 miles of station grew 2 to 3 times faster than those at greater distances.

In State of Washington, four completed BTOD projects in King County resulted in significant housing price premiums. Specifically, the sales prices of single-family homes located within 0.5 miles of a transit center were 3–5 percent higher than those of similar homes located more than 1.0 mile away from the transit center (Shen et al., 2018).

Of course, actual BRT project implementation may encounter some difficulties. For example, in the Bogota and Quito BRT cases, mistrust between public and private actors regarding urban development dynamics is an important barrier to promoting TOD. The presence of a strong public agency seems to be a necessary condition for a comprehensive transformation of the built environment Around BRT Sites (Vergel-Tovar, 2023).

Level 3: Other Improvements

There are also some non-BRT adaptive transit measures in non-urban areas. For the spread-out low-density suburbs or exurbs in China, the following adaptive transit measures have been recommended: 1) the deviated fixed-route service; 2) the timed transfers at transit hubs; 3) small vehicles; 4) other services such as demand-responsive service, subscription commute bus, etc, which are similar to the paratransit services in some American cities (Yang et al., 2008).

Adaptive Land Use Strategies

This set of strategies includes the following three core planning measures:

Level 1: Coordinate Transportation and Land Use Planning Processes

Coordinating transportation and land use planning is crucial, especially in the vicinity of a transit station. The following concrete measures are particularly important:

- **Integrated Planning Across Development Phases**: Bus transit and land use planning for BRT station areas should be closely coordinated and integrated throughout all stages of development—planning, design, and construction. For instance, the city's general plan, managed by the Planning Department, includes a circulation element to address transportation concerns, ensuring that transit systems are well-connected with surrounding land uses.
- **Environmental Impact Assessments**: At the same time, local transportation department should conduct environmental impact assessments that consider the effects of local land uses and zoning ordinances. This ensures that transportation planning accounts for existing and potential land uses in the area, fostering an environment that supports transit-oriented development.

See Figure 4 for an example (Lin & Zong, 2006).

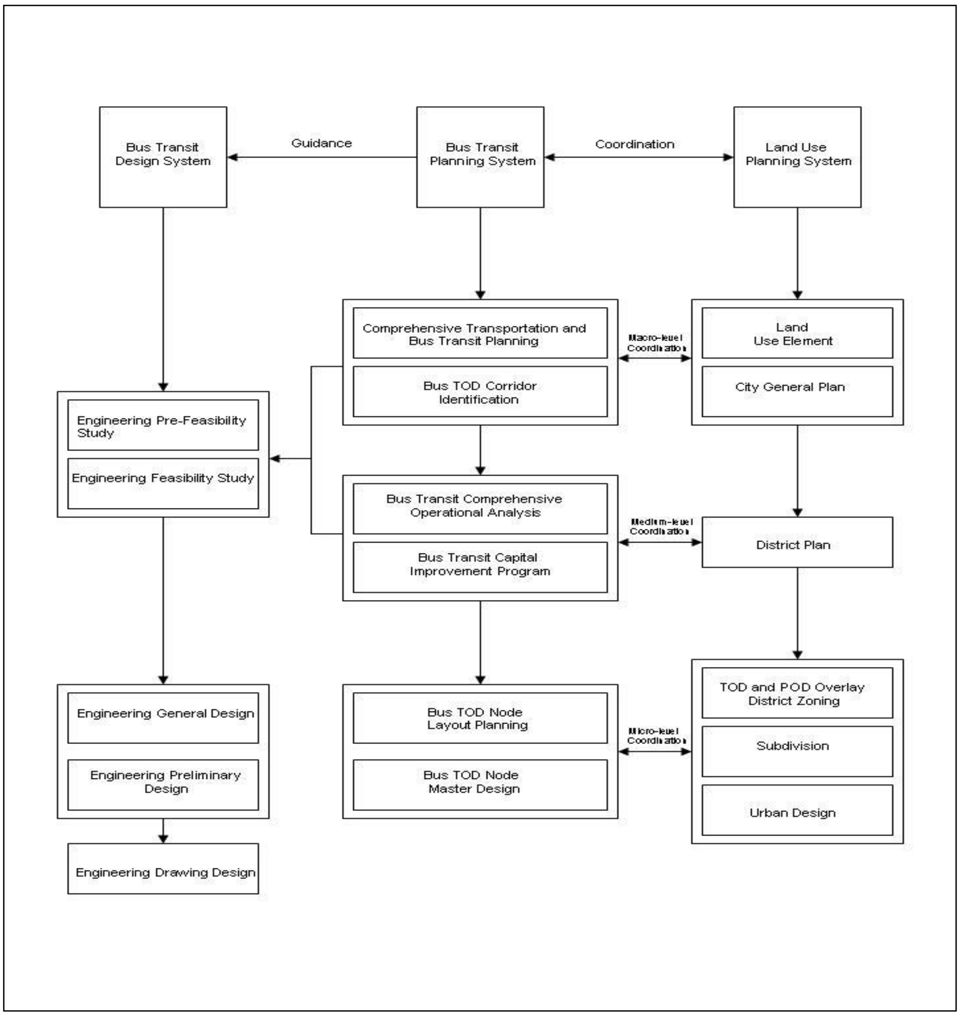

Figure 4. The TOD-Based Bus Transit Planning and Design System

- **Create a TOD Overlay District**: Establish an overlay district in zoning to encourage mixed-use and moderate-to-high-density development around transit stations, supporting public transportation. This district should include all land uses that are supportive of transit.
- **Establish a Pedestrian Overlay District (POD)**: This district aims to preserve and promote pedestrian-friendly character of commercial areas, enhancing street life and activity. It regulates building orientation, design, accessory parking facilities, and prohibits certain high-impact, automobile-oriented uses.
- **Local Government Support**: Since land use regulation largely falls under jurisdiction of local governments, securing their support is essential for successful BTOD development.
- **Offer Density Bonuses**: Implement density bonuses to incentivize mixed-use and high-density development near transit stations.
- **Develop Pedestrian-Friendly Infrastructure**: Build sidewalks, street furniture, and other facilities that prioritize pedestrians, encouraging walking as a primary mode of transportation.
- **Consider the 7-D Framework**: BTOD design should consider its impacts on 7 Ds—Density, Diversity, Design, Distance, Destination, Demand Management, and Dissonance—as these factors are crucial to the success of BTOD.

Level 2: Encourage Public/Private Partnerships

- **Private Sector Involvement**: The private sector plays a crucial role in transit-joint development projects by donating land, paying in-lieu fees, and contributing development impact fees.
- **Engagement of Key Professionals**: Private consulting firms, land surveyor firms, design companies, real estate agents, and lending institutions are essential to the success of BTOD projects and should be actively engaged throughout the process.

Level 3: Strengthening Public Participation and Community Outreach

- **Engage the Community Early**: Community support for public transportation, bus transit-oriented development, and the construction of bus lanes is essential. Strengthening public participation and outreach early in the process helps address the public's biases and perceptions regarding the undesirability of bus transit.

- **Involve All Stakeholders**: Successful BTOD implementation requires the collaboration of transit operators, highway agencies, and the general public. Therefore, it is crucial to include all relevant stakeholders as formal participants in the planning process.
- There are many public engagement mechanisms or techniques, such as: forming Technical and Policy Advisory Committees, holding public forums, stakeholder meetings, and design charrettes, conducting surveys, etc.
- **Marketing TOD**: Effectively marketing TOD is key to achieving several goals: increasing public knowledge and awareness of TOD, attracting high-quality development, boosting ridership of mass transit, providing amenities and services not currently available, and revitalizing local economy.

The aforementioned adaptive transit and land use strategies represent generalized approaches for BTOD. These two sets of strategies are empirically utilized in BTOD planning practices across the US.

Challenges of BTOD Implementation: A Summary

Implementing Bus Transit-Oriented Development (BTOD) — a planning strategy that promotes dense, mixed-use, pedestrian-friendly development around bus transit corridors — presents several challenges. The main ones are summarized in Table 4.

Table 4. Potential Challenges in BTOD Implementation

Challenge	Description
1. Perceived Inferiority to Rail	• Public perception often favors rail-based TOD (e.g., light rail or subways) over bus systems, which can be seen as less reliable or prestigious. • This can affect political and community support, investment attraction, and long-term commitment.
2. Lack of Permanent Infrastructure	Unlike rail lines, bus routes can be easily rerouted, reducing confidence for developers and investors in the long-term stability of transit service. This flexibility becomes a disadvantage when permanence is needed to anchor real estate development.
3. Zoning and Land Use Conflicts	Existing zoning laws may not support higher density or mixed-use development near bus corridors. The higher property value may conflict with the provision of affordable housing, causing an equity concern. Land use changes require lengthy approvals, community outreach, and sometimes political negotiation.
4. Funding and Investment Limitations	• Public funding often prioritizes rail projects over bus infrastructure, which can hinder the development of high-quality bus corridors. • Private developers may be less inclined to invest in BTOD due to the perceived lower return on investment.
5. Lack of High-Quality Bus Service	• Without features like dedicated lanes, frequent service, real-time info, and well-designed stations, buses may fail to anchor TOD. • Inconsistent or poor service undermines the potential benefits of development near bus stops.
6. Community Opposition	• Local residents may resist densification due to concerns about traffic, gentrification, or changes to neighborhood character. • The stigma associated with bus ridership can also fuel NIMBY (Not In My Backyard) sentiments.
7. Coordination Challenges	Effective BTOD requires collaboration between transit agencies, urban planners, private developers, and communities. Misalignment in goals or timing can lead to poorly integrated projects or underutilized developments.
8. Environmental and Spatial Constraints	• Some bus corridors may run through areas not suitable for redevelopment due to environmental constraints, lack of space, or fragmented land ownership.

SELECTED BTOD PLANNING PRACTICES IN THE US

This section introduces five BTOD planning practices in the US. These TOD projects are in different project development phases: planning, design, construction, and operation.

Boulder Transit Village, Colorado

Project Location

This 160-acre Transit Village area is located in the City of Boulder, State of Colorado, US. It is in the geographic center of the community, and is close to 29th Street, a major shopping and entertainment destination. Pearl Street connects the area to Downtown Boulder. Separated by the Union Pacific railroad tracks, the project includes Phase 1 (west of the tracks) and Phase 2 (east of the tracks). See Figure 5 for details.

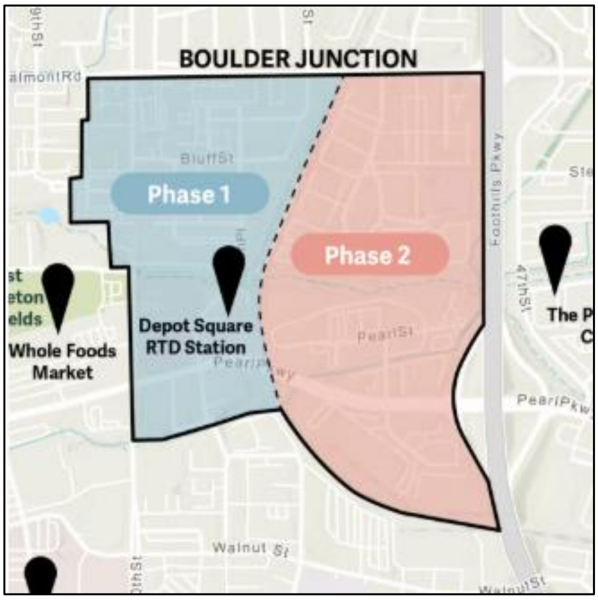

Figure 5. Boulder Transit Village Development Phases

(Source: https://bouldercolorado.gov/projects/boulder-junction-phase-2)

Transit Facilities

The Boulder Transit Village is designed as a multi-modal regional commuter rail, bus, and Bus Rapid Transit (BRT) transit station of Regional Transportation District (RTD).

The core of Boulder Transit Village Phase 1 is located at the northeast corner of Pearl Parkway and 30th Street in Boulder, Colorado.

The total land area spans approximately 11 acres.

TOD Facts

The Boulder Transit Village Phase 1, located west of the railroad tracks in Boulder Junction, is a mixed-use development focused on transit-oriented development (TOD). It aims to create a vibrant, pedestrian-friendly area with housing, retail, and jobs, while also facilitating easy access to regional transportation. Phase 1 is nearing completion, with the city prioritizing the implementation of Phase 2 east of the tracks.

At present, Phase 1 of this project has completed nearly 1500 workforce and affordable housing units, RTD BRT station, new hotel, restaurants, shops, and office space, protected bike lanes and pedestrian zones, preservation of the historic depot building, flood protection for the community and surrounding businesses.

Phase 2 is in progress, which includes updates to proposed land uses to allow greater flexibility for many types of uses and overall density, and proposes additional transportation connections to ensure the area is more walkable and pedestrian friendly.

Project Funding

Funds for site selection, concept planning, and land purchase were primarily provided by the City of Boulder and the Regional Transportation District (RTD).

The City and RTD have secured a $7.8 million federal grant to fund master planning, site planning, and design, as well as the construction of the first phase of the regional bus/BRT transit station.
Housing and commercial project elements will likely be financed by a future private developer and a public/private partnership.

Relationship to the BTOD Strategies Proposed
This project underscores the critical importance of public (City of Boulder)/public (RTD) and public (City of Boulder)/private (private developer) partnerships. Governmental initiative and support are vital to the success of the project.

District NoHo, Los Angeles

Project Location

As shown in Figure 6, District NoHo is located in the North Hollywood ("NoHo") Arts District of Los Angeles' San Fernando Valley, a region with over 1.8 million residents.

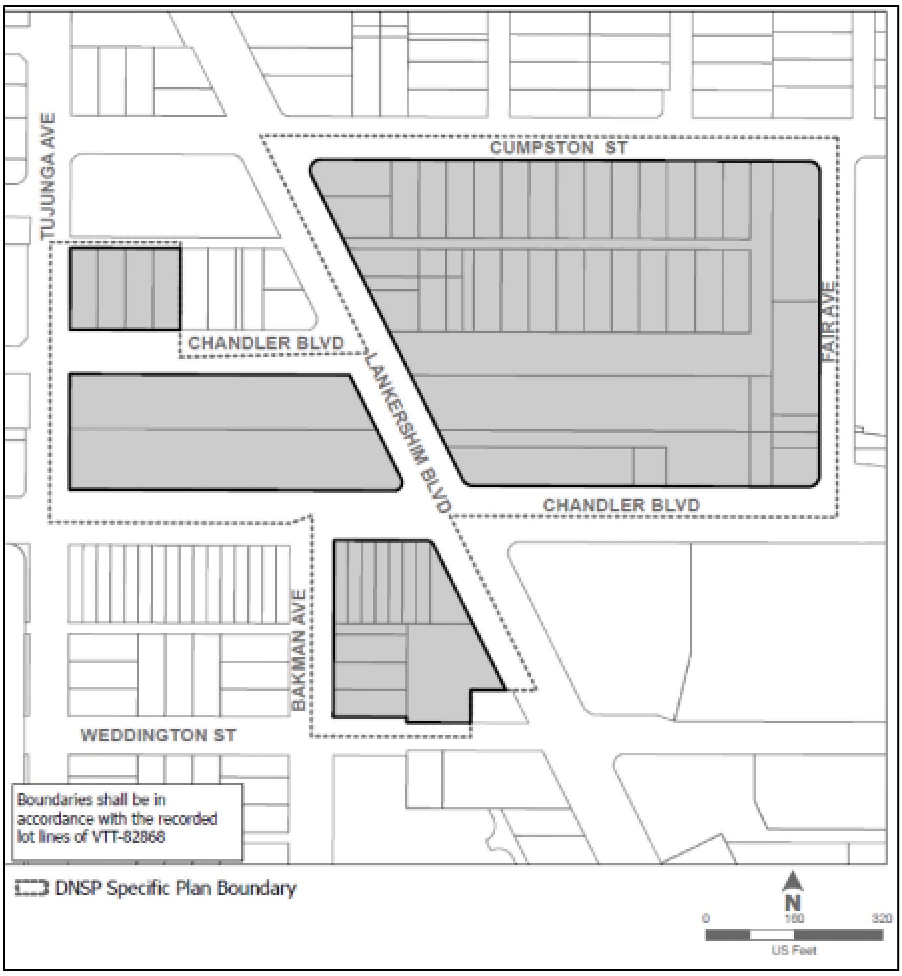

Figure 6. District NoHo Boundary Map

(Source: https://planning.lacity.gov/odocument/78663e3f-1e0c-4fbd-97de-cdbb927357aa/SP_23-1264-S1_ord_188144_4-22-24.pdf)

Transit Facilities

The 15.87-acre site is uniquely situated directly atop the Metro NoHo Station, the major junction of the Red Line subway, Orange Line Bus Rapid Transit, and over 15 municipal bus lines, serving 28,000 daily transit riders and providing over 1,100 parking stalls. Trammell Crow Company (TCC), in partnership with MetLife Investment Management, is currently operating under an Exclusive Negotiating Agreement with Los Angeles Metro to master plan the development, obtain the entitlements, and execute the vertical development.

TOD Facts

District NoHo is a two-million-square foot master-planned, mixed-use development comprised of market-rate multifamily units, developed by TCC's residential subsidiary, High Street Residential; Class-A creative office space; place-making retail; and affordable multifamily units. The project will be developed in up to nine phases on individual, 99-year ground leases with the Los Angeles Metropolitan Transit Authority ("Metro").

The project would re-develop 15.6 acres (63,000 m^2) with 600,000 square feet (56,000 m^2) of commercial space and nearly 1500 residential units in three high-rise towers. The project was awarded to Trammell Crow Company and High Street Residential by the Los Angeles Metro board. See Table 5 for its land use control.

Table 5. Permitted Floor Area and Density by Land Use Category

Land Use Category	Permitted Floor Area	Permitted Density
Office	580,374 SF	N/A
Retail or Restaurant	105,125 SF	N/A
Residential, Multi-family	1,523,528 SF	1,527 DU
Total	2,209,027 SF	1,527 DU

Source: District NoHo Specific Plan.

This TOD project started in Quarter 3 of 2022, and will be completed in Quarter 3 of 2032.

Project Funding

In the future, North Hollywood plans a $1 billion mixed-use development at Lankershim and Chandler, surrounding the Metro B and G line terminals. Funding for $100,000 in transit amenities came from a Federal Transit Administration's Livable Communities grant. Local developers involved in the project include the Los Angeles Neighborhood Initiative (LANI), North Hollywood Community Forum, among others.

Relationship to the BTOD Strategies Proposed

This BTOD case highlights the vital importance of community outreach and public/private partnerships in creating an adaptive land use pattern conducive to transit-oriented development. By giving community groups control over the funds used in their neighborhood, ongoing public involvement and engagement were successfully promoted.

Martin Luther King Jr. East Busway, Pittsburgh

Project Location

The Martin Luther King Jr. East Busway is a two-lane bus-only highway serving the city of Pittsburgh and many of its eastern neighborhoods and suburbs. See Figure 7 for the busway alignment map.

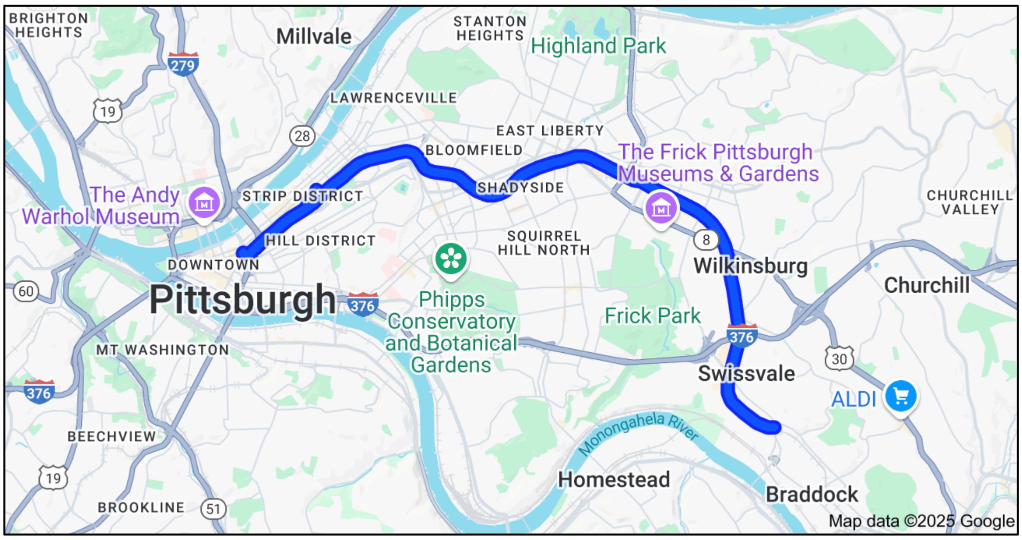

Figure 7. Martin Luther King Jr. East Busway Map

(Source: https://www.google.com/search?q=Martin+Luther+King+Jr.+East+Busway+Map&sca_esv=45c41d3e543101a5&source=hp&ei=XhPaZ8fFOMGGptQP9OijqAk&iflsig=ACkRmUkAAAAAZ9ohbjSU6HwZy79Q2AfgAuwnTK4s-Hjm&ved=0ahUKEwjH7MyQ9ZSMAxVBg4kEHXT0CJUQ4dUDCBg&uact=5&oq=Martin+Luther+King+Jr.+East+Busway+Map&gs_lp=Egdnd3Mtd2l6IiZNYXJ0aW4gTHV0aGVyIEtpbmcgSnIuIEVhc3QgQnVzd2F5IE1hcDIFECEYoAEyBRAhGKABMgUQIRigATIFECEYoAFIjBRQywxYywxwAXgAkAEAmAF_oAF_qgEDMC4xuAEDyAEA-AEC-AEBmAICoAKQAagCCsICChAAGAMY6gIYjwGYAw3xBVn9QXLGEMsVkgcDMS4xoAeEBLIHAzAuMbgHgwE&sclient=gws-wiz)

Transit Facilities

The 9.1-mile-busway runs from Penn Station in downtown Pittsburgh to Swissvale, with 10 BRT stations (Penn Station, Herron, Negley, East Liberty, Homewood, Wilkinsburg, Hay Street, Hamnett, Roslyn, Swissvale).

TOD Facts

The major TOD initiatives along this busway include, but are not limited to the

Following projects:

1. **East Liberty Transit Center (EL TC):**

A multimodal transit station and mixed-use development on the busway, including housing, parking, bike facilities, and retail. The TOD project will build a series of interconnected infrastructure elements (the Station and Site Projects) that will allow for the building of a $77 million privately-funded development consisting of 360 multi-family housing units and 43,000 square feet of retail and commercial space (the Vertical Project). The multiple elements of the project include: Converting one-way streets to two-way traffic, new construction of a modern two-level bus station, new bike/walking infrastructure, new street signs, better lighting, and increased pedestrian accessibility.

2. **Wilkinsburg and Brushton Stations:**

Plans to create a new Wilkinsburg Station as a major transit hub and a new station at Brushton Avenue to improve accessibility and integrate TOD.

3. **Herron Station Area Plan:**

A plan to improve access to the station and the station design itself to make it more comfortable, user-friendly, and attractive.

4. Building on the East Busway (BOTEB):

A planning effort exploring opportunities for new stations, transit-oriented development, and multimodal improvements along the busway. At present, PRT is conducting design for three major station areas: Wilkinsburg Station Area and Brushton Station; Larimer Station; and Baum-Centre Station.

Below are summary facts of this busway TOD project:

- 59 new developments within a 1,500-foot radius of the stations
- $302 million in land development benefits, of which $275 million was for construction (80% clustered around the station)
- New construction and renovation of existing buildings

The most common uses for new developments are retail, office, and residential.

Project Funding

The Port Authority of Allegheny County (now rebranded as Pittsburgh Regional Transit, or PRT) is receiving federal funding and additional local funds for Transit-Oriented Development (TOD) projects along the East Busway, specifically to study an extension of the Martin Luther King Jr. East Busway. A 2022 Federal Transit Administration (FTA) Pilot Program for TOD Planning Program award of $556,500, along with PRT's Capital Budget, is funding the planning phase of this project. Additionally, a $142.3 million US Department of Transportation grant is supporting various projects, including improvements to the Parkway East and East Busway.

Relationship to the BTOD Strategies Proposed

This case embodies both the adaptive transit and adaptive land use strategies outlined in the preceding section. The upgraded bus transit services, provided by the Busway, have attracted significant development near the bus stations. In turn, these BTOD developments boost bus transit ridership. The public/private partnership has been crucial to the success of the project.

Uptown District, San Diego

Project Location

The Uptown District in San Diego is roughly bordered by Interstate 5 on the west, Old Town San Diego on the north, the existing height limit boundaries on the east, and Washington Street on the south. Uptown encompasses several distinct neighborhoods, including Hillcrest, Mission Hills, Bankers Hill/Park West, University Heights, Middletown, and the Medical Complex. See Figure 8 for its boundary map.

Figure 8. Uptown District Location Map

(Source: https://missionhillsbid.com/proposed-uptown-community-plan-update-special-meeting/san-diego-uptown-community-map-boundries/)

Transit Facilities

Trolley Service: The UC San Diego Blue Line Trolley extension, which began service in November 2021, connects the Uptown District to downtown San Diego and beyond. The Hillcrest station, located at 5th Avenue and University Avenue, serves as a key stop in the Uptown area. This line provides a convenient and efficient mode of transportation for commuting and leisure travel.

Bus Routes: MTS operates several bus routes that serve the Uptown District and provide extensive coverage, making it easy to travel within the Uptown District and to other parts of San Diego.

TOD Facts

The Uptown District is a 14-acre mixed-use bus TOD developed under the leadership of the City of San Diego. The primary goal of the project was to create a mixed-use development that would be well-integrated with the surrounding community. The project faced little public opposition, largely because it required minimal changes to the existing community structure.

The 14-acre mixed-use development (Retail on ground floors with housing above) in the Hillcrest neighborhood was built on the site of an abandoned department store and parking lot. Multi-family housing is common, especially near University Avenue.

Many amenities are located within Walking Distance: Grocery stores (Trader Joe's, Ralphs), healthcare (UCSD Hillcrest), entertainment, and restaurants.

In summary, this Uptown District TOD project covers 14 acres and is a mixed-use bus TOD, featuring:

- 318 housing units. Residential density is over 20 units per acre, far greater than the city average of less than three units per acre.
- 145,000 square feet of retail and commercial space
- A 3,000 square-foot community center

Uptown is increasingly becoming a model for sustainable infill development, reducing car dependency, with an emphasis on green space integration, urban tree canopy, and reduced parking minimums.

Project Funding

The Uptown project was funded by the City's redevelopment agency ($9 million) along with private companies, particularly the land developer Oliver McMillan / Odmark & Thelan.

Relationship to the BTOD Strategies Proposed

This BTOD project fully aligns with the BTOD strategies proposed in this paper.

This project reflects the following smart growth principles:

- Mix land uses
- Compact building design
- Range of housing choices
- Walkable neighborhoods
- Distinctive and attractive places
- Direct development toward existing communities
- Variety of transportation choices
- Community and stakeholder participation

The Pulse BRT in Richmond, Virginia Region

Project Location

The "Pulse" BRT project of the Greater Richmond Transit Company (GRTC) is a BRT system in Richmond, Virginia, connecting Willow Lawn (West End) and Rocketts Landing (East End) with a 7.6-mile route along Broad and Main Streets. See Figure 9 for its alignment and surrounding areas.

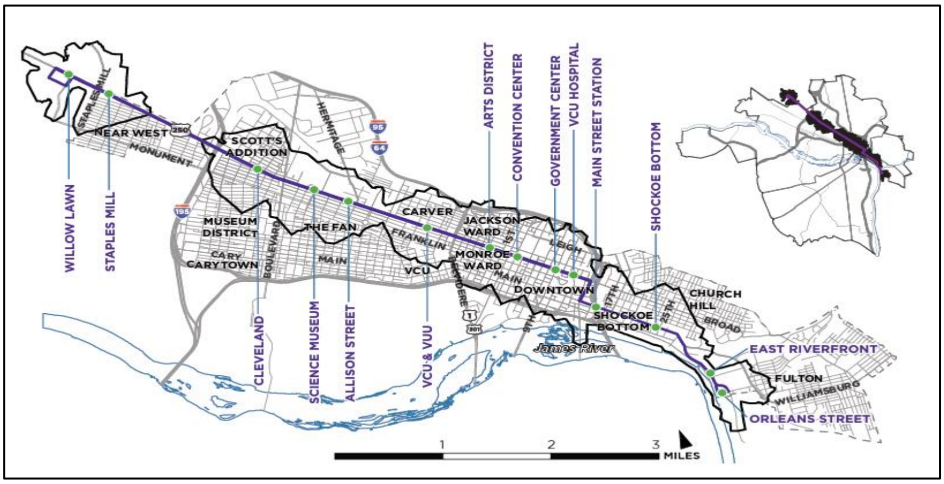

Figure 9. GRTC Pulse Rout

(Source: https://www.rva.gov/sites/default/files/2021-01/PulseCorridorPlan-July2017.pdf)

Transit Facilities

In the northwest-to-southeast direction, the GRTC Pulse BRT Route has the following 14 stations:

- 1. Willow Lawn (Broad Street and Willow Lawn Drive)
- 2. Staples Mill (Broad Street and Staples Mill Road)
- 3. Scott's Addition (Broad and Cleveland Streets)
- 4. Science Museum (Broad Street and Terminal Place)
- 5. Allison Street (Broad and Allison Streets)
- 6. VCU & VUU (Broad and Shafer Streets)
- 7. Arts District (Broad and Adams Streets)
- 8. Convention Center (Broad and Fourth Streets)
- 9. Government Center (Broad and Ninth Streets)
- 10. VCU Medical Center (Broad and Twelfth Streets)
- 11. Main Street Station (Main Street east of I-95 bridge)
- 12. Shockoe Bottom (Main and Twenty-fourth Streets)
- 13. East Riverfront (Main and Nicholson Streets)
- 14. Rocketts Landing (Orleans and Old Main Streets)

The Pulse BRT offers fast, frequent, and free service, using smart traffic signals and platform-level stations. The Pulse BRT runs every 10 minutes on weekdays until 7 PM, every 15 minutes during evenings and weekends, and every 30 minutes late night.

TOD Facts

The three goals for future development along the Pulse Corridor are (City of Richmond, 2017):

- **Compact & Mixed:** Development around Pulse stations has a rich mix of uses and is compact, sustainable, and high-quality.

- **Connected**: Pedestrians and cyclists access homes, jobs, entertainment, everyday needs, and transit in a safe, pleasant, and engaging public realm.
- **Thriving & Equitable:** New development includes housing for all income levels and new jobs. Increased development in the Corridor supports Pulse ridership with a goal of over $1 billion in additional assessed value over the next 20 years.

Development along the Corridor will seek to follow six guiding principles of TOD: 1) Mixed-Use; 2) Viable Transportation Options; 3) Dense, Compact Development; 4) Historic Preservation; 5) Transit Access; 6) Connectivity.

The Pulse Corridor Plan has made station-area recommendations. The key station area visions are shown in Table 6.

Table 6. Key Station Area Visions along the Pulse Corridor

Station Name	Station Area Vision
Staples Mill	This station is transformed into a walkable node with new, denser, mixed-use buildings, and streetscape improvements along W. Broad Street and Staples Mill Road. As density of activity grows, there is a new infill Pulse Station at Malvern Avenue and W. Broad Street.
Scott’s Addition	This station area unifies two vibrant, distinct, pedestrian-oriented neighborhoods by maximizing the potential of under-utilized parcels and supporting new forms of development that are walkable, dense, and mixed-use. Scott’s Addition continues its evolution as a mixed-use neighborhood, and W. Broad Street transforms into a high quality urban avenue that is safe to cross, while becoming a destination in its own right for residential, office, retail and compatible entertainment uses.
Science Museum	The significant redevelopment of low-density parcels at W. Broad Street and Boulevard creates a prominent node with signature architecture that capitalizes on this strategic gateway to the city. New, taller, mixed-use development that promotes walkability extends down the north side of W. Broad Streets toward the Science Museum’s landmark public grounds and the Pulse Station from the Boulevard gateway intersection. The potential for new development across from the new Science Museum green space means a singular opportunity for a high-quality urban avenue which invites visitors to the Museum, with mixed-use infill along the south side of W. Broad Street. The preservation of historic building stock and adequate buffers to residential neighborhoods is a priority.
Allison Street	Major redevelopment around the Allison Station breaks up superblocks by reintroducing the street grid and creating a walkable environment with high-density, mixed-use buildings on the north side of W. Broad Street; medium-density, mixed-use buildings infill the south side of W. Broad Street. As redevelopment proceeds, an infill Pulse station at Lombardy Street facilitates transit connections and access to jobs, daily shopping, and homes at this intersection. Redevelopment occurs on sites with auto-oriented uses and deep setbacks that currently disrupt the historic pattern of the street-oriented commercial corridor. The preservation of historic building stock and adequate buffers to residential neighborhoods is a priority.
VCU & VUU	The area around the VCU & VUU Station continues to develop as a street-oriented commercial corridor and urban avenue, providing shopping, dining, and housing for students and neighborhood residents alike. The station area continues to benefit from its proximity to the VCU Monroe Park campus and continues to be a job center and nexus of activity with services and cultural attractions for the region. The intersection of Belvidere and W. Broad Streets becomes a signature intersection with new development complementing the VCU Institute for Contemporary Art with prominent architecture.
Arts District	Located at the heart of the Downtown Arts District, this Pulse Station creates a hub of activity at the newest urban plaza on the Pulse Corridor, Maggie L. Walker Plaza. Historic buildings are preserved and complemented by denser development on vacant lots that generates more activity through a greater concentration of residents, shoppers, workers, and tourists who are attracted to the residential options, retail and restaurant destinations, jobs, and cultural attractions, including galleries, parks, museums, theaters, and other such destinations throughout Jackson Ward, Monroe Ward, and along W. Broad Street.

Convention Center	The gap in vibrant uses between the Arts District and the Government Center Stations is filled as vacant and underutilized parcels around the Convention Center are developed to include uses that enhance the Convention Center visitor experience and also provide for the daily needs of residents and workers in the area. Monroe Ward transforms into a denser, more complete neighborhood and more uses along Broad Street are created to serve these future residents. City-owned property fosters mixed-income redevelopment.
Main Street	Main Street Station continues to serve as the multi-modal transportation hub of Richmond by augmenting its offerings to include bikeshare, BRT service, and high-speed rail service. Uses around Main Street Station support the bustle of a train station with amenities that serve commuters, visitors, and a growing residential and employment base. The Shockoe Bottom neighborhood better connects to amenities such as the Virginia Capital Trail and the Canal Walk, and new development supports further public space amenities like the 17th Street Farmer's Market Plaza and the Low Line. Ongoing efforts to commemorate, memorialize, and interpret the historic and cultural significance of Shockoe Bottom are supported as a key part of the neighborhood identity and are a priority for City investment.
Rocketts Landing	This station area provides easy access to the James River and amenities that support the Riverfront. Fulton Gasworks is remediated and redeveloped as part of a much larger revitalization along the entire East Riverfront. Future development along the Riverfront embraces the values of river views while facilitating appropriate development. The Orleans Station area is a dense, walkable destination for workers, residents, and visitors. Residents of Greater Fulton easily access the terminus station via Orleans Street which is a "great street" featuring active ground floor uses and a walkable environment.

Project Funding

GRTC Pulse TOD projects are funded through a combination of federal, state, and local sources, including grants and partnerships. The GRTC and City of Richmond received a $750,000 grant from the Federal Transit Administration for planning Transit-Oriented Development (TOD) on Chamberlayne Avenue. The GRTC also receives funding from the Central Virginia Transportation Authority, which includes local, state, and federal sources. The Central Virginia Transportation Authority's funding is a combination of regional sales and use tax (0.7%) and wholesale gas and diesel tax (7.6 cents and 7.7 cents).

Relationship to the BTOD Strategies Proposed

The GRTC Pulse BRT system in Richmond, Virginia, is designed to strategically align with and support mixed-use, transit-oriented land uses. This approach aims to increase transit ridership and encourage more vibrant, walkable neighborhoods. The Pulse BRT stations are intentionally located near land uses that foster walking and transit use, such as grocery stores, rather than simply across from less transit-supportive uses like automotive parts stores.

CONCLUSION

Compared to RTOD, BTOD remains a relatively minor player. However, BTOD can become more successful and sustainable if adaptive transit and land use strategies are implemented in a coordinated and effective manner.

On the transit side, adaptive transit strategies aim to improve bus transit in several key areas: enhancing its operating performance, boosting its external image, and better serving bus riders. These improvements can be achieved through a combination of macro-, intermediate-, and micro-level bus transit planning measures. At the heart of these strategies is the implementation of Bus Rapid Transit (BRT) technology, which will play a critical role in shaping the future success of BTOD.

From a land use perspective, it is essential to align bus transit planning with land use planning to ensure that transit-supportive developments are created around bus stations. Additionally, strengthening public-private partnerships and community outreach will help foster greater involvement from private developers and the general public, which is key to the success of BTOD projects.

The proposed adaptive transit and land use strategies are supported by real-world examples from various BTOD planning practices in the US, demonstrating their practical applicability and potential for success. The success of BTOD projects requires the public-public partnership, public-private partnership. The public sector plays a leading role in this process.

Despite the efforts made in this research, the paper still has several limitations. First, several BRT-based TOD initiatives only have plans or are still under development, thus lacking quantitative performance data. Due to this reason, it is difficult if not impossible to realistically assess the city-shaping effects of BRT projects. Second, there are few bus-based TOD projects in the US, which limit the exploration of BTOD planning practices and planning lessons. Third, the absence of project funding prevents a comprehensive planning agency survey from being conducted. This limitation constrains the modeling simulation.

ACKNOWLEDGMENT

I would like to thank the financial support in part received from the National Natural Science Foundation of China Grant No. 71774133.

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