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Cultivating Bus Rapid Transit (BRT) Station Areas within Freight Rail Corridors

Perceptions and Reality

Cultiver les zones de gares de Service Rapide par Bus (SRB) dans les corridors ferroviaires de marchandises : perceptions et réalité

Cultiver SRB

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Article abstract

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Cultivating Bus Rapid Transit (BRT) Station Areas within Freight Rail Corridors: Perceptions and Reality

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Abstract

Using rail corridors for BRT may limit right-of-way costs, yet little is known about the land development impacts of this model. This research examines the perceptions and outcomes of implementing BRT station area developments within freight rail corridors using (1) surveys with planners, homebuilders, and developers and (2) Poisson regressions of building permit data in Winnipeg, Canada. Our survey results show that while planners do not view the existence of freight lines positively, homebuilders and developers do not see rail corridors as a barrier to development. This is confirmed by regression results of permit data that show that Winnipeg has experienced more non-detached single-family dwellings, like row- or townhouses, in close proximity to BRT stations. These findings demonstrate that while planners perceive rail lines as a barrier to transit-oriented development, in some cases, land adjacent to rail lines exhibit significant development interest from a market perspective.

Résumé

L'utilisation de corridors ferroviaires pour le SRB peut limiter les coûts d'emprise, mais nous ne savons que très peu sur les impacts de ce modèle sur l'aménagement du territoire. Cette étude examine les perceptions et les résultats de la mise en œuvre des développements de la zone des gares SRB dans les corridors de fret ferroviaire à l'aide (1) d'enquêtes auprès des urbanistes, des constructeurs d'habitations et des promoteurs immobiliers et (2) de régressions de Poisson des données de permis de construire à Winnipeg, au Canada. Les résultats de notre enquête démontrent que même si les urbanistes ne considèrent pas l'existence de corridors de fret comme étant positive, les constructeurs d'habitations et les promoteurs immobiliers ne considèrent pas les corridors ferroviaires comme un obstacle au développement. Ceci est confirmé par les résultats de régression des données sur les permis qui montrent que Winnipeg a connu davantage d'habitations unifamiliales non attenantes, comme des maisons en rangée, à proximité des stations SRB. Ces résultats démontrent que même si les urbanistes perçoivent les lignes ferroviaires comme un obstacle au développement axé sur le transport en commun, dans certains cas, les terrains adjacents aux lignes ferroviaires présentent un intérêt important en matière de développement du point de vue du marché.

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Introduction

In the text accompanying Bryan Scott's comprehensive photographs of Winnipeg, Manitoba, Canada in *Stuck in the Middle*, Bartley Kives (2013) identifies the city as being "stuck in the middle of two possible destinies" (p. 6). On one hand, Winnipeg's destiny involves enhancing its urban core and maintaining its older neighborhoods. This could prove financially sustainable and allow Winnipeg to mature into a responsible medium-sized city. On the other, it involves continuing with sprawling, post-war developments that strain the city's financial resources and infrastructure. The opening of Winnipeg's first bus-only transitway, the Southwest Transitway, could help shift Winnipeg's destiny towards the former with more intensive urban core land-uses and increased transit use. Winnipeg's first Bus Rapid Transit (BRT) corridor runs through the middle of the city within underutilized spaces, connecting two established activity centers – downtown and the University of Manitoba.

However, the Southwest Transitway opened alongside an in-use freight rail corridor, which could provide a barrier – both figuratively and literally – for BRT station area developments. Siting new transit infrastructure within in-use rail corridors minimizes disruptions to existing homes and businesses for right-of-way (ROW) acquisitions. However, freight rail corridors are often in peripheral spaces not entirely integrated within existing neighborhoods, limiting the visibility of and accessibility for potential BRT riders.

Winnipeg is not the only city at this crossroads of implementing large-scale transit projects within peripheral land to alter its trajectory. Pittsburgh, Cleveland, and Los Angeles have established BRT lines in former railroad or distressed corridors (Hook et al., 2013; Tsao & Pratama, 2013). Yet, none of these BRT operate alongside working rail ROWs.

While existing rail corridors can potentially support new urban development, the implications of this model from a land use perspective remain largely unexamined. Drawing on a critical case study of Winnipeg, we ask:

> *How does the presence of freight rail lines in BRT station areas influence residential developments?*

We examine this question in terms of both the perceptions and reality of development in rail-adjacent corridors using a mixed-method approach. For perceptions, we begin by drawing on surveys with planners and homebuilders and developers (HBDs) to understand their views concerning development interest in BRT station areas. For the reality – or outcomes, we next draw on a series of Poisson regressions to assess development intensity in station areas using building permit data. Finally, we analyze these findings to assess how freight rail lines influence station area developments.

We found that planners did not view the in-use freight rail lines positively, while most HBDs did view them positively in terms of developing near station areas. Even though planners did not view the rail lines positively, both planners and HBDs selected railroad infrastructure less frequently as a development barrier when compared to other issues like lack of political will and neighborhood opposition. We also found an intensity of non-detached single-family dwelling units surrounding BRT station areas when compared to non-station areas. This finding is important for planners aiming to enhance middle- or medium-density housing in cities dominated by single-family homes.

Literature Review

BRT TODs and Residential Developments

Research generally points to increased property values in BRT station areas overall (Acton et al., 2022; Deng et al., 2016; Rodríguez & Mojica, 2009; see Zhang & Yen, 2020, for a breakdown of studies examining BRT and residential price effects) and shows positive support for BRT's potential for increasing property values and inducing development near stations (Cervero & Dai, 2014; Currie, 2006; Shen et al., 2018; Stokenberga, 2014). One key strength of BRT is that it needs less population and employment densities compared to light- and heavy-rail transit to be a top performing, cost-effective investment (Cervero & Dai, 2014; Guerra & Cervero, 2011, McGreevy, 2021). This indicates that BRT systems may perform well in establishing transit-oriented development (TOD) in lower or moderate density cities, possibly without other forms of rapid transit. Research also examines the proximity effect of BRT on housing prices (Perk et al., 2010). Residential developments due to new transit investments may be localized around transit stations considering that people generally access stations by walking (Cao & Porter-Nelson, 2016). Other studies note decreased housing prices closer to BRT stations due to the nuisance effects of buses such as noise and air pollution (Currie, 2006). However, only relying on housing or property prices overlooks land development impacts that building permit data can show, particularly when the interest is in how transit stimulates new development. Using building permits to show rapid transit's impacts on real estate development is beneficial but is still largely under-examined, particularly for BRT.

Policy and Market Conditions to Promote BRT-related Development

As Rodríguez et al. (2016) note, development depends on a variety of factors including "developer appetite, market conditions, land availability, and land regulations" (p. 4). That is, a BRT line is necessary but likely not sufficient to induce noticeable station area development. Exclusive BRT right-of-ways plus supportive policies and strong markets that support TOD and related station area developments provide the conditions needed for a higher likelihood of positive development impacts (Stokenberga, 2014). Policy tools include density bonuses, tax increment financing, and joint development opportunities (Stokenberga, 2014). Ottawa, Canada and Curitiba, Brazil provide examples of cities using supportive policies to induce BRT developments. Ottawa had a transit-oriented policy that prioritized new public transit infrastructure over auto-oriented infrastructure in the 1970s to promote BRT, resulting in successful transit mode split (Al-Dubikhi & Mees, 2010). Curitiba's 1965 regional plan included goals to encourage sustainable growth patterns along four radial corridors supported by a strong public transit system (Miller & Buckley, 2001).

Given the importance of market and regulatory conditions, planner and developer perspectives can identify issues that may influence policies and shape market conditions. As Guthrie and Fan (2016) identify in their study on developer perspectives of TOD in Minneapolis, developers already perceive there to be an incumbent market demand for development around transit and in the form of TOD. Overall, Guthrie and Fan (2016) emphasize the "pent-up demand for transit access" among developers in the Minneapolis/St. Paul, Minnesota region (p. 112). Better understanding this demand for transit access could ultimately offer insight into market conditions and "developer appetite" for BRT station area developments.

Land Availability

While BRT has been promoted as faster and less expensive to implement than light rail (Hook et al., 2013), there are still significant costs to acquiring land for dedicated right-of-ways (Hess et al., 2005). Miller and Buckley (2001) note that BRT systems may face political challenges regarding their physical placement, particularly in the availability of land and acquisition for right-of-ways. This is particularly a challenge for older, established, cities with less developable land available, as well as slow-growth cities with less development pressure to justify dedicated right-of-ways acquisition. This can lead to the siting of transit routes in "peripheral" locations such as highway medians and disused or even in-use freight corridors. In cities, such as Pittsburgh, PA and Hartford, CT, BRT corridors helped connect major points of interest while also minimizing disruptions and both construction and land acquisition costs (Pultz & Koffman, 1987; Watkins et al., 2002). However, as freight rail lines were designed to serve industrial uses, their alignment is usually not oriented towards transit supportive land uses, like higher-density residential or commercial. Loukaitou-Sideris and Banerjee (2000) remark that these locations are often the 'back-door' of communities, which by design avoid population and activity centers.

Nevertheless, cities across North America continue to use rapid transit in attempts to shift development, reduce less sustainable land use patterns, and reinvigorate core spaces. Cleveland's BRT HealthLine, for instance, has been cited as contributing upwards of $6 billion (US) in investments along a formerly distressed corridor by promoting transit-oriented development (TOD) (Hook et al., 2008). Los Angeles's Orange BRT line was constructed along a former railroad corridor (Tsao & Pratama, 2013). Pittsburgh's MLK Jr East BRT corridor was also developed along brownfields and below-grade, former rail right-of-ways (Hook et al., 2008).

Despite the financial and logistical reasons for using "peripheral alignments," the impact of site context on transit-related development is mixed. For Pittsburgh's East BRT corridor, proximity to a BRT station resulted in higher single-family home property values near stations compared with surrounding neighborhoods. This points to the positive effect proximity to BRT stations has on property values (Perk et al., 2010). In other cases, alignments along rail infrastructure have seen limited development. In Los Angeles, the alignment of the Blue Line light rail along existing rail tracks was an "opportunistic" investment that paid little attention to existing land uses and resulted in little development in the ten years after construction (Loukaitou-Sideris & Banerjee, 2000, p. 106-107).[1] Contrary to Winnipeg, though, none of these rapid transit lines mentioned operate alongside working rail ROWs.

The land development potential for BRT adjacent to in-use rail lines may be substantially different, given the concern for derailments (particularly of hazardous goods), noise, and vibration issues.[2] Recent guidance notes, "commercial and industrial properties in proximity to railway operations… are increasingly being converted to residential uses. At the same time, both the passenger and freight operations of railways are growing steadily, leading to an increasing potential for conflicts between rail operations and adjacent land uses" (Dialog & J.E. Collier Associates, 2013, p. 1). Despite these concerns and the seeming increase in siting BRT along rail infrastructure, these specific land use characteristics are not frequently addressed in understanding development impacts (Deng & Nelson, 2011; Nelson & Ganning, 2015). As such, examining Winnipeg's BRT station area developments can provide insights for North

[1]As in most cases, land uses were only one factor related to development surrounding the Blue Line, as there was a complex social, economic, and political context.

[2]In Canada, increasing attention has been paid to minimum setbacks from rail lines, particularly in the wake of a catastrophic derailment in the town of Lac-Mégantic, QC in 2013. As railways are federally-regulated, municipalities have no direct control over rail issues.

American cities that are developing rapid transit projects in underutilized spaces.

Context

Winnipeg opened its first section of the Southwest Transitway in 2012, followed by a second phase in 2020. The transitway connects downtown Winnipeg with the University of Manitoba (see Figure 1). Rapid transit corridor planning began as early as 1959 with corridors proposed to connect to the central business district (Wilson, 1959). While the mode of rapid transit has changed, the corridors have generally remained the same with the Southwest Transitway being a standard corridor across later Winnipeg plans (City of Winnipeg, 1976; DeLeuw-Dillon, 1978; Linovski et al., 2018). Southwest Corridor alternatives included widening Pembina Highway – a major north-south route – or increasing bus frequency along Pembina Highway (DeLeuw-Dillon, 1978). Later plans also emphasized options for accompanying projected growth, which would focus on development adjacent to the Southwest Transitway and existing railway corridors (City of Winnipeg, 1981). Road widening was not further considered with the argument that it would likely result in increased congestion (Linovski et al., 2018). Rather, rail-adjacent BRT alignment was chosen due to lower capital costs and fewer disruptions as well as potential service improvements, As a result, much of the dedicated BRT route runs alongside either main or sidetrack rail lines (see Figure 1). Due to this siting, many station areas are adjacent to working rail

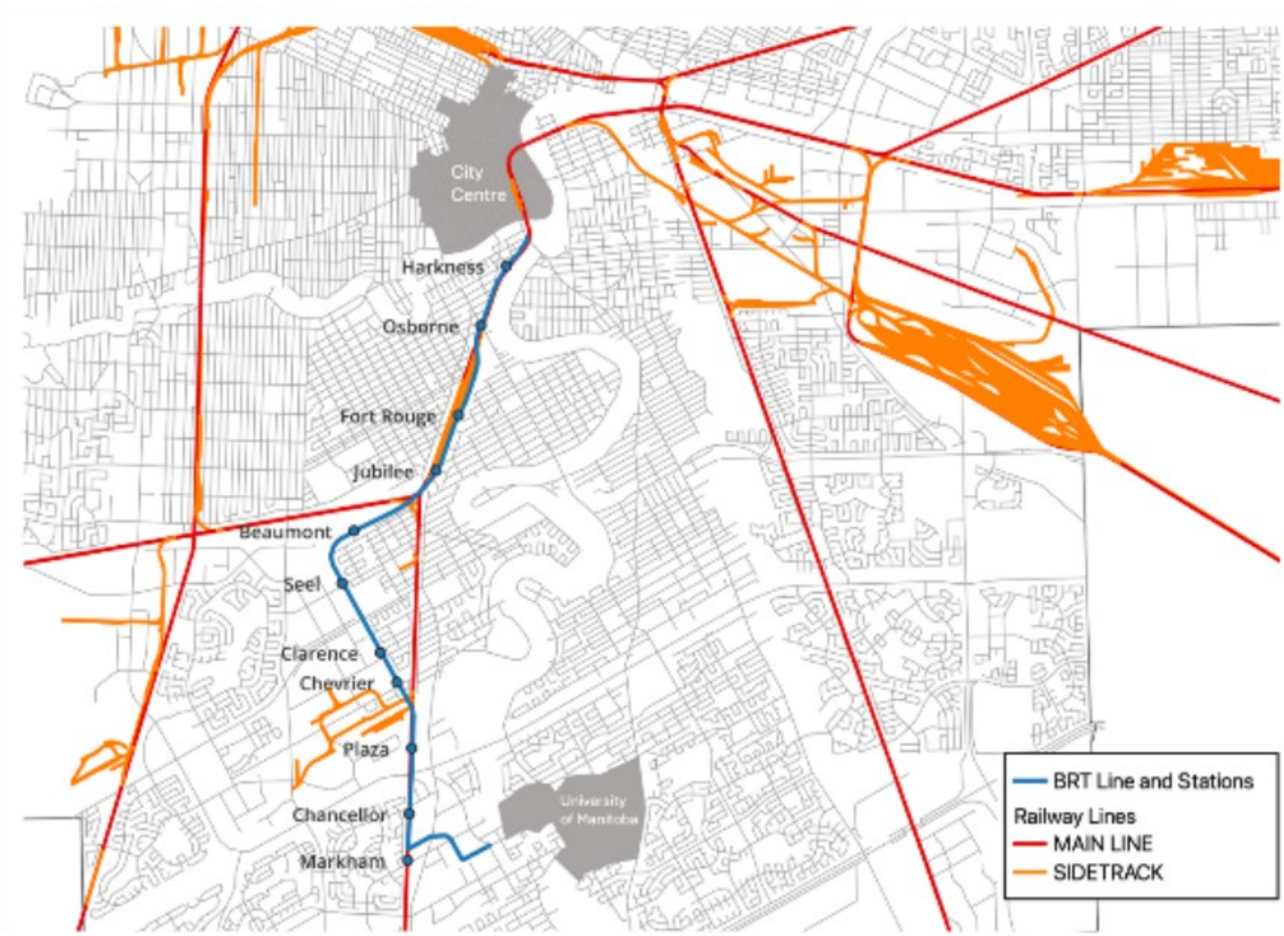

Figure 1. Dedicated BRT line, railway lines and major destinations.

lines with no pedestrian crossings and low density land uses (see Figure 2) and facing the backs of existing development (see Figure 3).

Identifying Perceptions and Measuring Realities

For this study, we ask: How does the presence of freight rail lines in BRT station areas influence residential developments? We answer this question using an independent mixed methods design, where the qualitative and quantitative strands are distinct in implementation and mixing of data occurs in the interpretation stage (Creswell & Clark, 2011, p. 64-67) (see Figure 4). Given the exploratory nature of this research, this design was chosen to allow more in-depth understanding of both data types (Creswell & Clark, 2011). Winnipeg was selected as a critical case because of the co-location of working rail lines and rapid transit, typical levels of development pressure, and robust planning and development communities. The surveys examine the perceptions of development-related professionals regarding freight rail corridors' influence on residential developments, while the statistical analyses demonstrate whether and to what extent developments have occurred within

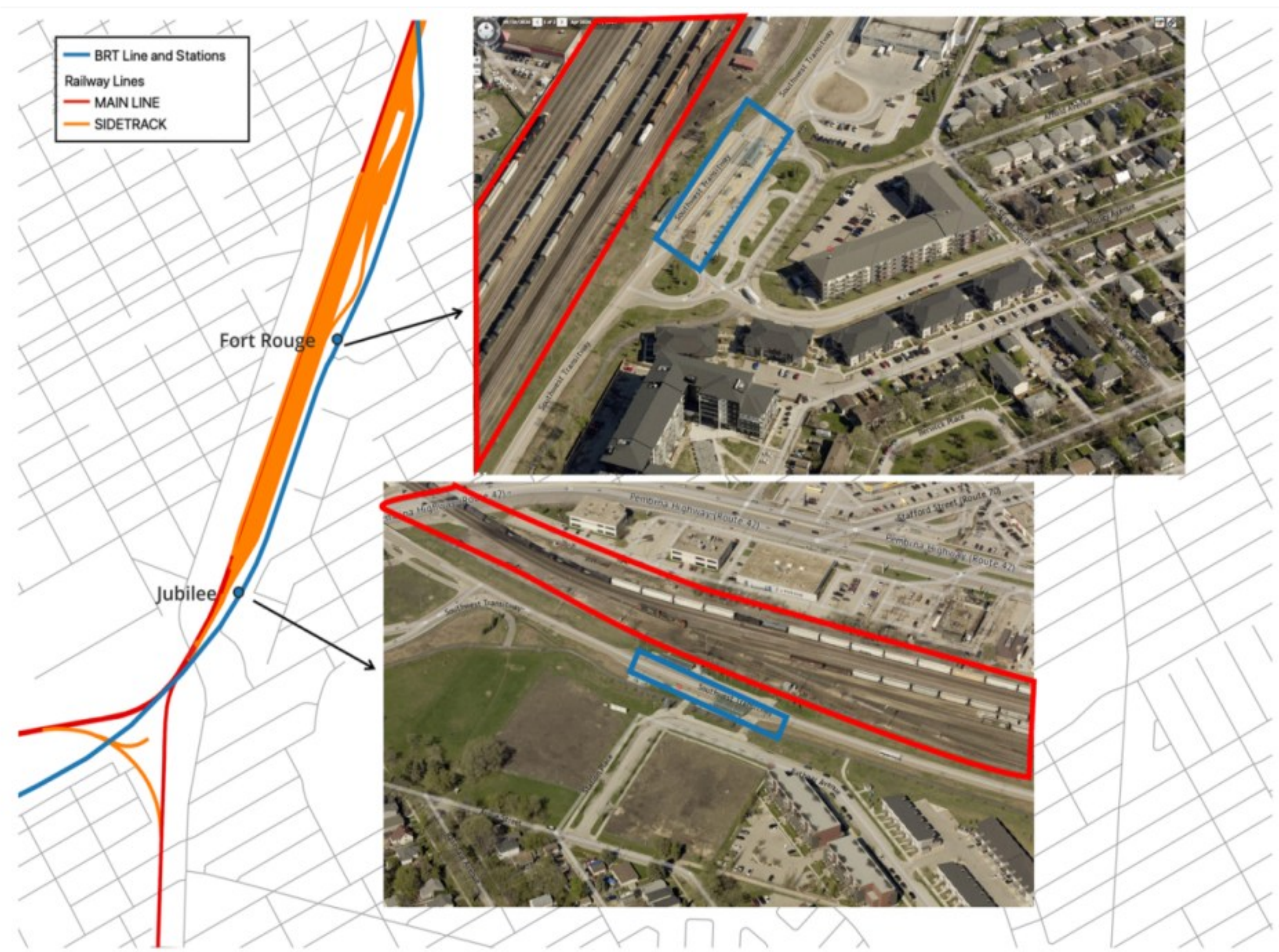

Figure 2. Sample station areas and adjacent land uses (Aerial photos, City of Winnipeg 2024, https://legacy.winnipeg.ca/pictometry/ipa.aspx).

BRT station areas. The combination of these data sources offers unique insight into both the perception of development potential and its implementation.

Surveys: Perceptions of Building near Railways

We conducted online surveys to understand the perceptions of two types of actors influential in land development decisions: (1) urban planners and (2) home builders and developers. The first survey (conducted March 2018) targeted planners, including professionals listed in Winnipeg's publicly available BRT, TOD, and transportation plans and studies who worked for the City of Winnipeg's Planning Department or Winnipeg Transit, as well as consultants listed in BRT plans (hereafter: planners).

The second survey (conducted March 2020) targeted homebuilders and developers (HBDs) located and working in Winnipeg. We gathered developer contact information from newspaper articles, TOD plans, and the Manitoba Home Builders Association's publicly available list of members. The planner survey targeted 63 planners with a response rate of approximately 13% (n = 8) and the HBD survey targeted 125 professionals with a response rate of approximately 14% (n = 17). Both surveys involved only close-ended questions. Given

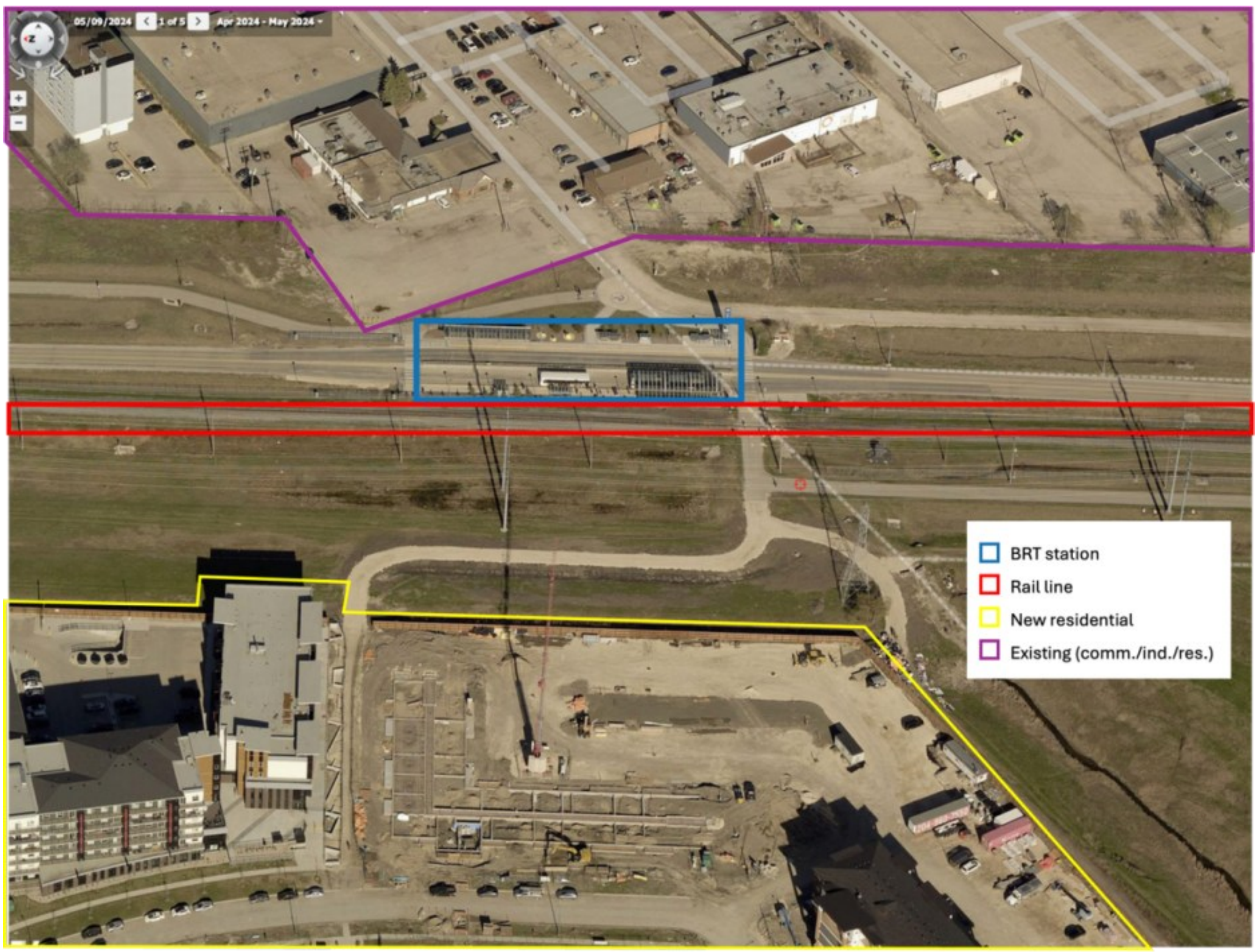

Figure 3. Plaza BRT station with adjacent land uses (Aerial photo, City of Winnipeg 2024, https://legacy.winnipeg.ca/pictometry/ipa.aspx).

the exploratory nature of this research, the survey data offers descriptive information, rather than inferential analyses.

Regressions: Reality of Building near Railways

To measure the scope of BRT-adjacent residential developments, we analyzed residential building permits and conducted a series of quasi-Poisson regressions. The purpose of our statistical analyses is to understand developer interest in station areas. We use quasi-Poisson regressions to better understand and explain how being within a BRT station area predicts the likelihood of the number of dwelling units per building permit. That is, we aim to identify how being within a BRT station area predicts an increase or decrease in dwelling units – which we use as a proxy for developer interest. We use Poisson regressions due to using a count variable as our dependent variable (the number of dwelling units per building permit) and because we aim to understand the likelihood of number of dwelling units, and, hence, developer interest. Due to overdispersion in data for all models, we use quasi-Poisson regressions. With overdispersion, the variance in the predicted values is greater than would normally be expected. The formula for the Poisson regression model is:

$$ln(\mu i) = xi1\beta 1 + xi2\beta 2 + xi3\beta 3 + xi4\beta 4 + xi5\beta 5$$

where

μi represents the Poisson distribution of the dependent variable (dwelling units) at location i,

β represents the regression coefficients for the x independent variables: Location (1), Neighborhood (2), Socio-economic (3), Zoning (4),

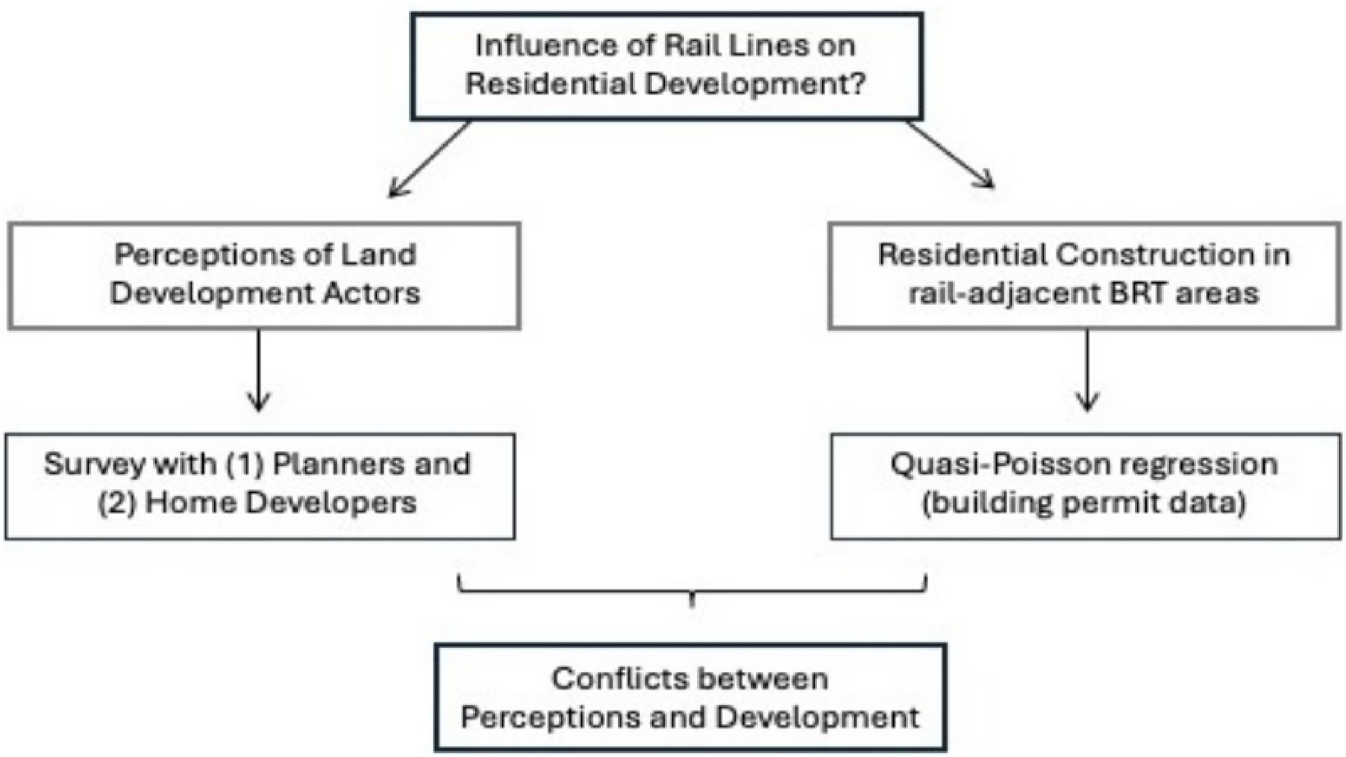

Figure 4. Summary of research methods.

and Permit Type (5) characteristics (see Table 1 for variable descriptions).

The total number of dwelling units per residential permit from 1 January 2010 until 29 September 2022 – where the permit address serves as our unit of analysis – is our dependent variable (see Figure 5 for maps showing building permits across Winnipeg and the BRT transitway). This provides the earliest publicly available permits prior to the opening of the Transitway to after the Transitway's completion. We only used the number of single-family dwelling (SFD) or multi-residential (i.e., apartment or multi-residential rowhouses) units per permit in Winnipeg. We further extracted SFDs by detached or non-detached status due to the building permit data including rowhouses (only if the permit does not identify the construction as multi-residential) and townhomes or duplexes (non-detached) as SFDs. We then mapped the permits using ArcGIS (ESRI, 2019). No other mathematical manipulations were done to the permit data before the statistical estimations. We ran five sets of regressions, using the number of dwelling units per the following permits as the dependent variable for each set: 1) all residential permits, 2) only SFD permits, 3) only SFD, non-Detached permits, 4) only SFD, Detached permits, and 5) only apartment permits. Essentially, the number of dwelling units represents development interest.

Our main predictor variable was the Station Area dummy variable. We created separate 400-, 800-, and 1200-metre network buffers around all BRT stations. These buffers are not mutually exclusive. That is, the 800m network buffers could contain all or portions of the 400m buffer areas and the 1200m buffers could contain all or portions of the 400m and 800m buffer areas. We then gave permits scores of one (1) if they were in a selected buffer and zero (0) if not. Three issues are important here. First, creating a network distance is imperative when establishing the buffers as the rail lines impose a physical barrier for both pedestrians to access the stations and for actual developments. Second, the different buffers allow us to identify whether residential developments are more likely to occur in close proximity to the stations or farther away. Third, all buffers with residential permits had an in-use, freight rail line intersect it. In this regard, we are assessing whether being located within a BRT station area has a statistically significant influence on development interest (i.e., dwelling units). For each regression set, we only used one of the separate Station Area dummy variables. This ultimately gave us fifteen (15) different regressions to assess the influence of the BRT stations on residential development interests.

Additionally, we included location, neighborhood, socio-economic, and zoning characteristics as control variables. The neighborhood and socio-economic characteristics are included to account for how neighborhood and socio-economic conditions influence building permits. We selected the given variables based on existing research analyzing BRT impacts on housing and land use (Acton et al., 2022; Sidloski & Diab, 2020) and model fit. We include zoning characteristics to control for the amount of land area that would actually allow for new residential building developments.

Data Sources

We cleaned data and ran the analyses using ESRI's ArcGIS and R Studio along with various R packages, respectively (ESRI, 2019; Hijmans, 2020; Hlavac, 2018; R Core Team, 2022). ArcGIS was used to create the maps and identify station locations, while R Studio allowed us to perform the statistical analyses. We collected the bus, including BRT, stop data from Winnipeg Transit (2022) – providing stop data as of June 2020. Building permit data, community areas, downtown business improvement zones for the central business district location, park,

Table 1. Variable Descriptions for the Poisson regressions.

Variable	Description
<u>Dependent Variable</u>	
Dwelling Units	Number of Dwelling Units and Dwelling Unit Type by Building Permit
<u>Independent Variables</u>	
Station Area	Dummy variable: 1 if building permit is within a 400-, 800-, or 1200-metre network buffer around BRT stations, 0 otherwise
Location Characteristics	
Distance to Nearest Rail Line	Distance from Building Permit Location to Nearest Rail Line (in km.)
Distance to Central Business District (CBD)	Distance from Building Permit Location to the Central Business District (CBD) (in km.); the CBD was taken as the centroid of the Downtown Business Improvement Zone as determined by the City of Winnipeg
Neighborhood Characteristics	
Distance to Nearest Park	Distance from Building Permit Location to Nearest Park (in km.)
Bike lane Density	Length of Bike Lanes in Census Tract / Census Tract Land Area (in sq. km.)
Population Density	Total Population / Census Tract Land Area (in sq. km)
Socio-economic Characteristics*	
Distance to Nearest Park	Distance from Building Permit Location to Nearest Park (in km.)
Bike lane Density	Length of Bike Lanes in Census Tract / Census Tract Land Area (in sq. km.)
Population Density	Total Population / Census Tract Land Area (in sq. km)
Socio-economic Characteristics*	
Income	Median Household Income ($2,011)
Housing Burden	% of owner and tenant households paying more than 30% of household income towards housing
Occupied Housing	% of occupied housing
Visible Minorities	% of visible minorities per census tract
Zoning Characteristics	
Single-Family Residential	% of parcels zoned as single-family residential
Two-Family Residential	% of parcels zoned as two family residential
Multi-Family Residential	% of parcels zoned as multi-family residential
Mixed-Use	% of parcels with mixed-use (residential and commercial)
Permit Type	
Apartments**	Dummy Variable, 1 if a Building Permit is an Apartment, 0 otherwise

*Notes: *Socio-economic conditions were gathered at the census tract level for 2011. We gave the building permit the census tract characteristics of the census tract in which it is located.*

***The Apartments variable was only included in the regressions using all dwelling unit types.*

Figure 5. BRT transitway and building permits.

bicycle lane, sidewalk, and road network (including BRT line) spatial data come from the City of Winnipeg's Open Data Catalogue (City of Winnipeg, 2022a, 2022b, 2022c, 2022d, 2022e, 2022f, 2024). The census tract shapefile comes from Statistics Canada (2019) with Winnipeg hydrology data from the Manitoba Land Initiative (n.d.). The hydrology data was needed in order to identify only land area for Winnipeg census tracts. Census data come from the Cancensus package in R (von Bergmann et al., 2021). We gathered rail line data from the Government of Canada (2021).

Limitations

There are several limitations to this research. The response rate is on the lower end for direct recruitment surveys. Declining response rates from elites have been noted as an issue, particularly as online surveys become more prevalent (Krause et al., 2024). Participants with strong interest in the issues may also have been more likely to participate in the research. While we focus on key actors on the development side – builders, developers, and planners – further research could address other stakeholders, such as residents and elected officials. Additionally, we conducted our surveys approximately six (6) and eight (8) years after the initial opening of the first stage of the Southwest Transitway. Many of the initial actors listed in the planning documents may no longer work within the same area or have access to the publicly available emails we used to recruit participants. Thus, surveys conducted as close as possible to the initial opening or planning could yield more robust response rates. In terms of the statistical analyses, different statistical approaches could yield different results. We use Poisson regressions, quasi-Poisson specifically, to identify the likelihood of a developments in station areas. Indeed, given our purposes here and focusing on permit locations as the unit of analysis, a statistical method focusing on count data provided the best method. However, other models could better explain causality (e.g., Difference-in-Difference) or even the influence of freight rail lines at different geographic units like the census tract or community area level (e.g., spatial or ordinary least squares regressions).

Results

Perceptions of Development near Rail

The surveys held targeted questions for each group, but we also asked a few overlapping questions in each survey. Overall, the different groups largely had disparate responses, but did converge on a few key questions. For starters, we asked, "How do you view the existence of an in-use freight rail line regarding TOD and station area planning?" The majority (76%) of HBDs responded that they viewed them positively, while no planner viewed them positively. Rather, half of the planners indicated that they viewed freight rail lines negatively.

Surprisingly, when asked about barriers to TOD implementation, both planners and HBD selected railroad infrastructure as a barrier the least frequently (Figure 6). Railroad infrastructure was selected the least overall (16% of respondents) but also one of, if not the least, for each selected group (17.7% of HBDs and 12.5% of planners). HBDs and planners also did not view lack of available land as a barrier. However, no planner selected this as a barrier while 24% of HBDs selected it as a barrier. On the other hand, a higher percentage of respondents overall selected lack of political will (44%), lack of funding (44%), and neighborhood opposition (40%) as barriers. When broken down by group, lack of political will was selected most frequently as a barrier by HBDs (53%) and planners selected neighborhood opposition most frequently as a barrier (63%).

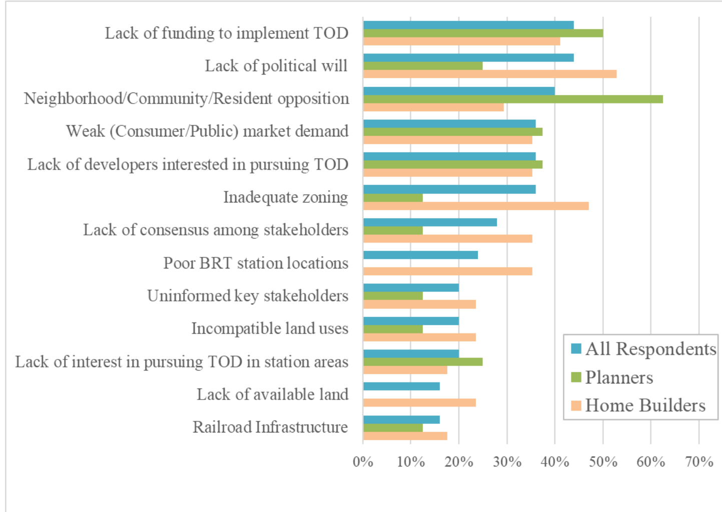

Figure 6. BRT Perceived barriers to TOD implementation, all respondents.

We also asked about the planning-related tools used to implement TOD (Figure 7). Planners were asked, "What tools were or are being used to implement TOD for Southwest Transitway Phase 1?" while HDBs were asked, "What tools do you think should be used to implement TOD?" First, even though neighborhoods opposition and weak market demand were commonly chosen as barriers, gathering community support was not chosen as a tool used by Planners during Phase 1 and was one of the least selected tools identified as needed by HBDs. Meanwhile, infrastructure improvements (e.g., sidewalks, street-lighting, bike lanes, street beautification/landscaping, etc.) were highly identified by both groups as a tool both used and needed for TODs. However, while 82% of HBDs noted Zoning Incentives as a needed tool, only 13% of planners identified it as actually used in developing around BRT stations.

Development in Station and Non-Station Areas

With building permits, a few differences are worth noting between the characteristics of different station areas and the remaining areas of Winnipeg (Table 2). When comparing the average number of dwelling units in station areas and the rest of Winnipeg, station areas have between just over three to more than five times more dwelling units than the rest of Winnipeg – meaning station areas have considerably more new dwelling units than non-station areas, on average per building permit. Permits in the station areas were also in census tracts with greater bike lane and population densities. However, some of the biggest differences in census tract characteristics between station area and non-station area permits come in terms of median household incomes and the percentage of visible minorities. Income for Winnipeg as a whole and in all non-station areas was roughly $30,000 greater than in any of the different station areas for 2011. Meanwhile, visible minority rates for Winnipeg's non-station areas were at least double compared to station area rates.

We also assessed the total number of new dwelling units constructed between 2010 and 2022 for all of Winnipeg the different station areas, and Winnipeg Community Areas (Table 3). Community Areas are clusters of Winnipeg neighborhoods used for planning and administrative purposes (see Figure 8). Identifying developments in Community Areas can provide a description of development occurring across different spaces throughout Winnipeg. However, our aim in this study is to focus on station areas specifically and we limit our discussion of permits in Community Areas to this descriptive section. Further studies could better explore permits in different Community Areas. Table 3 shows the percentages of permits for the different dwelling unit types across the different geographies. Notably, single -family dwellings and apartments were almost evening split, 51% versus 49%, respectively. SFD, detached dwellings accounted for 37% of total permits for Winnipeg. Station areas, regardless of size, exhibited very different distributions. SFDs accounted for between 12-15% while SFD, detached dwellings accounted for 2%, 6%, and 8% for 400m, 800m, and 1200m station areas, respectively. Apartments made up the overwhelming majority of permits in station areas with at least 85% of total permits. The Downtown Community Area had roughly the same distribution of permits as Winnipeg's different station areas where Apartments also accounted for 88% of total permits. However, the dwelling units in 400m, 800m, and 1200m station areas represented just 2%, 4%, and 6% of overall Winnipeg dwelling units, respectively.

Southwest Transitway, Phase 1 stations are part of the River Heights and Fort Garry Community Areas. Fort Garry held the most amount of building permits of any Community Area at 14,022, more than twice

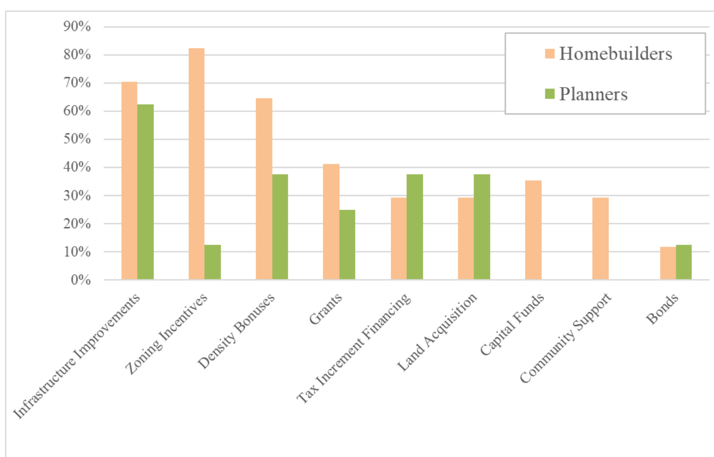

Figure 7. Planning-related tools currently used to encourage TOD.

the next largest amount of 6,832 for St. Boniface. More than a quarter of Winnipeg permits during the study period were in Fort Garry and almost a third of all permits went to Community Areas holding the Southwest Transitway. The distribution of Fort Garry permits was similar to Winnipeg's overall permits: 55% single-family dwellings and 45% apartment dwellings. River Heights, though, had a higher distribution of apartments at 70% which was the largest share of apartment permits for any Community Area.

The Reality of Station Area Developments

Table 4 shows Poisson regression results. The main independent variable of interest was the dummy variable indicating whether the dwelling unit was within a 400-, 800-, or 1200-metre network-distance buffer of a BRT station. As such, we identify whether and to what extent being within the different BRT station area buffers impacts the number of dwelling units – indicating development intensity. We omit results for SFDs with only Detached dwelling units due to all coefficients being zero (0).

With Poisson regressions, the Dwelling Unit – as the independent variable – is log-transformed and exponentiated values of dependent variables in Poisson regressions are easier to interpret than the raw coefficient values (Musunuru et al., 2020). The Station Area variable is a dummy variable whereby the exponentiated values of the Station Area coefficients indicate the proportional difference between dwelling units within station area and outside of station areas. For instance, when examining models using All dwelling units, 19% (1.19 exponentiated value of 0.173 coefficient) more dwelling units are expected in 400m station areas compared to non-station areas. Meanwhile, 5% (0.95 exponentiated values of -0.055 coefficient) less dwelling units are expected in 800m station areas. Models using the 1200m station areas showed statistically insignificant results for the Station Area variable. Thus, with all other conditions being equal, if a building permit outside of a 400m station area held 10 dwelling units, a building permit within a 400m station area would hold approximately 12 dwelling units, indicating an increased level of development intensity within 400m station areas, but less development intensity is expected within 800m station areas.

SFD and SFD, non-detached models showed that being within a BRT station area has a statistically significant and positive relationship on the amount of dwelling units. More total SFD dwelling units are expected in all station areas than non-station areas for all SFD models: 19%, 21%, and 15% for 400m, 800m, and 1200m station areas, respectively. The relationships between the number of SFD, non-detached dwelling units and 800m and 1200m station areas were positive and statistically significant with 32% and 34%, more SFD non-detached dwelling units expected in the respective station areas compared to outside of those station areas. The SFD, detached models had statistically significant relationships with all dwelling units, but these models all showed coefficient values of 0.00 indicating no practical relationship. Meanwhile, results for Apartment models showed no statistical significance for dwelling units in the different station areas.

Our results indicate three things for Winnipeg BRT station areas. First, more intense development in station areas has occurred compared to non-station areas overall as seen with the number of dwelling units for each residential permit. Regardless of the station area size, this could be due to land availability in station areas. Second, non-detached, single-family housing development is significantly more intense in station areas than throughout Winnipeg. Third, station areas provide no significant influence for new apartments. These results may indicate more of a preference for non-detached, single-family housing in station areas – representing a middle ground for denser housing in a city dominated by single-family homes.

Table 2. Descriptive Statistics.

	Winnipeg (All)				Winnipeg (No Station Areas)				400m Station Area				800m Station Area				1200m Station Area			
	Mean	**St. Dev.**	**Min**	**Max**	**Mean**	**St. Dev.**	**Min**	**Max**	**Mean**	**St. Dev.**	**Min**	**Max**	**Mean**	**St. Dev.**	**Min**	**Max**	**Mean**	**St. Dev.**	**Min**	**Max**
Dwelling Units	2.05	9.60	1.0	352.0	1.96	9.15	1.00	352.0	10.56	29.59	1.00	156.0	7.78	3.54	1.00	156.0	7.13	23.48	1.00	234.0
Nearest Rail Line	1.29	0.83	0.02	3.6	1.31	0.82	0.02	3.65	0.16	0.07	0.03	0.47	0.26	0.13	0.03	0.58	0.33	0.20	0.02	0.94
Distance to CBD	9.33	2.97	0.4	16.4	9.42	2.90	0.42	16.47	3.71	1.29	1.12	8.85	3.81	1.66	1.01	9.25	4.03	1.89	0.59	10.02
Distance to Nearest Park	0.12	0.12	0.00	2.9	0.12	0.12	0.00	2.91	0.09	0.03	0.02	0.16	0.13	0.08	0.00	0.56	0.15	0.10	4.00	0.76
Bike Lane Density	0.10	0.53	0.00	8.2	0.08	0.49	0.00	8.23	0.11	0.43	0.00	2.00	0.66	1.14	0.00	3.00	0.98	1.37	0.00	4.00
Population Density	1155	1178	23	12008	1119	1123	23	12008	2758	804	1030	6136	3088	1643	1030	10021	3205	2082	528	10021
Income($000)	92.8	17.5	28.2	148.6	93.3	17.2	28.2	148.6	62.4	9.0	50.1	105.3	62.7	9.16	41.9	105.3	65.5	11.8	42.9	105.3
Housing Burden	0.20	0.06	0.06	0.4	0.20	0.06	0.06	0.45	0.24	0.03	0.13	0.30	0.25	0.04	0.13	0.41	0.26	0.04	0.13	0.41
Occupied Housing	0.94	0.04	0.82	1.0	0.94	0.04	0.82	1.00	0.95	0.01	0.92	0.99	0.95	0.02	0.92	0.99	0.95	0.02	0.88	0.99
Visible Minorities	0.32	0.16	0.02	0.7	0.32	0.16	0.02	0.71	0.11	0.06	0.05	0.31	0.15	0.08	0.05	0.46	0.16	0.10	0.05	0.47
Single-Family Residential Zoning	0.69	0.46	0.00	1.0	0.69	0.46	0.00	1.00	0.12	0.32	0.00	1.00	0.46	0.50	0.00	1.00	0.57	0.50	0.00	1.00
Two-Family Residential Zoning	0.09	0.28	0.00	1.0	0.09	0.28	0.00	1.00	0.08	0.28	0.00	1.00	0.18	0.38	0.00	1.00	0.17	0.37	0.00	1.00
Multi-Family Residential Zoning	0.08	0.27	0.00	1.0	0.08	0.28	0.00	1.00	0.04	0.19	0.00	1.00	0.07	0.26	0.00	1.00	0.08	0.27	0.00	1.00
Mixed Use (Residential) Zoning	0.00	0.06	0.00	1.0	0.00	0.06	0.00	1.00	0.11	0.31	0.00	1.00	0.05	0.21	0.00	1.00	0.03	0.17	0.00	1.00

Notes: Observations (i.e., number of Permits): Winnipeg (All): 24852, Winnipeg (No Station Areas): 24425, 400m Station Area: 85, 800m Station Area: 243, 1200m Station Area: 427

Additionally, the distance to the nearest rail line exhibits a negative and significant relationship for All dwelling units regardless of station area size. Yet, this pattern does not hold when examining dwelling units by dwelling unit type. With SFD, non-detached models, more dwelling units are expected as distance to the nearest rail line increases. This may seem counter to station area variable results, but distance to nearest rail line accounts for dwelling units throughout Winnipeg and only a small fraction of Winnipeg's new building permits go in BRT station areas. For additional controlling characteristics, while Income and Population Density were statistically significant for All dwelling units (and all SFD dwelling units for Population Density), but practically insignificant with coefficient values of 0.00. Statistically significant zoning characteristics showed similar patterns across all models: negative coefficients for One- and Two-Family Residential Zoning, but positive coefficients for Multi-Family and Mixed-Use Zoning. This makes sense given that our independent variable is the number of dwelling units for new building permits; that is, single-family and two-family zoning areas would have less dwelling units than multi-family and possibly mixed-use zoning areas.

Linking Perceptions and Realities for BRT Station Developments

In answering our research question, – "How does the presence of freight rail lines in BRT station areas influence residential developments?" – we found a split between the perceptions of and realities involved in Winnipeg's BRT station area developments. Perceptions of developing around BRT stations within existing freight rail corridors were split down the middle between HBDs and planners. On one hand, survey respondents in total did not view the rail lines as major barriers to BRT station area developments. On the other hand, planners generally viewed the existence of an in-use, freight rail line negatively, but homebuilders and developers viewed the existence positively. Given the experiences with light rail – where co-location is seen as suppressing development potential (Cervero, 1984; Nelson & Ganning, 2015), this is a surprising finding from developers. As the private sector is largely responsible for implementing TOD, this may point to alignment tradeoffs having less impact on the resulting built form, though this does not address larger questions about transit use.

Interestingly, both planners and HBDs highly regarded infrastructure improvements like sidewalks, street-lighting, or landscaping as needed for TODs. This could be especially important given the peripheral alignment of Winnipeg's BRT where there is limited pedestrian focused infrastructure surrounding or connecting the stations to the existing landscape. Pezeshknejad et al. (2020) reveal that improved access to stations with multiple pedestrian routes could improve station accessibility and the chances of establishing BRT TOD. For other cities with peripheral BRT alignments and limited existing pedestrian-focused infrastructure, offering multiple pedestrian focused routes to stations becomes imperative. Indeed, the removal of transport barriers has positively transformed land uses and increased housing prices around selected rail crossings in Melbourne, Australia (Gbban et al., 2023; Liang et al., 2021). Moreover, improving station accessibility could provide a diversity of pedestrian activities and, in turn, enhance safety by increasing the number of people using the stations (Zandiatashbar & Laurito, 2023). More people using the stations, moving throughout the area, and just the added presence of people could deter crime – which would induce more people to use safe station spaces (Zandiatashbar & Laurito, 2023). Additionally, both planners and HBDs highly regarded neighborhood opposition as a barrier to station area developments.

Table 3. Total Dwelling Units for all building permits and broken down by residential type.

	All	SFD	SFD, detached	SFD, non-detached	Apartments
Winnipeg	51011	26170 51%	19073 37%	7097 14%	24841 49%
400m	898	105 12%	15 2%	900 10%	793 88%
800m	1891	277 15%	117 6%	160 8%	1614 85%
1200m	3044	459 15%	257 8%	202 7%	2585 85%
Assiniboine South	2704	1047 39%	1011 37%	36 1%	1657 61%
Downtown	2648	310 12%	128 5%	182 7%	2338 88%
Fort Garry	14022	7705 55%	5594 40%	2111 15%	6317 45%
Inkster	2008	1783 89%	1108 55%	675 34%	225 11%
Point Douglass	800	475 59%	334 42%	141 18%	325 41%
River East	3325	1069 32%	873 26%	196 6%	2256 68%
River Heights	2525	766 30%	420 17%	346 14%	1759 70%
Seven Oaks	5153	3074 60%	2136 41%	938 18%	2079 40%
St. Boniface	6832	4206 62%	3111 46%	1095 16%	2626 38%
St. James - Assiniboia	1183	597 50%	521 44%	76 6%	586 50%
St. Vital	3680	1678 46%	1299 35%	379 10%	2002 54%
Transcona	6131	3460 56%	2538 41%	922 15%	2671 44%

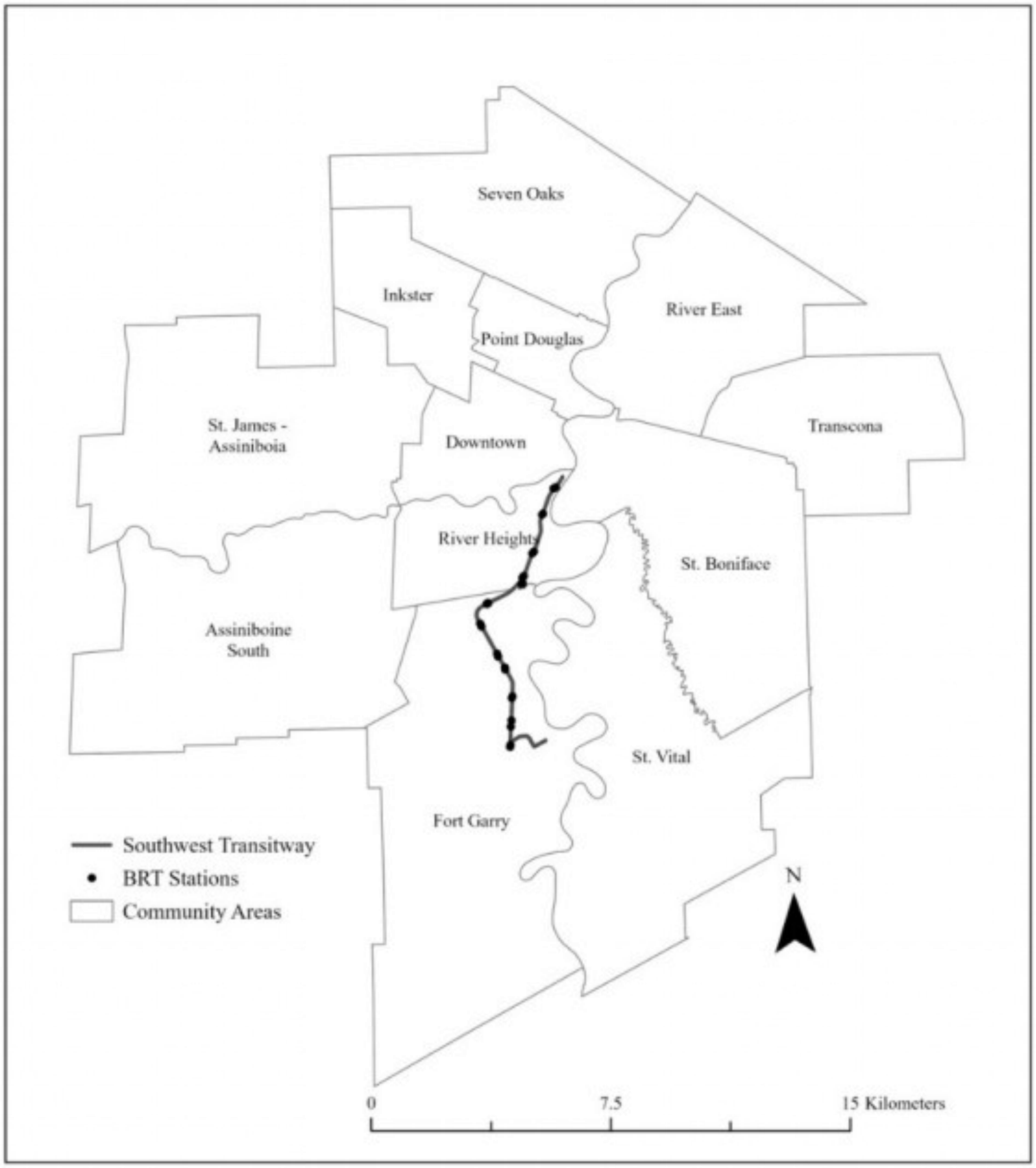

Figure 8. Winnipeg Community Areas.

This may be surprising given the peripheral alignment and the purported minimal disruptions on existing neighborhoods. However, this could be due to a difference between the perception of neighborhood opposition and actual opposition. In this regard, future studies could examine the true extent of neighborhood opposition to these peripheral alignments.

Empirically, regression results suggest that despite being adjacent to in-use freight lines, the BRT corridor has experienced increased development intensity. Based on our results, Winnipeg has experienced intense in-fill development in previously underutilized spaces largely in the form of non-detached single-family housing (i.e., row- or town-uses) when compared to non-station areas, arguably due to investment in BRT. However, the station areas still hold a relatively small share of Winnipeg's new residential developments. Nevertheless, the increased intensity is beneficial in two ways. First, while there is still demand for single-family dwellings, BRT's influence may be supporting the development of denser residential development and helping diversify available housing options.

Overall, the implications of this research for planning practice are highlighted in two important findings. First, planners, who can create the conditions allowing for development around BRT station areas (e.g., establishing allowable zoning and land use regulations), do not generally view in-use freight lines positively. However, home-builders and developers have positive views of developing in BRT station areas within in-use freight rail corridors. With HBDs' positive views, our results inform planners of the potential of developing in such areas. Thus, planners could be apt to help establish conditions and zoning to make these areas more suitable for new developments, while ensuring that long-term safety and quality of life issues surrounding in-use freight rail corridors are addressed. Certainly, planners and city leaders supporting TOD in BRT station areas has been instrumental in shaping TOD in cities like Ottawa and Curitiba (Cervero & Dai, 2014; Santos, 2011). In both cases, city leaders are noted as using TOD specific zoning, tax policies, infrastructure investments, and, in Curitiba specifically, mandates for larger scale developments to be sited along BRT corridors (Cervero & Dai, 2014). However, with in-use rail lines adjacent to corridors, careful attention must be paid to the perceived and actual drawbacks to these peripheral areas.

Second, the results of the regressions show an increase in development intensity surrounding BRT stations – all of which are within in-use freight rail corridors. Our results suggest more dwelling units per building permit to be expected in station areas overall compared to non-station areas. This intensity is best shown with non-detached, single-family dwellings. Thus, we expect substantially more row- and town-house style homes within 800 and 1200 metres of a BRT station than elsewhere within Winnipeg. Our results lend positive support to researchers and practitioners aiming to highlight and entice developments in BRT station areas – especially those within freight rail corridors. In particular, planners and developers can take advantage of missing middle housing opportunities that exist in these peripheral station areas. This is especially pertinent in cities with an affinity for single-family housing. As Wegman (2020) details, cities across North America and especially Portland, Oregon and Minneapolis, Minnesota have recently begun challenging single-family only zoning. Creating zoning allowing for non-detached single-family housing in transit station areas in peripheral spaces could help push cities like Winnipeg to enhance its urban core and offer additional housing choices without completely overturning single-family zoning.

While our results show promise and can indicate to planners the existing appetite for developing in BRT station areas, Soliz et al.'s (2024) research provides a note of caution. TOD goals were created in association with the announcement of Montreal's light rail transit (LRT) system in 2015. Yet, Soliz et al. (2024) found that limited bylaws were established to actually support and implement the TOD goals. They also found that low-density zoning continued around new LRT stations. While Winnipeg's BRT station areas actually show more medium-density or missing middle housing developments, our study also underscores the need for planners and policy-makers to better enact zoning regulations to more fully support TOD. Indeed, developers' generally positive perceptions of freight rail lines and the significance of non-detached housing in Winnipeg's BRT station areas provide a firm foundation and the necessary support for planners and city officials to now fully

Table 4. Regression Results, Dependent Variable: Dwelling Units in 400m, 800m, and 1200m Buffer Network Areas.

	All			SFD, All			SFD, non-Detached			Apartments		
	400m	800m	1200m	400m	800m	1200m	400m	800m	1200m	400m	800m	1200m
Station Area	0.173***	-0.055*		0.171**	0.190***	0.137***		0.279**	0.290**			
Distance to Nearest Rail Line	-0.021**	-0.023**	-0.021**				0.143***	0.146***	0.147***			
Distance to Central Business District	0.015***	0.015***	0.015***	-0.006**	-0.005**	-0.005**	-0.038***	-0.037***	-0.036***	0.042*	0.041*	0.041*
Distance to Nearest Park	0.276***	0.256***	0.262***	-0.100**	-0.099**	-0.102**						
Bike Lane Density												
Population Density	-0.000**	-0.000**	-0.000**	0.000***	0.000***	0.000***						
Income	-0.000*	-0.000**	-0.000**									
Housing Burden							-0.679*	-0.689*	-0.715*			
Occupied Housing		-0.331*	-0.298*	-0.282**	-0.290**	-0.302**	-2.792***	-2.853***	-2.890***			
Visible Minorities	0.191***	0.183***	0.184***									
Apartments	3.645***	3.643***	3.644***									
Residential Zoning, One-Family	-0.287***	-0.290***	-0.290***	-0.175***	-0.175***	-0.177***						
Residential Zoning, Two-Family	-0.485***	-0.494***	-0.490***	-0.055**	-0.054**	-0.055**	-0.120**	-0.114**	-0.117**	-1.369***	-1.382***	-1.378***
Residential Zoning, Multi-Family	0.040**	0.038*	0.038*	0.128***	0.129***	0.128***	0.101**	0.109**	0.110**			
Mixed-Use Zoning (Residential/ Commercial)	0.275***	0.293***	0.289***	2.082***	2.084***	2.084***	2.305***	2.325***	2.327***			
Constant	0.391*	0.505**	0.458**	0.419***	0.421***	0.441***	3.285***	3.304***	3.356***	3.959*	4.179**	4.113**
Observations	24,852	24,852	24,852	24,371	24,371	24,371	5,298	5,298	5,298	481	481	481
Residual Deviance (df = 24836)	20,519.98	20,537.5	20,541.9	3,869.44	3,863.39	3,864.89	3,546.58	3,536.97	3,533.60	15,047.6	15,092.67	15,087.9
Null Deviance (df = 24851)	148848.30	148848.30	148848.30	4,433.62	4,433.62	4,433.62	4,011.75	4,011.75	4,011.75	18,086.48	18,086.48	18,086.5
R^2	0.57	0.57	0.57	0.09	0.09	0.09	0.10	0.10	0.10	0.12	0.12	0.12
R^2 (adjusted)	0.57	0.57	0.57	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.09	0.09

Notes: *p<0.05, **p<0.01, ***p<0.001; Results for SFD with Detached Dwelling Units omitted here due to all coefficients being 0.
Only significant coefficients shown here. Full results for all models are shown in the supplemental materials.

integrate previously peripheral spaces to create thriving core.

Despite the importance of our study and significance of our results, some limitations must be noted and future research is still warranted. Notably, given the limited research in this area and exploratory nature, our study focused on a single urban area. Nevertheless, the development of the BRT corridor within an underutilized or even post-industrial space can resonate with various cities specifically within North America. Our results are especially important for older or post-industrial cities shifting towards reducing sprawl and re-using either undeveloped or former industrial inner city land to implement rapid transit systems and develop their related stations. Indeed, development potential exists within in-use freight rail corridors. The development impact of BRT has important implications as financially constrained jurisdictions work to implement rapid transit in difficult land use conditions. Despite these important land use implications, this does not offer insight into whether these developments impact ridership. As shown previously, while land use impacts are often an important focus of BRT investments (Linovski et al., 2018), this may conflict with ridership goals or the needs of existing transit users. It remains to be seen how these developments support the arguably primary goal of transit in serving users, particularly those that have less residential mobility. As cities continue to use peripheral sites for transit investments, this work demonstrates the need to balance development potential with ridership and quality of life goals.

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