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Transit-Oriented Data: The Importance of Data and Coordination to Transit-Oriented Urban Transformation

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Planners, academics, and policy-makers recognize the importance of transit-oriented development (TOD) in building resilient and sustainable cities, though implementation has not always lived up to expectations. TOD is an example of a network governance problem as actors from multiple organizations (developers, lenders, and multiple government agencies at different scales), each with their own goals, must come together for an extended time to manage risk and implement a single solution. Less well-studied is the importance of spatial data and state-level coordination to this task, both in identifying sites and in developing policies at the state or regional level to encourage and prioritize TOD in certain areas. This study uses a 1+n case study model, focusing on a primary case (Connecticut's TOD efforts) but using the experience of other states (MassGIS and the New Jersey Transit Villages program) to inform the primary case. Working from interviews with Connecticut stakeholders and participant observation in TOD policy development, the study explores the coordination and governance challenges surrounding state intervention as well as the role that Connecticut's weak state geospatial data play in the efforts to develop TOD projects. Connecticut was until recently one of only five states without a state geographic information officer, making it a "black swan" case that can illuminate the perhaps unseen role that strong spatial data infrastructures play in other states' policymaking. Moreover, the comparison between New Jersey's Transit Villages Program and Connecticut's efforts signal that more work is needed to manage the difficult paradigm shift toward state support of TOD.

Keywords: TOD, coordination, walkability, state planning, GIS data

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INTRODUCTION

Transit-oriented development (TOD) is a term that originated from Peter Calthorpe's work in cities on the West Coast of the United States without legacy rail systems (Renne and Appleyard, 2019). It originated as a way to shift auto-oriented cities to more sustainable urban forms through the construction of "pedestrian pockets" around new transit projects (Renne and Appleyard, 2019). The context for TOD in cities with legacy rail systems and street patterns that pre-date the car is different, in that the urban fabric necessary for TOD may exist, but brownfield clean-up emanating from the industrial legacy of such cities may make new development costly.

With some notable exceptions (Renne, 2008), there has been relatively little research on state-level policymaking around TOD, particularly around the prioritization of new-build vs. legacy sites. Connecticut, Massachusetts, and New Jersey all contain legacy rail, and have explored or completed the development of new transit lines recently, but Connecticut's TOD efforts lag behind the other two. New Jersey's Transit Villages Initiative began in 1999, while Connecticut's grant program began in 2012.

This paper benchmarks Connecticut's efforts to support transit-oriented development against its peer states, New Jersey and Massachusetts. We identify New Jersey's Transit Villages Initiative as a model for state-level coordination and municipal support, while MassGIS provides a model of robust spatial data infrastructure at the statewide level. Both Connecticut and New Jersey operate transit at the state level, and operate or have operated state grant programs for TOD, but New Jersey's Transit Villages program is older and has been in continuous operation since 1999. MassGIS was cited in interviews as a potential model for Connecticut's data struggles. Until December 2021, Connecticut was one of only a few states without a state geographic information officer (Wood, 2021). There is also no single state repository for geographic data, and no standard for commonly used layers, such as parcels. Transit level shapefiles are available where transit is operated by the state, in contract with private providers, but the availability of transit operated by local transit districts is more variable. As such, there are no statewide data on transit use or the ability to easily identify the most used lines or stops, much less an inventory of stop amenities.

The central question that we address in this paper is what effect does the lack of coordination and of robust data have on the state's TOD planning efforts? Using a 1+n case study model (Mukhija, 2010), we assess the outcomes of Connecticut's transit-oriented development policies with respect to governance and data availability, using a mixed-methods approach. We find that while the legacy cities represent many of the most TOD-ready areas along the line, the state's focus on new-build transit, a reluctance to include buses in their TOD plans, and a lack of meaningful performance metrics to guide state funding hinder TOD efforts in the state. These three effects collectively represent a failure to coordinate TOD efforts across multiple departments and policy areas at the state level. These tensions between existing and new-build TOD, and around TOD as a multimodal project are not unique to Connecticut, but New Jersey in particular provides an instructive example of how to manage these tensions.

CASE BACKGROUND

The state of Connecticut defines transit-oriented development (TOD) as "the development of residential, commercial, and employment centers within one-half mile of walking distance of public transportation facilities, including rail and bus rapid transit and services, that meet transit supportive standards for land uses, built environment densities, and walkable environments, in order to facilitate and encourage the use of those services (CGS 13b-79o)." The definition accords with Peter Calthorpe's initial conception of the idea: building out islands of dense, mixed-use, walkable neighborhoods connected by transit, and slowly expanding those islands to transition away from auto-dominated land uses (Calthorpe, 1993). However, along the Metro-North New Haven Main Line, cities are as much returning to past transit-oriented urbanism as they are building new TOD.

The New Haven Line links Connecticut's two southwestern counties, Fairfield County along the border with New York and New Haven County to its east, to New York City (**Figure 1**). Fairfield County is one of the most unequal places in the country, with wealthy suburbs interspersed with declining post-industrial cities like Bridgeport (Sommeiller and Price, 2018). Strung out along the 74 mile-line are the relatively walkable downtowns of Greenwich, Stamford, Norwalk, Fairfield, Bridgeport, Stratford, Milford, and New Haven, all built before the car dominated city streets. Some of these downtowns, notably Stamford, Bridgeport, and New Haven, were redeveloped to accommodate the car, necessitating efforts to restore the dense, mixed-use downtowns, and the transit service that once supported them (Polinski, 2015). Restoring TOD around these areas means activating and valuing the existing transit resources and walkable urban gird.

The state department of transportation is heavily involved in the provision of transit along the corridor but only tangentially involved in development. It owns the rail infrastructure and provides two-thirds of the operating subsidy for the New Haven Line, manages the parking provision at stations, and provides the operating funding for bus transit along the corridor (CTDOT, 2012). In Stamford and New Haven, the state also serves as the contractor for local bus service, while transit districts serve that function in Norwalk, Milford, and Bridgeport. Connecticut, however, is a strong home rule state, meaning the localities control the land use around stations. Connecticut has in the past been one of the few states with a state development plan, but the most recent plan was never officially approved by the state legislature and local plans are not required to be consistent with the state plan (Lewis and Knaap, 2012).

THE ROLE OF THE STATE IN TOD GOVERNANCE

TOD represents a significant challenge of coordination. TOD is an example of networked governance, requiring multiple actors from both the public and private sector to collaborate on a complicated project, manage multiple goals, and mitigate risk for an extended period (Mu and de Jong, 2016). It also in many cases requires a paradigm shift, as car-oriented regions reorient their planning strategies to conduct integrated land use and transit planning (Curtis, 2012). As such, there is an extensive literature on the challenges of implementing high-quality TOD (Curtis et al., 2009). Research has found tensions between maximizing transit's competitiveness with the car with respect to speed and shaping walkable places; the shortest distance between two points does not always run through downtown (Curtis, 2008). Similarly, TOD is manifestly a project that occurs at multiple scales, with regional transit actors interfacing with local planners to shape specific station areas, resulting in usually incremental and contextual

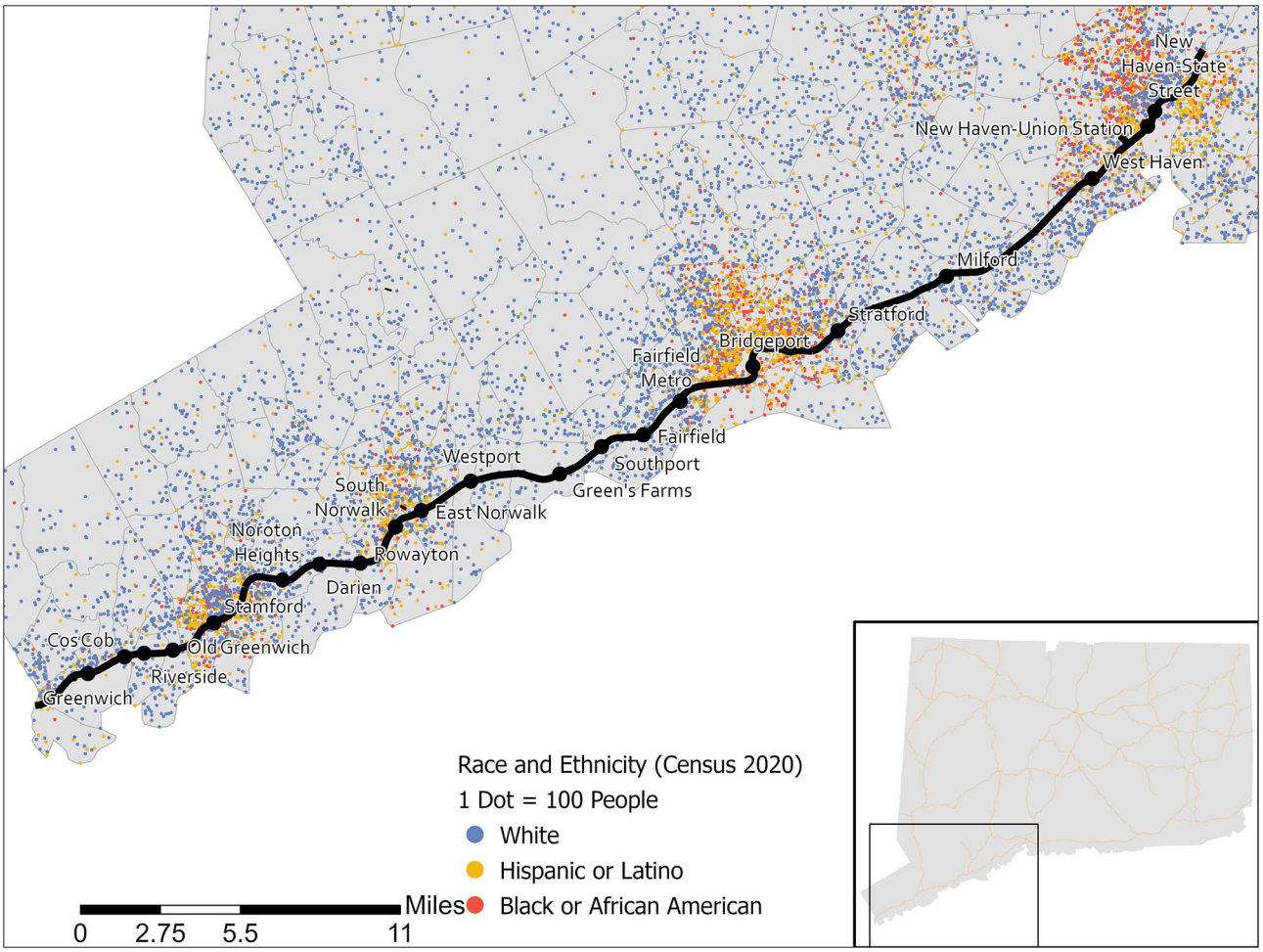

FIGURE 1 | Overview map of the Metro-North New Haven Corridor, showing racial demographics.

change (Paulhiac Scherrer, 2019). Where state/regional actors can play a larger role, as part of a redevelopment agency or land development agency, TOD outcomes may be better than when local governments are left to plan alone, though this is dependent on the state or region's commitment to TOD (Curtis, 2012). While theory suggested that coordination between transit agencies and land use planners could be improved by bringing debates within an organization, experience in Western Australia found that network building and outcome-focused regulation was more important than in-house organizational structure (Legacy et al., 2012).

Paying attention to TOD outcomes has also been a feature of the literature, drawing a distinction between transit "oriented" development, which is designed in a way to foster walkability and prioritize non-car trips, and transit "adjacent" development (TAD), located near a station but not supportive of transit for reasons of density, diversity of uses, or design (Renne, 2009). TAD developments may have cheaper housing, but those costs are offset by higher transportation costs because travel behavior is not meaningfully different between traditional suburban development and TADs (Kamruzzaman et al., 2015; Renne et al., 2016). As such, there is a two-part implementation gap at play, the first being whether to act at all on TOD principles, and the second is whether the projects that meet TOD goals.

While land use regulation remains a fiercely guarded responsibility of the local level, states play multiple roles in TOD governance (Renne, 2008). They control transportation investments and funding, and in all three states reviewed here, that funding includes significant operating assistance for transit as well as capital funding. They also can coordinate across departments to streamline permitting and support pilot programs, and in general use financial and regulatory incentives to reward towns for "doing it right" (Renne, 2008, p. 103). In the background of this coordinating role, and understudied, is the role state departments play in providing standardized data usable for performance measurement. This article explores the significance of both the coordinating function and the data function for state DOT governance.

BEST PRACTICE CASES

New Jersey and Massachusetts represent two pieces of a concerted state-wide support for TOD—multi-agency coordination providing support for municipalities and state-level GIS data coordination. Below, we lay out each program and the key lessons learned to develop a set of evaluation questions for Connecticut.

The New Jersey Transit Villages Initiative began in 1999 with the goal of supporting municipalities in providing dense, walkable districts near existing transit stations (Noland et al., 2012). Municipalities apply to a multi-agency Transit Village Task Force for a transit village designation. Transit villages are eligible for both access to a dedicated (though small, generally $1 million a year) fund and priority for other funding from the Task Force's agencies. The process of assembling the application, which includes developing ideas for TOD sites in town is as important as the funding itself, because it involves coordinating among the various town stakeholders and agencies to develop a shared vision (Munoz, 2018). Municipalities are held to a set of TOD standards found in *Planning for Transit-Friendly Land Use: A Handbook for New Jersey Communities* (Diepeveen et al., 1994). Developers also get "one-stop shopping" from state agencies, rather than having to go through separate processes with each agency (Drake, 2001). Since 1999, the program has grown from 5 to 34 municipalities, with the City of Newark the most recent addition in 2021 (Newark Gets Transit Village Designation, 2021).

In addition to the New Jersey Transit Villages program, NJ Transit has its own Transit Friendly Planning Program that assists municipalities in developing "vision" plans for transit and a Real Estate and Economic Development unit that actively solicits TOD proposals on properties owned by NJ Transit (NJ TRANSIT, 2021). NJ Transit also worked with the Voorhees Transportation Center at Rutgers to develop a transportation and land use mapping tool (NJLUTRANS.org), but the land use data have not been updated since 2017.

Massachusetts's Executive Office of Energy and Environmental Affairs developed the Massachusetts Geographic Information System (MassGIS) in the 1980's. In 2010, recognizing the value of MassGIS outside of solely environmental projects, the state moved MassGIS to the Executive Office of Technology Services and Security and maintained its board of stakeholders from across the MassGIS community. MassGIS's tools and data have been used to evaluate the effects of various plan scenarios on vehicle miles traveled (Ferreira et al., 2013) and to conduct a healthcare needs analysis (Edward and Wang, 2016). More recently, the Massachusetts Housing Partnership utilized MassGIS data to create TODex, mapping density around Greater Boston transit stations (TODEX, 2021). TODex was made possible by MassGIS's collection and standardization of each town's assessed parcel data, its creation of an address database for 911, and its maintenance of data for all transportation modes. While the Massachusetts Housing Partnership still had to supplement with private data for large, complex, mixed-use buildings, the standardized data formed the basis of an automated assessment process able to quickly compare station areas for TOD potential.

Both New Jersey and Massachusetts support municipalities in developing TOD proposals. In New Jersey, the thrust comes from the department of transportation and the transit provider, the departments which have the most to gain from TOD. While New Jersey did develop a data tool, it did not necessarily create the infrastructure for continual updates. In Massachusetts, the focus was on the GIS data, with a state agency designated to continually update and maintain the necessary data for coordination.

The examples of New Jersey and Massachusetts suggest the following questions for the Connecticut case. First, to what extent is there governance coordination at the state level to support TOD in municipalities and to what degree does it leverage the state department of transportation's vested interest in TOD? Second, how does the coordinated effort hold towns to a set of TOD standards? Third, to what extent are there useful transportation and land use data to support TOD, and if so, what does it tell us about the state's readiness for TOD?

METHODOLOGY

To answer these questions, we conducted a content analysis of the TOD plans for all towns along the Metro-North main line that had conducted studies and then contextualized the findings with 13 interviews. On the quantitative side, after a fruitless search for standardized land use data, we analyzed the street networks and bus transit around the main line stations, to assess whether there was sufficient urban fabric to support TOD.

Content Analysis of Existing Plans

For the content analysis of plans, we searched town websites for TOD plans. If none were identified, we googled the station name and TOD. In one instance, Darien, this revealed a development rather than a plan, and we searched successfully within the city website and developer website for the plan that initiated the development (Connecticut Main Street Center Resource Team, 2006). Bridgeport and Stamford stations are unique in that rather than having station area TOD studies, the TOD is included in the general town plan. We focused on the Downtown Plan for Bridgeport, and in Stamford, we supplemented a recent bus and shuttle study with presented material on Stamford's TOD efforts (Downtown Special Services District, 2007; WESTCOG, 2018; Woods, 2018).

In total, we found 17 plans for the 21 stations along the corridor. Six stations (Greenwich, Riverside, Old Greenwich, Rowayton, Green's Farms, and Southport) had no plans, while Stamford and New Haven Union Station had two each and Fairfield covered two stations in one plan. We also included Bridgeport's Barnum Station TOD plan in the review even though the station was not constructed. The plans range in date of publication from 2006 to 2020. All but two of the plans were completed after Governor Malloy established a state TOD program to support planning efforts in 2012; New Haven completed its TOD report for its Union Station in 2008 and Darien's plan was based not on TOD specifically but completed as part of a Main Street project in 2006. The range of years

is instructive, in that it provides a window into changes made to TOD planning over the period. Most notably, the newest plan (East Norwalk) is the first to incorporate sea level rise into its analysis.

Interviews

Interviewees were identified through snowball sampling, in which initial interviewees are asked to recommend others whose perspectives might be valuable. Snowball sampling has some limitations, in that interviewees may only offer those participants who agree with them, biasing the sample. To counteract this, we made our initial contacts through towns and councils of government, including places that were both friendly and hostile to TOD. Because of interview request-response rates, the interviewees were biased toward Fairfield County and places that were embarking on or had experience with TOD. To the extent possible, we tried to capture the voices we were not hearing through reference to their TOD plans.

In total, we spoke to four town planners or economic development specialists, two transit agency directors, two real estate developers and one real estate banking specialist, two planners for the state department of transportation, one executive director of a council of governments (COG), and one transportation activist. For each interview, we asked them to describe their involvement in TOD efforts in Connecticut and what they saw as the primary obstacles to TOD. We probed for specific policies, if any, and asked them to describe the decision-making process around a TOD project they had been involved in. Following Guthrie and Fan's interviews with developers on TOD (Guthrie and Fan, 2016), as much as possible, the interviewer kept themselves out of the conversation, to capture the experiences from all sides of TOD in Connecticut.

Street Network Analysis

To assess the station area's capacity for transit-oriented development in the absence of detailed, standardized parcel data, we analyzed the walkability of the surrounding street network. We calculated the intersection density of station areas, the link-node ratio, the number of city connectors exiting the station area, and walkability for the street level analysis of station areas (**Table 1**). The intersection density serves as a quick estimate of block size and walkability: denser street grids have more spaces for economic activity and, therefore, more possible destinations within a short walk. The link-node ratio measures the number of streets per intersection (Ewing, 1996). Used in combination with intersection density, it serves as a valuable indicator of connectivity, with some cities incorporating a standard ratio of 1.4 links per node to measure whether a neighborhood is walkable (Dill, 2004). The city connectors concept measures how accessible the neighborhood is to other neighborhoods. Our definition of city connectors began with state numbered routes but extended to any major roadway (e.g., West Ave in Norwalk) that extends beyond the station area. The walkability assessment was qualitative, based on an estimation of travel speed, road width, sidewalk availability, and building frontage (as opposed to parking or large lawns; Marshall and Garrick, 2010; Marshall et al., 2015; Marshall and McAndrews, 2017).

Bus Network Frequency Analysis

We conducted an online search to identify all the bus routes that connected with the Metro-North mainline, or connected to a route that connected to the main line. These routes spanned five transit districts: CT Transit-Stamford, Norwalk Transit District, Greater Bridgeport Transit District, Milford Transit District, and CT Transit-New Haven. We then pulled their pre-Covid schedules from online and calculated the average daily headway. We also identified peak times and the number of buses per peak, to account for buses with high frequency at the peak and low or no frequency off-peak.

The following section lays out the findings for each analysis, and then the discussion section draws out the common threads of a failure to see investing in cities as transit-oriented development, the omission of bus transit planning as part of an overall transit-oriented development strategy, and a reluctance to reduce parking at both the state and local levels.

FINDINGS

Considerable Variation Among Local TOD Plans

To assess the degree to which towns meet TOD standards, we conducted a content analysis of all TOD plans along the corridor. We assessed them in four areas: parking, their problem-solution framings around congestion, their treatment of the bus network, and the attention paid to street network design and walkability (**Table 2**). For parking, we used a five-point scale, in which cities gained 1 point for each of the following: planned parking reduction, removal of parking minimums, provision of shared parking, preferencing structured over surface parking, and placing parking behind buildings. For congestion, the assessment had two parts: first, whether they even viewed congestion as a problem (some cities desired congestion as a sign of economic development), and second, if they did, whether congestion was used as a reason for or against implementing TOD strategies. As such, in the congestion column, an x represents a city who was not concerned about congestion, while a plus symbol indicates congestion used to support TOD and a—for cities where congestion was used to oppose it. At two stations, Stratford and Fairfield Metro, congestion was used to support pedestrian improvements but also used to be tentative about encouraging new development, so they have both. For the bus network, cities received a zero if they failed to include the bus network in their TOD plan, a one if their sole intervention was improvements to stop amenities, a two if they addressed improving bus access to stations, and a three if they considered route changes, increased frequency, or the ticket interface between rail and bus. One city received a−1, as they included the bus network only to reject any proposed improvements. For walkability, stations received one star if it was a goal of the plan, two if they included a basic suite of measures, such as complete streets, and three if they discussed active interventions that prioritized pedestrians over cars, such as mid-block crossings, street narrowing, driveway consolidation, slower speeds, and in the case of Fairfield Metro, a pedestrian-only crossing over a body of water.

TABLE 1 | Street level analysis metrics.

Metric	Definition	Purpose	Calculation
Intersection density	Number of intersections per square mile	Measure of density	Number of intersections within half-mile buffer/$\pi(0.5)^{'}$
Link-node ratio	Number of links (streets connecting two intersections or an intersection and a dead end)/number of intersections or dead ends	Measure of connectivity	Number of links/Number of nodes
Count of City connectors	Multi-lane roadways and state numbered routes	Measure of permeability	Identified by Google Map scan
Walkability	Comprised of provision of pedestrian infrastructure, building frontage, and perceptions of safety based on road width and observed speed	Measure of walkability	Identified by observation of Google Streetview images of roadways along the likely travel paths away from the station.

TABLE 2 | Station plan analysis.

Station	Year	Parking	Walkability	Congestion	Bus network
Greenwich				No plan	
Cos Cob	2014	1	*	-	−1
Riverside				No plan	
Old Greenwich				No plan	
Stamford (1)	2013	3	**	+	0
Stamford (2)	2016	2	-	+	2
Noroton Heights	2018	0	**	X	1
Darien	2006	4	***	+	1
Rowayton				No plan	
South Norwalk	2016	2	***	+	3
East Norwalk	2020	2	***	+	2
Westport	2018	2	**	+	2
Green's Farms				No plan	
Southport				No plan	
Fairfield	2019	3	**	X	0
Fairfield Metro	2019	3	***	+/-	0
Bridgeport	2007	4	**	X	2
Barnum Station	2016	2	**	X	2
Stratford	2015	1	**	+/-	3
Milford	2017	1	***	+	1
West Haven	2016	1	***	X	0
Union Station (1)	2008	1	-	X	0
Union Station (2)	2013	1	**	X	2

**walkability was a plan goal, **walkability analyzed, ***included active interventions to improve walkability.*

The station plan analysis shows considerable variation. Four plans—Darien, South Norwalk, East Norwalk, and Bridgeport—score highly in all four aspects. Of those, only the East Norwalk study was funded by the state TOD planning grants. The other three, funded by the state–Westport, Barnum, and Milford—are a step above most of the remaining plans, but have either only average attention to walkability or to the bus network. When looked at standard-by-standard, plans to set parking maximums rather than minimums and plans to increase frequency or adjust bus routes were equally rare, and no city had both contained within a single plan. In sum, there is no single set of enforced standards guiding TOD planning in Connecticut. New Jersey's plans are enforced by the existence of the Transit Village program and NJ Transit's *Planning for Transit-Friendly Land Use* handbook. The comparable handbook in Connecticut, the *Transit-Oriented Development Toolkit for CT* (2013), was produced by a consortium of advocacy groups and non-profits and following it is not a requirement for planning and development grants. Linking state coordination and resources to a set of standards would remove variation and improve the quality of station area TODs.

State-Level Coordination Focused on New-Build Transit

Much of the state's focus on TOD over the last decade has been not on the Metro-North corridor but along the Hartford Line and the CT Fastrak bus rapid transit in the middle of the state. Interviewees suggested that state agencies perceived the Metro-North corridor as being able to "organically" develop TOD due to existing market demand (Interview with state employee, 4/27/21). In contrast, the two large capital investments represented opportunities to catalyze denser development opportunities in other locations.

The focus away from the Metro-North corridor and larger cities in general is visible in the distribution of grants from the Transit Oriented Development Planning Grant program (**Figure 2**). The program first started as a project of the department of transportation (DOT) in 2015. Subsequent rounds in 2016 and 2017 became Planning and Implementation Grants, funding construction of complete streets improvements and property acquisition in addition to planning, and awarded by a network of state actors in the Department of Energy and Environmental Protection, the Department of Economic and Community Development, the Office of Policy and Management, and the DOT. Of the 17 plans reviewed below, only four (East Norwalk, Saugatuck, Milford, and Barnum) were funded by the program, supporting the DOT's understanding that towns along the corridor would be able to stimulate TOD without significant state attention. **Figure 2** shows the dollar amount of grant activity by town. Grants were made outside of TOD areas for complete streets efforts, and larger numbers generally reflect implementation projects rather than planning projects. As **Figure 2** shows and the interviewees discussed, the bulk of activity happened away from the Metro North corridors, with some funding for Stamford and New Haven, though Stamford's investment was along a branch line station.

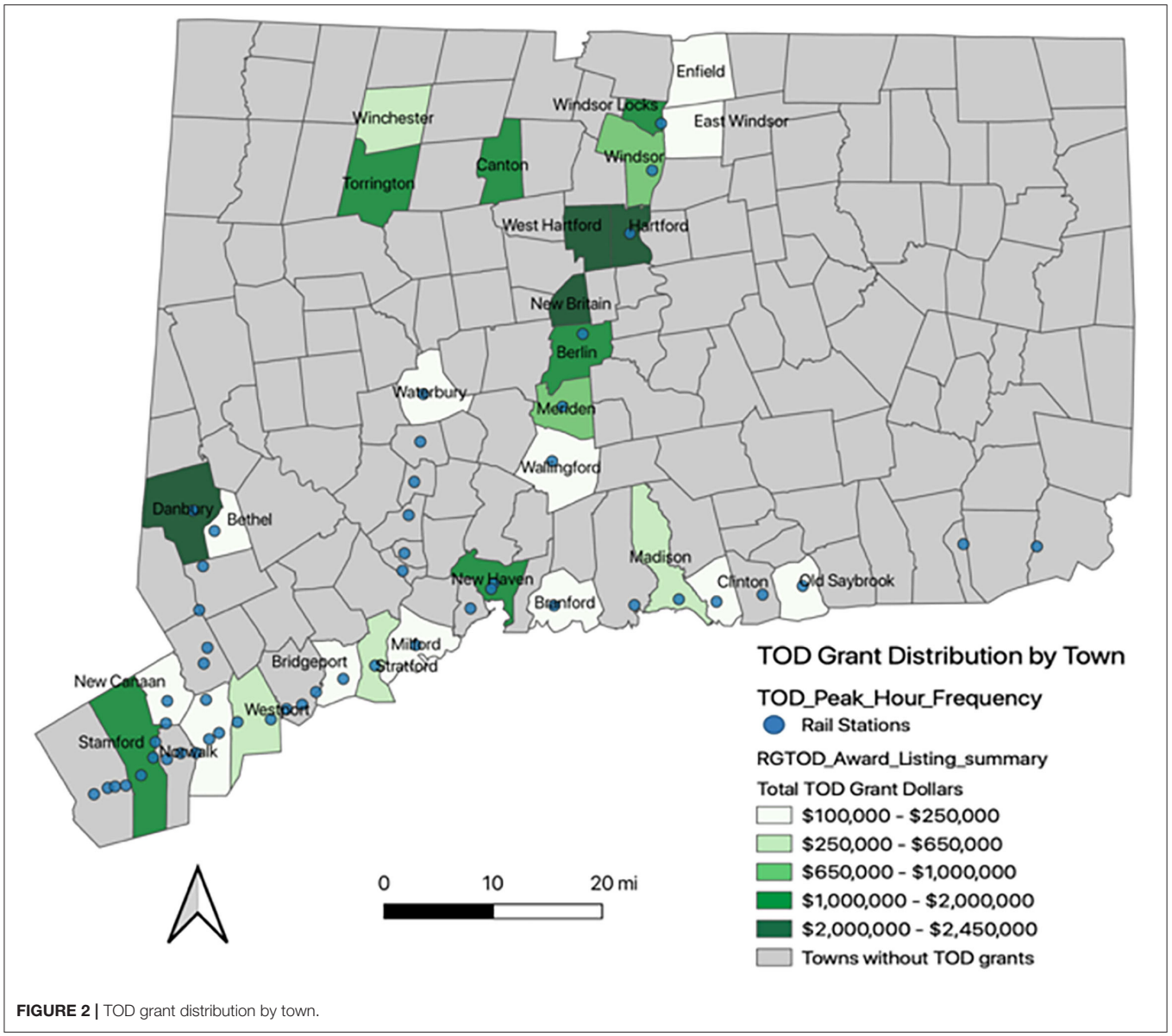

FIGURE 2 | TOD grant distribution by town.

Among real estate finance professionals, TOD is one of the most preferred types of real estate investment along the Metro-North main line, but it does not always feel that way from the perspective of planners and advocates. This tension lies in the fact that while there is demand for more car-lite living, the supply of TOD is limited by the difficulty of finding and gaining approval for suitable sites. First, the New Haven main line is a premium service compared to the branch lines. The main line has more frequent service and electric trains; the first improves access, the second reduces noise. As such, access to one of those 21 station areas is a scarce commodity. Second, not all communities along the line are excited about or welcome growth. The Westport/Saugatuck station TOD plan, for example, contains a preamble from the community-appointed committee that worked on the plan expressing alarm at the estimations of market demand and its possible effects on the existing community. The plan then identifies five possible development sites, of which none would provide a sufficient rate of return at currently allowed densities due to the high costs of property acquisition. One developer we spoke to estimates that the parking lots at the Westport/Saugatuck station are the second most valuable location in all of Connecticut, exceeded only by the lots at Darien, a station two towns closer to New York City. Moreover, the Saugatuck TOD plan opposes structured parking, the current best practice to build out of the tension between a perceived need for parking to facilitate access to the train and the desire to build more human-scaled and less car-oriented development around prime transit hubs. There is a lack of political will to support TOD in some areas where the market would absorb it, and significant eagerness for TOD in areas with little demand.

The large cities along the Metro-North line (Stamford, South Norwalk, Bridgeport, and New Haven) represent the best

opportunities for TOD, and their advancement along the process of reducing car use is reflected in the market estimates of parking requirements. In Stamford and New Haven, interviewees provided estimates of less than one parking space per bedroom. Fifteen years ago, anywhere along the line would have been 1.67 spaces per bedroom, now in South Norwalk they would do 1.2. Other than Stamford, New Haven, and South Norwalk, very few places along the corridor are sufficiently urban for a developer to feel safe providing less than 1.67, but might be willing to do so for a place right next to the station. Unfortunately, in many towns, the parking minimums are high enough that the developer is not pushed to ask what the market demands. This may change as the result of a bill recently passed at the state level. Pub. Law 21-29 sets residential parking requirements at 1 space for a 1 bedroom and no more than 2 for 2+ bedrooms unless the local planning and zoning commission opts out of that provision. Bridgeport has also recently removed parking minimums in its North Downtown area and is seeking to remove them citywide. However, as long as the state DOT views parking as its primary land use mission around the stations, as was stated in interviews, the tensions around parking will remain.

The interviews also revealed uncertainty as to whether commuter rail-based TOD is sufficient to reduce the need for a car. One developer used an intra-Connecticut trip as an example, stating that even if a Milford-Darien commuter wanted to take the train to work, she would still have to drive to Milford station, and there is not enough parking at Milford for her to find a spot. One COG executive director made a similar argument that even if all the TOD sites were developed in their region, people would still drive to the station from single-family houses. As long as the land use remains car-oriented, car travel is inevitable.

Bridgeport stands out somewhat in the development context. Located in the middle of the line, it is the state's largest city, with 148,654 residents counted in the 2020 census, and one of its most impoverished localities. While the median household income in Connecticut is $78,444 (2019 dollars), the median income in Bridgeport is $46,662. Twenty percent of Bridgeport's residents are below the poverty level, compared to 9.7% statewide. These data points help to explain why despite having a strong gridded street network and extensive bus network, it was not mentioned by any developer as a primary TOD site. In Bridgeport, the rent you can charge on a building does not always cover the cost of construction, a phenomenon an economic development professional referred to as an "appraisal gap." It is as expensive to build in Bridgeport as it is in Stamford or New Haven, if not more so due to brownfield remediation, but rents are somewhat lower. As such, the Bridgeport planners recommended state programs that help to reduce the appraisal gap, reducing the costs of development even for construction that is not specifically designated as affordable housing, in the hopes of spurring Bridgeport to be a functional market.

Even With the Scarce Available Data, It Is Possible to Develop Meaningful Performance Metrics

In the absence of statewide standardized land use data, we attempted to identify spatial data by which to assess a station area's ability to absorb TOD. Despite considerable effort attempting to locate land use data, we were unable to find a layer that covered the entire length of the corridor. We pivoted to an assessment of local street and bus networks as the data most available, and also as meaningful metrics for the DOT to use in operating decisions.

Street Network Analysis

Our street network analysis uses publicly available road network data, combined with Google Streetview, to develop basic metrics of a pedestrian friendly area. The goal is to identify existing walkable areas to focus TOD efforts, as well as to identify aspects of a station area that need improvement. **Table 3**, below, displays the results of the assessment and is sorted by intersection density.

To understand how transit supportive a station area's street network is, the indicators need to be incorporated in combination with each other. **Figure 3** provides an example set for comparison. While Southport (A) has a high intersection density, it is not well-connected, with only a few routes crossing under the rail lines and highway. The walkable downtowns of Fairfield (B) and Greenwich (C) cover less than half of the station area, leading to a lower intersection density. Union Station in New Haven has a dense and well-connected street network, but the parking lots on Union Avenue and the highway disamenity along Water Street lower the walkability of the area (D). The proposed Barnum Station site places the highest of any of station areas on the intersection density and link-node metrics, but the existing sidewalks need repair. Five stations—Rowayton, Old Greenwich, Cos Cob, Riverside, and Green's Farms—lack city connectors and are therefore unsuited to TOD without significant, and likely politically infeasible, development. These metrics can be used to put numbers to the "transit-supportive standards for land uses, built environment densities and walkable environments" currently included in the state definition of TOD (Sec. 13b-79o), and can also guide towns in prioritizing how to improve the street network near their stations.

Bus Network Analysis

There are two governance models for bus transit in Connecticut; the transit district model and the CTTransit model. In the transit district model, a local transit district plans and operates service, with funding provided largely by the state. In the CTTransit model, the state-owned CTTransit contracts for transit service, with service areas broken into divisions. There are ten transit districts and eight CTTransit divisions. In both the transit district model and the state-run CT Transit model, coordination of transit and land use is formalized only at the level of the regional council of governments, which produce plans that include both transit and land use. On the day-to-day level of project approval and service adjustment, the relationships are currently only informal. This lack of a formal process leads to situations like one described in interviews, in which a medical office relocated from a downtown location well-served by transit to a new greenfield office location. Under current arrangements, unless the project is over a certain size threshold, that kind of move is something the transit agency only learns about when the office calls up and asks for more service to their location. Ideas put forward by interviewees for more formal coordination include

TABLE 3 | Street network analysis of Metro-North station areas.

Station	Count of intersections	Intersection density (intersections / square mile)	Link/node ratio	Number of city connectors exiting station area	Walkability assessment
Barnum Station (proposed)	126	160.4	1.75	2	
State Street	122	155.3	1.55	2	
Union Station	98	124.8	1.76	2	
South Norwalk	92	117.1	1.63	3	
East Norwalk	89	113.3	1.37	2	
Milford	89	113.3	1.44	2	
Southport	87	110.8	1.21	2	
Stratford	84	107.0	1.39	7	
Stamford	83	105.7	1.45	3	
Bridgeport	82	104.4	1.60	5	
Noroton Heights	79	100.6	1.35	2	
Fairfield Metro	76	96.8	1.41	4	
Darien	68	86.6	1.35	4	
Fairfield	68	86.6	1.52	2	
Rowayton	65	82.8	1.33	0	
Greenwich	61	77.7	1.21	2	
Riverside	61	77.7	1.31	0	
West Haven	60	76.4	1.46	2	
Old Greenwich	54	68.8	1.34	0	
Westport	46	58.6	1.31	3	
Green's Farms	30	38.2	1.35	0	
Cos Cob	25	31.8	1.25	0	

Red = unwalkable, Orange = poor walkability, Yellow = room for improvement, Green = walkable.

linking land-use proposals to transit service, or promoting transit corridors, which receive improved service as density along the corridors increases.

Currently, the large majority of all transit funding in the state comes from the state, whether CT Transit or the transit districts provide the transit service. However, the state only maintains data on performance for the transit they provide, making it difficult to compare transit across the corridor. For example, the state knows the top 100 busiest bus stops, but only among CT Transit lines, which notably omits Greater Bridgeport Transit, one of the busiest providers in the state. To develop our comparison, we assessed the frequency of 97 bus routes that interface with the Metro-North mainline.[1] Of these routes, only five have average daily headways of less than 20 min, and only New Haven's Whalley and Grand Avenue buses have headways more frequent than 15 min. Headways refer to the amount of time in between buses serving a given stop. Four buses an hour, evenly spread, means 15-min headways. Headways of 15 min or less are the gold standard of "show up and go" service, service that does not require the user to consult a schedule, though some advocates are pushing for 15 min to be considered the bare minimum for service labeled "frequent" (Higashide, 2019). Eighteen routes have average daily headways of between 20 and 30 min, reflecting routes that have "show up and go" service for some parts of the day and provide skeleton service in the off-peak and evening hours, including the Coastal Link, a joint venture among Norwalk Transit District, Bridgeport Transit District, and Milford Transit District. The remaining routes run either heavily peaked service, with almost no off-peak service, or regular service that operates less frequently than every 30 min. **Figure 4** highlights how New Haven's investments in bus frequency make effective TOD possible to a greater degree than elsewhere. Bridgeport also has excellent coverage every 20 min, with 95% of its residents within a quarter mile of a bus route. Stamford and Norwalk have less robust networks, while the Westport service barely registers. Milford's service is not depicted on the map because it does not have GTFS data, but it has two all-day hourly bus routes and one route that runs hourly only doing the morning and afternoon peaks. Investing in transit in Stamford, Norwalk, and Bridgeport, and in TOD in those cities with robust bus networks best leverages the existing state resources spent on transit.

Any investment in bus transit needs to contend with stigma around buses. Interviewees described the structural racism that shapes transit use in Connecticut. One developer, went so far as to say "white man doesn't ride a bus," in explaining why his company focuses on rail for TOD. His solution is to build other services, like light rails and streetcars, that do not have the same connotation, believing that the negative stigma of the bus will not be resolved in his lifetime. While not stated explicitly,

[1] An online search conducted in Fall 2020 revealed 101 routes that either connected to stations or connected to routes that stopped at stations, but schedules were only available for 97.

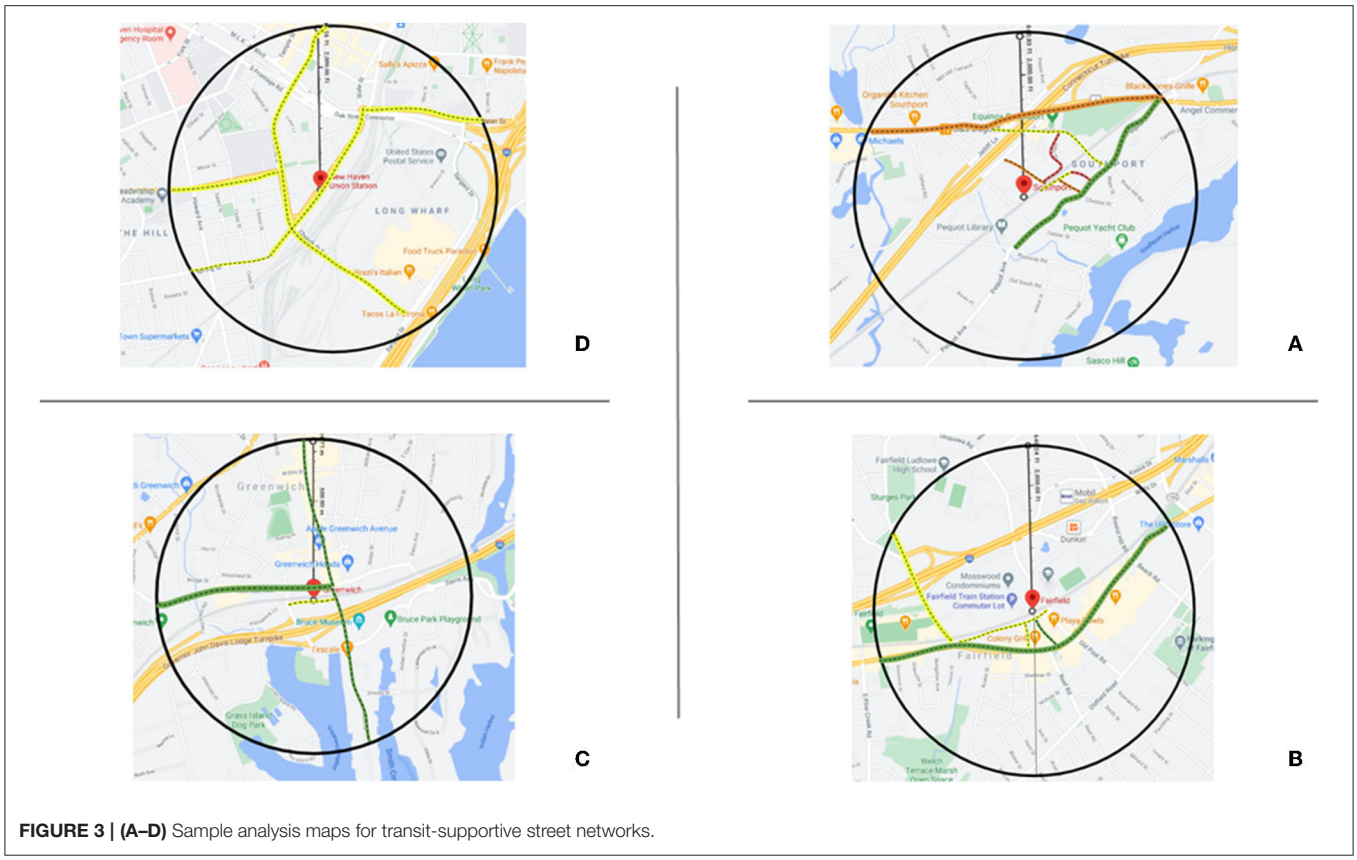

FIGURE 3 | (A–D) Sample analysis maps for transit-supportive street networks.

this reluctance to confront the structural racism around buses in Connecticut seems to also animate city proposals for circulators or micro-transit, as public officials seek a non-stigmatized service rather than investing in the existing bus network.

DISCUSSION AND CONCLUSION

When compared to peer states, Connecticut demonstrates that absent a strong coordinated program, TOD plans exhibit significant variation in content and quality, that state-level programs can overlook existing TOD potential in favor of supporting TOD around new capital investments, and that even with scarce available data, meaningful performance metrics are possible. Compared to benchmark programs in New Jersey and Massachusetts, Connecticut lacks statewide data, metrics, and standards by which to evaluate programs and projects and develop plans. Without metrics to ground evaluation, state grantmakers and departments are instead defaulting to TOD as originally defined, using new transit investments to create small pedestrian pockets in otherwise auto-oriented environments, rather than building on existing multimodal investments and walkable areas. The focus on building TOD around new service rather than existing service creates a blind spot toward to the potential to jumpstart economic development in Connecticut's older cities by leveraging transit-oriented development.

Connecticut is behind the curve for the availability of standardized GIS data. In attempting to find the data necessary to measure intersection density and the link-node ratio, the ease of calculation varied by county. In Fairfield County, whose regional council of governments has the staff and resources for significant GIS work, there are "local streets" and "local intersections" shapefiles and parcels with standardized zoning information. These kinds of standardized data did not exist for New Haven County, necessitating hand counting of intersections and streets. Moreover, no council of government had any sort of financial information, like sale price, available by parcel. This constraint makes independent assessments of the market nearly impossible. Similarly, while the National Housing Preservation Database contains geospatial data for federally subsidized affordable housing, CT is only now beginning to map its locally subsidized housing. With the December 2021 appointment of a state GIS officer, Connecticut can now begin to take responsibility for this sort of standardization, a gap that should be rectified.

The state lacks clear metrics for transit-oriented development and investment, leading to a focus around new transit investments rather than existing multimodal networks. While the state's definition of TOD includes the phrase "transit-supportive standards," those standards are not defined. Using metrics like intersection density and link-node ratio can encourage towns to build dense, connected, and walkable projects, in addition to existing attention paid to complete streets style improvements.

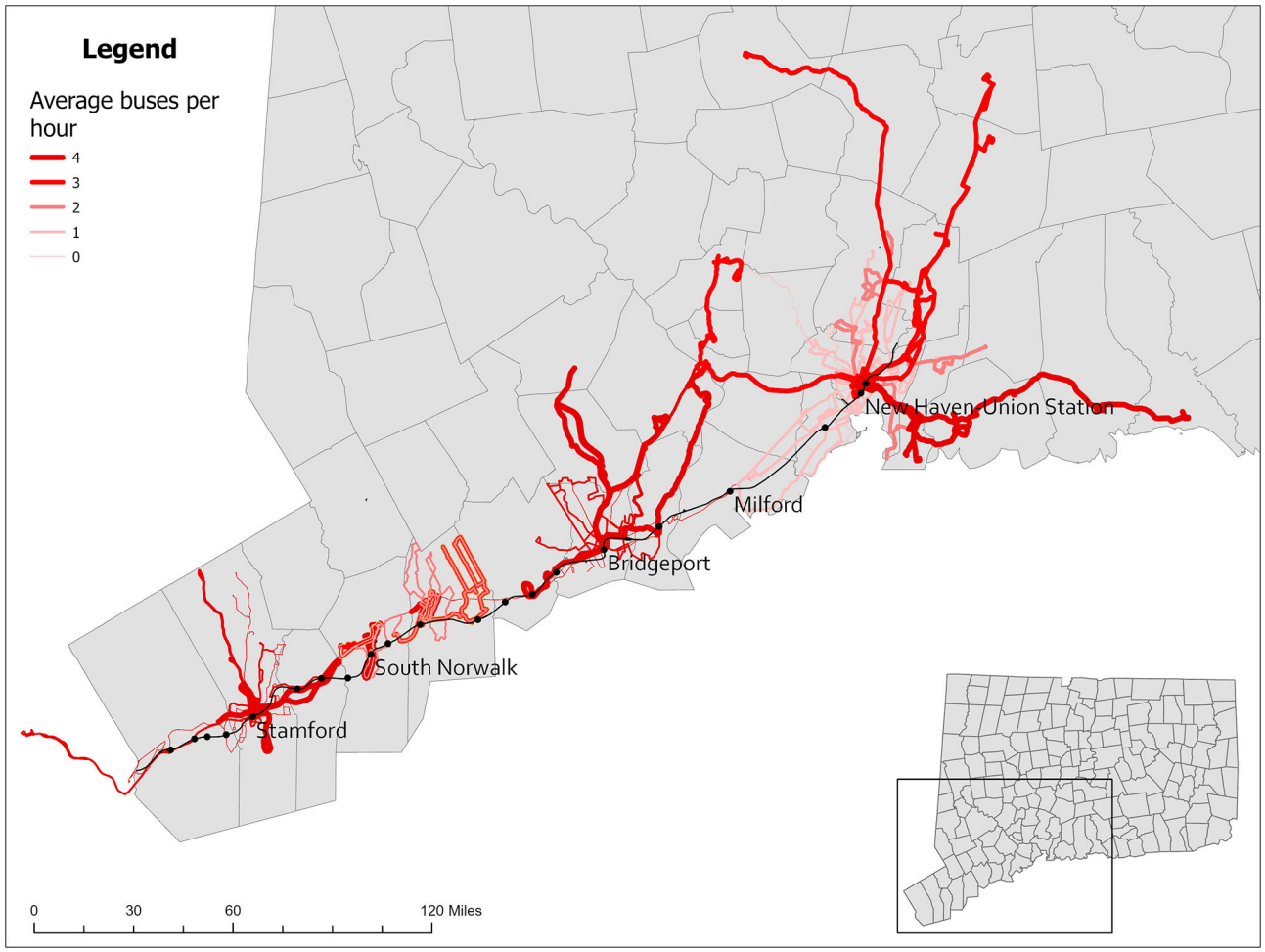

FIGURE 4 | Frequency map of bus service along the Metro-North corridor.

These metrics could ensure that development on large parcels, like Fairfield Metro, is built with small block sizes and a dense connected street grid, as additional connectivity is needed to bring the Fairfield Metro station area up to 100+ intersection density and 1.4 link-node ratio.

Absent such metrics, the state chooses to focus its TOD efforts in less dense areas, believing that the cities will take care of it themselves. While it is true that the market for TOD is more present along the Metro-North Line, this narrow understanding of TOD has created blind spots around the other essential aspects of TOD, such as reducing parking, improving bus service, and focusing attention where there are already strong walkable street networks. Such metrics also need to recognize that TOD is a multi-modal project, rather than development around rapid transit stations. Given the lack of good transit service other than the commuter rail in many towns, a reluctance to imagine a car-lite lifestyle is understandable. With the state's role as the main transit funder, they also have levers to coordinate transit and land use planning by targeting transit funding to key corridors, supported by incentives for densification. Performance metrics are needed for state bus service. The state can also incentivize focusing development along these corridors in the transit operating document, committing to giving more funding to those districts coordinating with cities and investing in resilient corridors. At the local level, transit districts can build in more scope for local governments to contribute financially to transit and support quarterly meetings between cities and transit providers.

While this research focused on Connecticut, it is among the first work to untangle the disparate understandings of TOD in existing vs. new-build transit contexts. In addition, it is part of a small but growing literature on state development planning and TOD. Future research should continue the research of TOD at the state-wide level, exploring how best to implement resilient corridors.

A TOD strategy aimed at existing transit-oriented built environments would leverage state funding to restart a virtuous cycle in existing walkable areas. Performance measures that favored urbanized environments would

improve existing transit assets and focus state resources on the cities. By investing in the transportation resources that provide the city's backbone, public money would support the smaller private developer network currently existing in cities to reinvest in their properties and create incremental growth.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The interviews were approved as exempt research under Protocol X21-0026 by the UConn Storrs Institutional Review Board. Interviewees provided recorded oral informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

RR: study conceptualization, data collection, data analysis, and write-up. NG and CA-P: study conceptualization and review of data analysis and draft. All authors contributed to the article and approved the submitted version.

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