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Assessing Richmond Transit Network Plan for Transit Oriented Development

Prepared for:

Greater Richmond Transit Company (GRTC)

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Author

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EXECUTIVE SUMMARY

The following document is an evaluation of Richmond Transit Network plan (RTNP) for transit oriented development. The study identifies gaps between new GRTC routes[1] and transit supportive/dependent areas based on transit propensity analysis. Major findings indicate that most of the high transit propensity block groups that are underserved, are located outside City of Richmond. Hence, recommendations for route extension to underserved areas with high transit propensity have been provided. Some of these extensions include:

- Extension of Route 19: Pemberton to Short pump. Future extension of BRT from Willow Lawn to Short pump.
- Extension of Route 3B- Highland/Jeff Davis to block groups (510411008192 and 510411008052) in proximity to Meadowbrook High School, along Cogbill road and near Iron gate shopping center

This study also identifies five potential nodes for transit oriented development (TOD), which are:

1. Broad St. node
2. East Main St. node
3. Chamberlyane road and Azalea avenue node
4. Willow Lawn node
5. Southside transfer plaza node

These nodes were selected based on transfer stops where 5 or more local routes meet. These nodes were then further studied for TOD potential and readiness based on the following factors such as transit propensity of block groups, land use mix (entropy index), walkability index, parking inventory and vacancy levels.

The study found Broad St. node and East main st. node to be established TODs as these nodes have high transit propensity, high walkability index and presence of high frequency routes. Willow lawn, Southside transfer plaza and Chamberlayne node appear to be as emerging TOD nodes, for their strengths such as large parking inventory, vacancy levels and good land use mix.

In addition, the plan provides following recommendations:

- Implement high frequency routes in Southside Transfer Plaza and Chamberlayne node

[1] New GRTC routes here means proposed routes under RTNP.

• Identify permanent transfer station within Broad St. node to improve on time performance and provide efficient transfer between routes

• Facilitate role of biker as feeder to bus transit by provision of bike lanes in Southside Transfer Plaza node and Willow Lawn node

• Build housing units in Willow Lawn and Southside Transfer plaza node; and create more jobs in Chamberlayne node

• Encourage infill development in Broad St node, Chamberlayne node and East Main St. node through utilization of vacant lots

• Conversion of parking lots into mixed use projects for transit oriented development in Willow Lawn and Chamberlayne node

• Encourage and support development practices that integrate land use with transportation; and development policies such as mixed use zoning in potential TOD nodes

• Provision of continuous sidewalks and decrease the number of existing gaps between sidewalks in Chamberlayne node and Southside Transfer Plaza node

• Repair and maintenance of existing sidewalks in Chamberlayne node and Southside Transfer Plaza node

1. CONTEXT

1.1 Client Organization

The Plan was requested by Greater Richmond Transit Company (GRTC) and it fulfills the requirements of the Master of Urban & Regional Planning program in the L. Douglas Wilder School of Government and Public Affairs at Virginia Commonwealth University.

GRTC is a public service corporation that provides public transportation service in the Greater Richmond area. It is jointly owned by the City of Richmond and Chesterfield County. GRTC relies upon federal, state and local grants to subsidize its day-to-day operations and its capital budget. Its history of being a progressive transit system was established when it was the first public transit agency to implement the system wide use of electric streetcars. That progressive attitude carries forth to today, as GRTC provides fixed-route, paratransit, and specialized transportation services to the City of Richmond, Henrico County, Doswell, Petersburg, and a small portion of Chesterfield County.[2]

GRTC Transit System seeks to become the leading provider of world class transportation services and mobility solutions. It describes its mission statement as, "to provide clean, safe, and reliable transportation and to improve mobility and access throughout Central Virginia." One of the core values of GRTC is having responsiveness to the needs of the communities it serves.

1.2 Plan Purpose

GRTC is preparing to implement the Richmond Transit Network Plan (RTNP) when the new GRTC Pulse service begins (anticipated by the end of 2017). RTNP study began in January 2016 to analyze the current GRTC Transit System bus network in the city and reconsider the design of the bus routes in the context of a changing city and the new Pulse BRT. Also, the current bus network has truly no frequent route, but with the new network Richmond city will have six, five new frequent routes plus the Pulse BRT under the daytime RTNP has been designed through collaboration among City of Richmond planning and transportation staff, GRTC staff, and consulting transit firms Jarrett Walker + Associates and Michael Baker International.[3]

[2] See GRTC website (http://ridegrtc.com/about-us/overview/).
[3] Final Recommended Network (http://www.richmondtransitnetwork.com/Pages/Final-Plan.aspx).

Under RTNP, 335 stops are being removed; and 467 stops are being moved or proposed.[4] The city will undergo major bus network change once the RTNP is implemented.

The client has requested this plan to measure the success of RTNP routes in terms of transit coverage. The Richmond Network Transit Plan is based on extensive public input (surveys & public meetings) and policy direction. It is a shining example of community engagement done right. As a part of its market assessment, RTNP studied existing conditions of the Richmond city such as residential density, job and activity density, walkability, senior population, race and ethnicity, zero car households and low income people for analysis but these factors were not combined to develop propensity scores that would reflect transit priority areas. Hence, this has presented an opportunity to identify transit areas that support and need transit the most based on transit propensity scores using Census data; and compare results with new GRTC routes.

The purpose of the plan is to analyze RNTP routes in terms of transit coverage of areas with high transit propensity. Another purpose of the plan is to identify major nodes/corridors in the GRTC service area for transit oriented development. TCRP Report 102 indicates that increased ridership is the principal goal of transit agencies in supporting TODs.[5] High ridership is important for GRTC to maintain the funding they receive.

The ultimate goal is to enhance mobility and accessibility by providing services in transit deficient areas. Another goal is to successfully implement TOD in identified nodes along GRTC routes which will lead to increase in ridership. These goals align with GRTC's mission and core values i.e. to respond to communities' needs; and increase accessibility in the region.

1.3 Literature Review

1.3.1 Transit Propensity

The transit industry has long considered the demographic makeup of an area's residents when determining locations that should have transit service. A transit propensity analysis identifies locations where the demographics of location indicate a higher propensity to use transit than do

[4] RTNP Stop Updates (https://www.arcgis.com/home/item.html?id=bd08b34d0fd64d30a66ed8866ef0a206).
[5] Arrington & Cervero, 2008.

other areas.[6] Transit propensity is a measure of demographics that indicate the propensity for people in a given area to use transit (Foursquare Integrated Transportation Planning, n.d.).

Transit Use Propensity (TUP) index as a combination of the strongest indicators of transit demand. It is based on population and employment densities, a transit dependency index[7] (low income households, persons with disabilities, and seniors aged 65+), and rates of access to automobiles.[8]

Transit Cooperative Research Program's (TCRP) Report 28 identifies demographic groups more likely to use public transit. It developed a transit use index by indexing transit use pattern for various demographic groups to the average transit use rate for all metropolitans in the United States. This Index is an indicator of magnitude of transit reliance; the higher the index, the greater the dependence on transit.

Bush (2012) proposed a methodology for conducting propensity analyses to identify areas of transit needs. His approach was based on TCRP report 28. He developed a weighted index that incorporates seven demographic factors, with an overall population density as an eighth evaluation factor. The demographic factors are the percentages of: zero vehicle housing units; mobility limitations; work disabilities; minorities; recent immigrants; low income households; and females. The relative percentage of each of these factors is calculated on the block group level and weighted to develop a composite score. The composite scores are arrayed into five categories using the "natural break" function found in ArcGIS to identify like groupings.

1.3.2 Transit Oriented Development

Transit Oriented Development has been defined generally as "a mixed-use community that encourages people to live near transit services and to decrease their dependence on driving (Carlton, 2007). Some other definitions by notable researchers include: TOD concept is an approach to expansion that aims to encourage the development of mixed use and compact, increasing the number of passengers of public transport and creating more livable communities, by Arrington and Cervero. A Transit-Oriented Development (TOD) is a mixed-use community

[6] Bush, 2012.
[7] Transit dependency refers to those individuals that rely on transit because they do not have access to a private vehicle or cannot drive due to a physical or mental impairment. It includes those who are unable to afford a vehicle and those who choose not to own a car.
[8] Seattle Transit Master Plan Briefing book (2011).

within an average one-fourth mile walking distance of a transit stop and core commercial area, by Calthorpe.[9] Federal Transit Association (2014) defines TOD as a mixed-use community extending for ¼ to ½ mile from a public transit station. It means development that is vibrant, pedestrian-friendly, and genuinely integrated with transit.[10]

According to State of California Statewide TOD Study 2003, Transit-oriented Development (TOD) is moderate to higher-density development, located within an easy walk of a major transit stop, generally with a mix of residential, employment and shopping opportunities designed for pedestrians without excluding the auto. TOD can be new construction or redevelopment of one or more buildings whose design and orientation facilitate transit use.

In 2014, Government Accountability Office (GAO) published a report, "Multiple Factors Influence Extent of Transit-Oriented Development," that identifies factors that support TOD. These factors include market demand for real estate, resident support for transit and transit-oriented development, availability of large parcels of land such as surface parking lots near transit stations or underutilized industrial land for development, and efficient transit routes that move from residential areas to job centers as directly as possible.

TOD principles state that development should be located around nodes or corridors where infrastructure capacity exists, or can be created. Prioritize locations with high levels of transit service frequency.[11] In addition, TOD seeks greater density but degree of density and compactness varies. It could be qualitative as well as quantitative. TOD is successful in regions that have strong economic indicators and housing demand.

Another important aspect to consider in TOD planning is infill development. Infill development, defined as new construction on vacant or underutilized sites within an established neighborhood or district, can similarly help reduce dependency on the private automobile by increasing the range of housing, employment, and other options available within a community. In addition, infill development can contribute to local economic development and help conserve rural and

[9] Sohoni, Thomas & Rao, 2016, p.3222.
[10] Marta, 2010, p.10.
[11] Queensland Government, 2010, p.12.

agricultural land. TOD often takes the form of infill development, but can also refer to greenfield or suburban development around a transit station.

All successful TOD should be transit supportive, but there are a few elements of TOD that are particularly important to supporting ridership. A regional TOD strategy can identify stations where small access improvements may leverage large changes in station access modes (shifting from the park-n-ride model to walking, biking, and taking transit.) Incorporating higher densities near transit also contribute to high ridership. This approach can also link regional goals of concentrating jobs and growing without sprawl to the goals of transit agencies, including increasing ridership during off-peak hours.[12]

1.3.3 Land use Entropy Index

The Entropy Index is a measure of land use mix which takes into account the relative percentage of two or more land use types within an area (Turner, Gardner, & O'Neill, 2001). Higher levels of Entropy correspond with greater land use mixture (Song & Knaap, 2004).[13]

Entropy (ENT) =

$$-\sum_{j=1}^{k} P_j \ln(P_j) / \ln(k)$$

In the equation above, P_j is the percentage of each land use type in group j in the area and k is the number of landuses in that given area.

Land use entropy is most extensively used metric. It is an area-based indicator that measures the degree to which different land uses are evenly distributed (Frank, Andersen and Schmid, 2004). Scores fall between 0 and 1, where 1 indicates a perfect mixture of all land uses in a given area. However, one shortcoming of the entropy measure, however, is its inability to capture land use diversity on a smaller scale, namely within a parcel or building.[14]

[12] Reconnecting America, 2013, p. vi.
[13] Rodriguez, Song, Merlin.,2013.
[14] Lavoie, 2012, p.9.

1.3.4 Job-Housing Balance

According to the APA, "A ratio of jobs to housing is most commonly used to express the concept of jobs-housing balance. Generally and simply stated, the jobs-housing ratio is a ratio between a measure of employment and a measure of housing in a given area of analysis."

Improving the jobs-housing balance can create economic and social opportunities by providing a mix of residential, office, retail, cultural and recreational uses. Further, mixed-use centers with jobs located close to housing are places where people may be able to walk, bicycle or take transit, reducing traffic congestion. Future transit station areas and other mixed-use centers should generally be planned for a jobs-housing ratio between 3.0:1 and 6.0:1. Centers with jobs-housing ratios significantly above 6.0:1 are not true mixed-use centers, but rather employment or business centers. The American Planning Association (APA) recommends that the ideal number of jobs to housing units is 1.5:1. Given below are some other recommended Job-housing balance ratios.[15]

Table 1.1. Job-Housing measurement

Jobs-Housing Measurement	**Recommended Target Standard (Implies Balance)**	**Recommended Target Range (Implies Balance)**	**Reference**
Jobs to housing units ratio	1.5:1	1.3:1 to 1.7:1 Or 1.4:1 to 1.6:1	Ewing 1996 Cervero 1991
Jobs to employed residents ratio	1:1	0.8:1 to 1.25:1	Cervero 1996

Source- Jobs-Housing Ratios: National Perspectives and Regional and Local Benchmarks

1.4 Precedent Plans

The Greater RVA Transit Vision Plan 2017

The RVA Transit Vision Plan identifies transit markets and gaps in service to those markets. It informs variables that make up TOD index such as population, age, household data, labor force, employment, commute mode, income and persons with disabilities. The following plan also provides information about data source such as 2009 – 2013 American Community Survey (ACS) estimates. Employment data was obtained from 2013 Longitudinal Employer – Household Dynamics (LEHD) by NAICS Code.

[15] Fairfax County Department of Planning & Zoning Planning Division, 2016, p. ii-iii, 3. (https://www.fairfaxcounty.gov/dpz/jobshousingreport.pdf).

The present plan, "Assessing Richmond Transit Network Plan for Transit Oriented Development," is different from RVA Transit Vision Plan based on the unit of analysis. The proposed plan uses Census block group[16] as the unit of analysis which is a smaller unit than TAZ. Furthermore, the latest census data i.e. ACS 2015, 5 year estimates will be used. Also, the present plan will use weighted suitability modeling to define transit propensity scores.

The Maryland Transit Administration (MTA) Bus Network Improvement Project 2013

The MTA Bus Network Improvement project informs about the variable inputs for transit propensity index and the methodology to assign scores to variables. It also tells about spatial representation and visualization methods for transit propensity scores. The plan studied existing and future land use and demographics of the region at the census tract level to identify areas with high transit needs. Socio-economic variables were obtained from American Community Survey (ACS) to develop transit propensity index. Data inputs are categorized into population, age, households, income, vehicle ownership, labor force size and commute mode. Overall, 33 different metrics were analyzed, including reviews of the data in the aggregate, by density and as a percentage of the total population.

Building on our Strengths: Evaluating Transit Oriented Development (TOD) opportunities in Greater Philadelphia 2017

The following plan informs about station screening methodology for TOD analysis. These stations were then screened for 3 basic factors related to transit orientation: Transit service quality, Population and Employment Intensity and Walkability. Furthermore, these stations were analyzed based on a methodology established by the Center for TOD (CTOD), these 12 factors were organized into two complementary categories designed to provide a comprehensive assessment of each station area: TOD Orientation and TOD Potential.[17]

North Miami Transit Oriented Development Feasibility Study 2004

This study informs about the methodology to select areas with the potential to be developed as TOD districts. The Miami-Dade Transit (MDT) transfer stops that enable transit riders to transfer between routes were chosen as preliminary transit nodes. The areas within a quarter mile radius of

[16] According to Census, a block group is a combination of census blocks that is a subdivision of a census tract or block numbering area (BNA).

[17] For more information see Delaware Valley Regional Planning Commission (DVRPC), 2017, p. 10 – 13.

these transit nodes were identified as the preliminary candidates for TOD districts. This plan also informs about the scoring methodology of nine potential TOD candidates districts identified in preliminary evaluation. The Study presents recommended policies and actions to implement TODs within North Miami.

1.5 Approach and Methodology

The following section informs about data collection and information gathering process, research methods; and analysis required to answer the research questions discussed above. This study is an applied research which is driven by practical aim to identify transit needs of the community and determine potential of GRTC routes. The study uses quantitative techniques for statistical analysis and interpretation of collected data. However, qualitative techniques are used to portray existing conditions.

1.5.1 Research Questions

As a part of research, the plan answers the following questions:

1. Which areas need transit the most?
2. How effective is RTNP in serving areas with high transit propensity?
3. Which corridors/nodes have potential for TOD?

1.5.2. Plan Implementation

The plan is divided into 2 sections to answer the research questions:

Section 1 Transit Propensity Analysis and Need Gap Analysis

This section covers transit propensity analysis that is used to identify areas with high transit needs and transit supportive areas. Demographic and socioeconomic characteristics are compiled into transit propensity index to determine transit groups that rely more on public transit. Methodology to develop Transit propensity index is based on underlying conditions of study area, TCRP report 28 and other precedent plans.

Study area for the research includes City of Richmond, Henrico County and Chesterfield County. Public transit in Richmond greatly impacts transit in surrounding counties. So, it is important to study these areas comprehensively and not just the city in isolation. Furthermore, most of GRTC's services are concentrated in these areas i.e. City of Richmond, Henrico County and Chesterfield County.

Demographic and socio-economic data such as population, age, household data, poverty, income, vehicle ownership, commute mode, labor force are studied at Census block group level. This data was obtained from American Community Survey (ACS) through American Factfinder; and employment data from LEHD. Demographic and socioeconomic analysis helps to determine development pattern which is strongly associated with Transit Demand. Hence, these variables are used to develop transit propensity index.

The following section also address the second question, i.e., how effective is RTNP in serving areas with high transit propensity. Need gap analysis[18] will be conducted to identify transit deficient/supportive areas and gaps in services to those identified areas. RTNP routes[19] and bus stops in Geographical Information Systems (GIS) data format (shapefiles/geodatabase) were obtained from GRTC.

Part 2 Transit Oriented Development

The following section focus on identifying potential nodes/bus stops for TOD. Preliminary screening based on transfer stops was performed as there are more than 1500 bus stops. A buffer of ¼ mile around identified stops (from preliminary screening) was used to study transit frequency, ridership, land use diversity, availability of vacant land, parking, transit propensity and walkability to evaluate TOD potential and readiness. Socioeconomic and land use data compiled into TOD index and its scores were used to identify established and emerging TODs.

Existing ridership and transit frequency data were obtained from GRTC. Existing land use data and parking data for Richmond was obtained from Richmond FTP website. Land use and parking data for Henrico County was obtained from open GIS data portal. Walkability index is based on National walkability index by Environmental Protection agency (EPA) and google maps/aerial images are used to check quality of sidewalks, connectivity to bus stops and parking inventory.

[18] A gap analysis can be defined as the determination of the difference between current knowledge/practices and current Evidence Based Practices (Janetti, 2012).

[19] RTNP routes and new GRTC routes have been used interchangeably and mean the same.

1.6. Road Map to the Document

1. Context

This sections includes information about client, describes purpose of the plan. It also includes literature review, precedent plans, research questions, approach and methodology for data collection, research and analysis.

2. Research and Analysis

This part of document contains analysis of existing conditions of the study area, transit propensity analysis and need gap analysis.

3. The Plan

This section includes information about the plan development, vision statement of the plan, suitable goals and objectives that align with GRTC's mission and fulfill needs of the plan.

4. Recommendations and Implementation Strategies

This section includes recommendations and strategies to fulfill goals and objectives. This section answers questions such as how and who will implement these strategies. It includes key players and funding sources available to execute the strategies. Phasing of activities reflecting priority levels and their timelines is included.

2. RESEARCH AND ANALYSIS

2.1 Transit Propensity of the Study area

To identify areas with transit needs and transit supportive areas, existing conditions of Richmond, Henrico County and Chesterfield County were studied at census block group level. Data was obtained from American Community Survey (ACS) 2011- 2015 5 year estimates through American Factfinder. The socio-economic data was then compiled into transit propensity index (see table 2.1) and Z scores of each variable were computed. The formula for standard score (Z score)[20] is

$$Z = (X - \mu) / \sigma$$

Where X= score, μ = mean and σ = standard deviation

The transit propensity index is based on factors identified in TCRP 28 report and various precedent plans. These scores were then aggregated and given suitable weights (see table 2.2) to compute weighted Z score of each Census block group. The composite scores are arrayed into five categories using the "natural break" function found in ArcGIS to identify like groupings.

Transit propensity scores of census block groups categorized into 5 groups (based on natural break function) are shown in map 2.1. Higher the scores, higher is the transit propensity of blocks. So, block groups that have scores ranging from 1.27 to 3.86 have the highest propensity i.e. these block groups are the most transit supportive and dependent areas. Some of these areas include block groups along Twin Hickory and near Short pump; core of Richmond city; Manchester, Scotts Addition, Boulevard near Diamond, along Genito road and Hull St; in Glen Allen along Staples mill road; Hampton Park and Ashbrook.; and in vicinity to Chesterfield County airport. Block groups that have scores ranging from -1.25 to -0.46 indicate least transit supportive and dependent areas.

[20] A Z-score (or standard score) represents how many standard deviations a given measurement deviates from the mean. In other words it merely re-scales, or standardizes, your data. A Z-score serves to specify the precise location of each observation within a distribution (http://influentialpoints.com/).

Table 2.1. Transit Propensity Index

Variable	**Measure**
Population	Total Population
Households	Total Households
Commute mode	Total Commuters Transit users
Age	Total Senior Population (65+)
Low Income households	Total persons below poverty population
Race and Ethnicity	Total Non-white Population
Disability	Total Disability Population
Zero Vehicle Households	Total Zero Vehicle Households
Employment	Average Employment in each block group Number of person employed

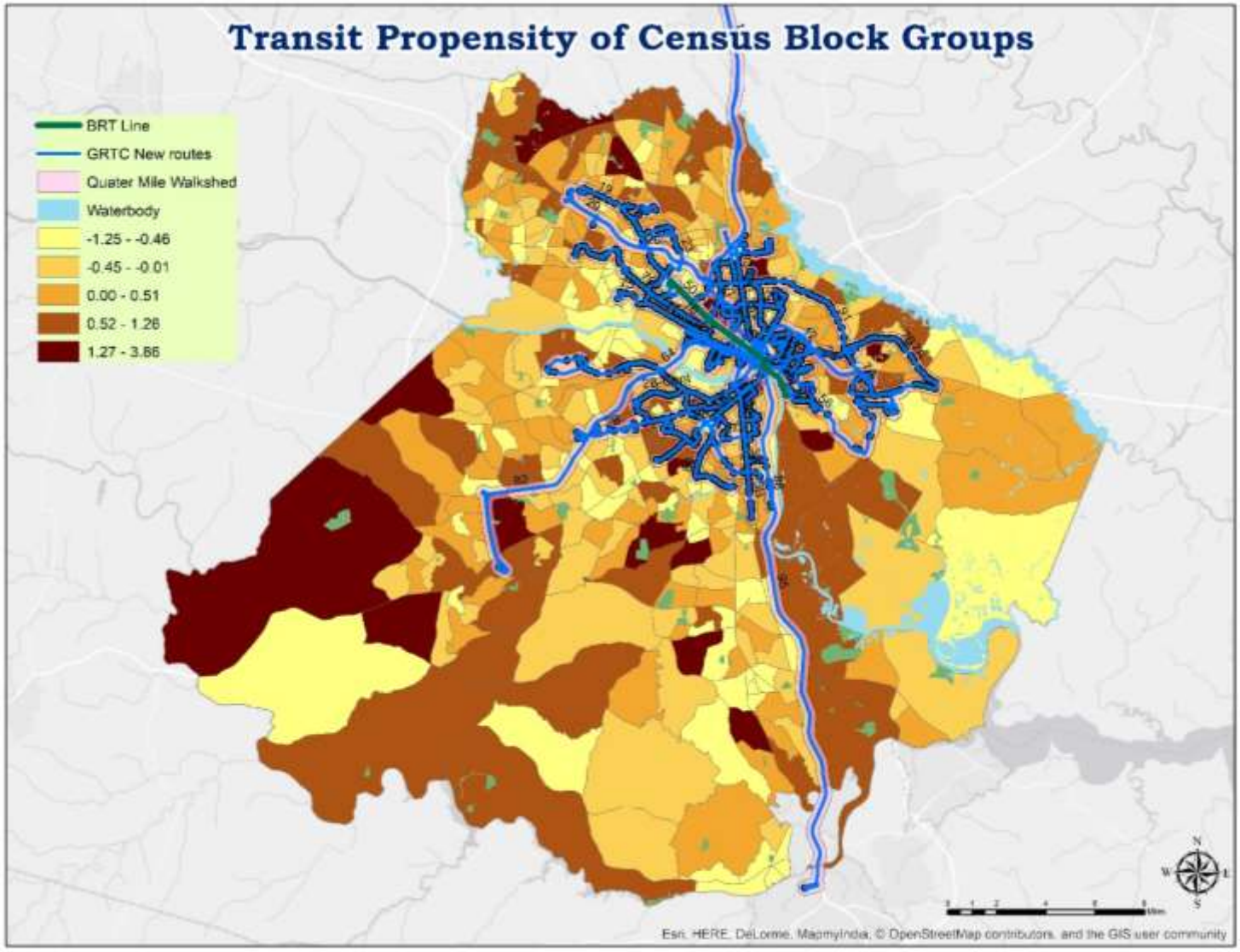
Given below are weights that have been assigned to each variable to compute weighted Z scores. Higher weight (50 percent) has been assigned to average Z scores of population, employment, households as these are most important factors in determining intensity and activity of the areas. Commuters and transit riders are given weight of 20 percent as these act as origin points of a trip. Poverty has been assigned weight of 10 percent as people below poverty line tend to use public transit more. Poverty, senior population, Zero Vehicle Households, People with disability, Non-white population are other important factors that are transit dependent and hence have been assigned weight of 5 percent each.

Table 2.2. Assigned weights to variables

Variable	**Weight (in percent)**
Total population Number of households Average Employment of block groups Number of Employees	50
Number of commuters Number of public transit riders	20
Persons below poverty line	10
Senior population	5
Zero Vehicle Households	5
People with disability	5
Non-white population	5

Source- Computed values

Map 2.1 Transit Propensity scores of census block groups



Source- ACS 2015, 5 year estimates and computed values, designed and produced by author

2.1.1. Observations

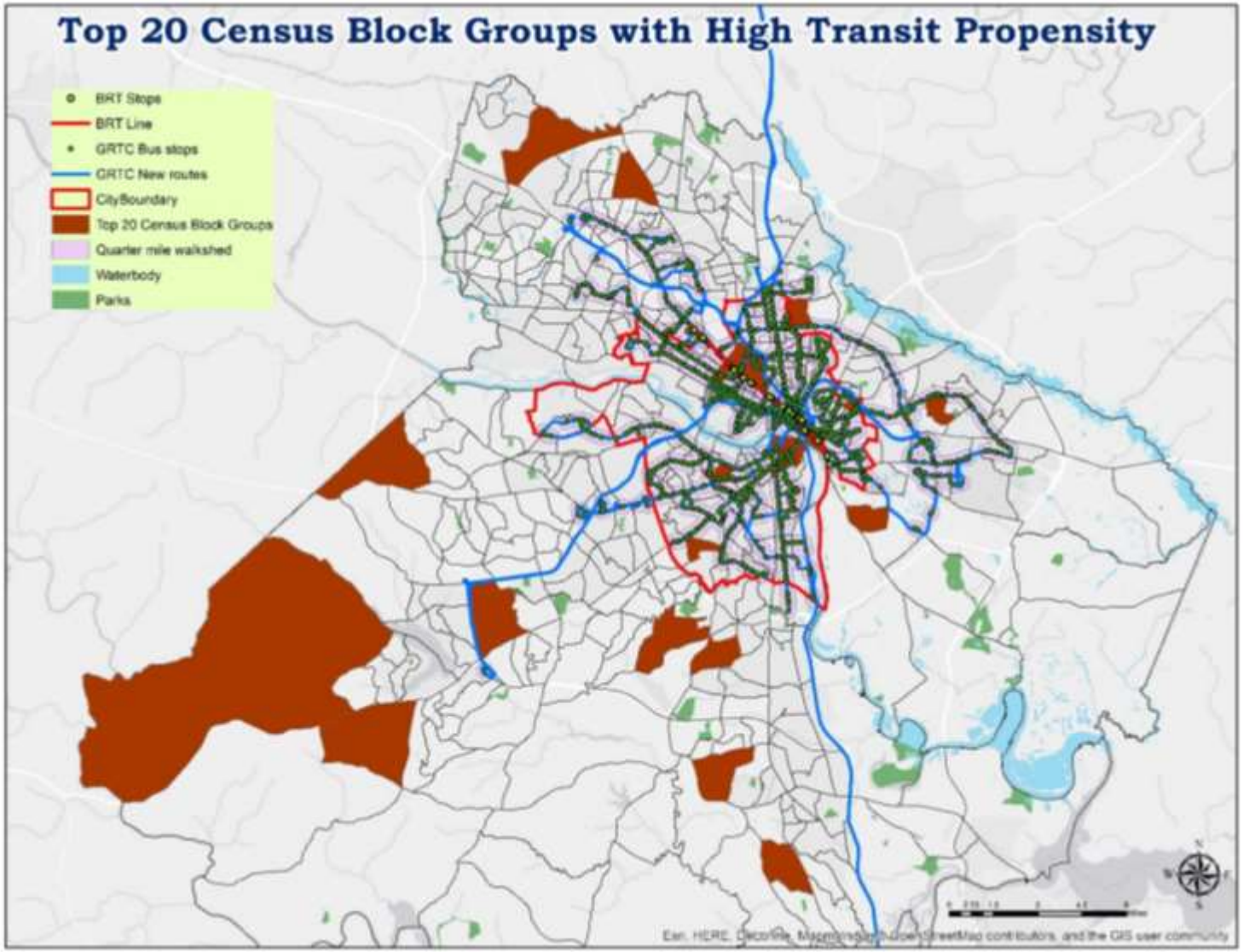
Most of the census block groups with high transit propensity that are underserved, are outside the jurisdiction of Richmond. Given below are census block groups with high transit propensity (top 20), underserved by quarter mile walkshed of new GRTC routes:

Table 2.3. Transit availability in high transit propensity block groups

Census Block group	Jurisdiction	Weighted Z score sum	Observations (Transit availability)
510872001291	Henrico	3.86	Completely underserved
510411008192	Chesterfield	2.12	Completely underserved
510872004131	Henrico	2.03	Completely underserved
510411010091	Chesterfield	2.03	Completely underserved
510872015012	Henrico	2.00	• Completely underserved • Route 56 South Laburnum slightly touches the following block group but there is no bus stop for accessibility. Hence there is a need to provide bus stop that serves this block group • Provision of park and ride facility at Orleans BRT station
510411008232	Chesterfield	1.76	Completely underserved
517600708014		1.75	Partially served by route 1C and route 86
510411010031	Chesterfield	1.74	• Completely underserved but residents of this block group can utilize Route 82 – Commonwealth 20 Express which has park and ride facility
517600610002	Richmond	1.67	Completely served by route 1C, 2C, 3B, 87
517600402002	Richmond	1.63	• Partially served by route 20 and 14 • Few blocks along Roseneath road and West Leigh St. underserved
510411009191	Chesterfield	1.62	• Touched by Route 82-Commonwealth 20 Express • Residents of this block group can utilize Route 82 – Commonwealth 20 Express which has park and ride facility
510872012021	Henrico	1.57	Partially served by bus stops on route 7B- Nine Mile Road
517600205002	Richmond	1.57	Completely served by route 12, 13, 14, 4A, 4B, 56, 7A, 95 & BRT
510872008051	Henrico	1.47	• Partially served by 2C and 91 • Large part of this block group that is unserved includes Forest Lawn cemetery. However, Cloverland neighborhood is underserved by public transit
517600407001	Richmond	1.40	Well served by route 50, 76, 77 & BRT
510411009241	Chesterfield	1.40	Completely underserved
510411008052	Chesterfield	1.40	Completely underserved
517600605005	Richmond	1.39	Served by route 2C, 2B, 20
517600202001	Richmond	1.37	Served by route 7A,12, 28
510411005071	Chesterfield	1.35	Completely underserved

Source- Compiled by author

Map 2.2 Top 20 block groups with high transit propensity



Source- ACS 2015, 5 year estimates and computed values, designed and produced by author

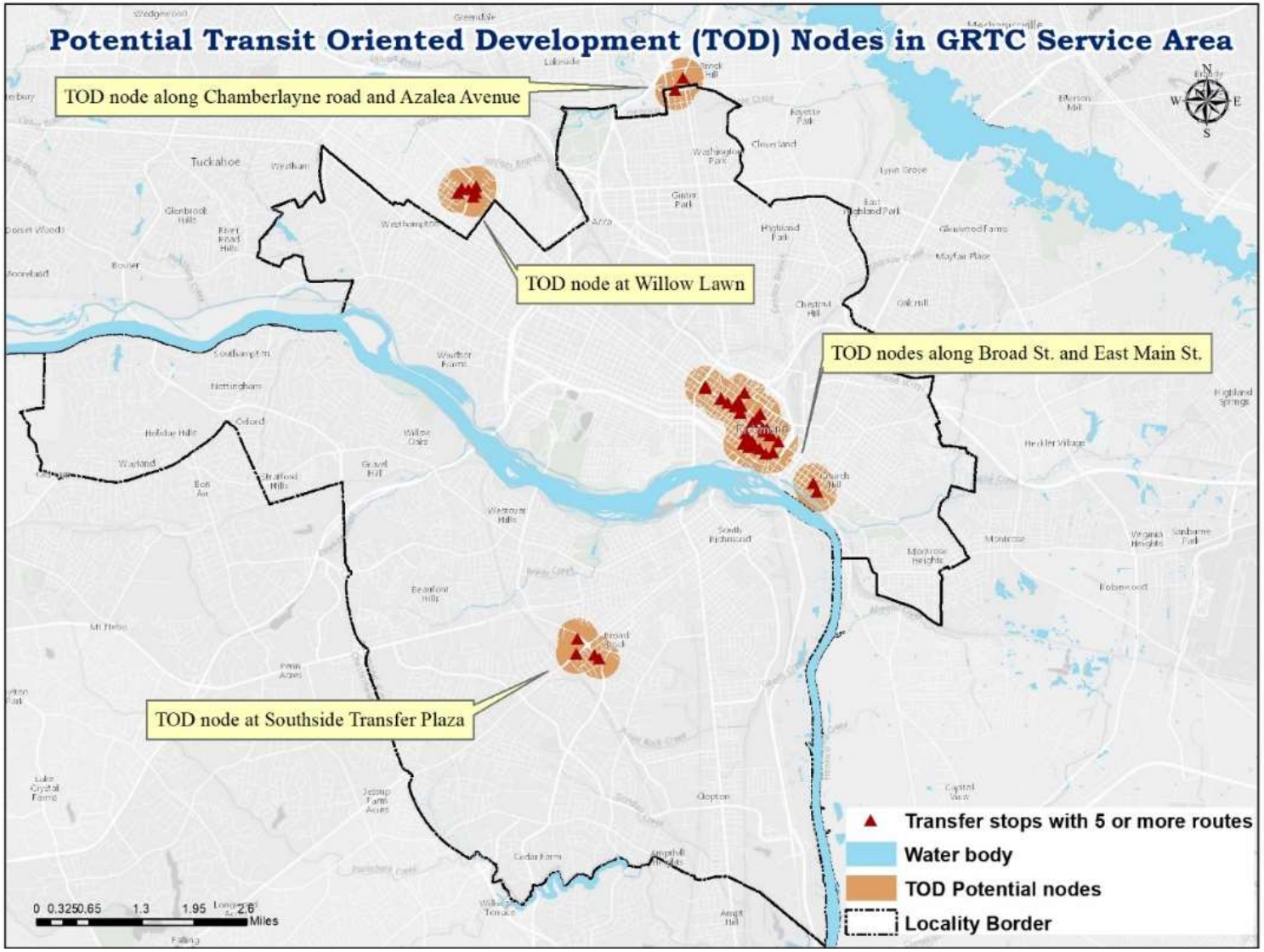
2.2 Transit Oriented Development Analysis

Change in bus network along with increased frequency of select routes have presented an opportunity to study TOD potential of the region. Hence, this chapter focus on identifying major nodes/stations for Transit oriented development in GRTC service area. To identify potential nodes and preliminary screening, bus stops where 5 or more local routes meet were selected. This data was obtained from GRTC. There are 44 stops which satisfy this criteria. However, these stops are in form of clusters. Five major nodes were identified in this process for further study. These potential TOD nodes are located at Southside plaza, Willow Lawn, Chamberlayne road, East Main Street and along Broad St. A quarter mile buffer was built around these clustered stops to study their TOD potential in terms of landuse, transit frequency and ridership. However, to study census data, all the census blocks which intersect with quarter mile walkshed have been included for analysis. These identified nodes also include major transfer points identified under RTNP i.e. Willow Lawn BRT, Broad and Robinson, 4th St. BRT station, 24th St. BRT station and Southside Plaza. However, Broad and Robinson is not included in analysis as it does not satisfy criteria of 5 or more local routes connecting. These nodes were studied based the following factors to evaluate TOD potential and readiness (see table 2.3).

Table no 2.4. TOD Evaluation Factors

Factor	**Measure**	**Data Source**
Transit	Stop ridership	GRTC, TBEST Software
	Bus frequency	GRTC
Market Conditions	Transit Propensity	Computed values
Development Readiness	Land use mix (Entropy)	City of Richmond GIS data (FTP website)
	Walkability	National Walkability Index by United States Environmental Protection Agency (EPA)
	Availability of vacant lots	City of Richmond GIS data (FTP website) and aerial images from google maps
	Availability of parking lots	City of Richmond GIS data (FTP website) and aerial images from google maps

Map. 2.3 Identified potential nodes for TOD



Source- GRTC, designed and produced by author

2.2.1. Existing Ridership of Bus Stops and Frequency of New GRTC Routes

It is important to study ridership and frequency[21] as these factors depict potential and success of TOD. No matter what the land use provisions—the best possible TOD can be in place—but if there is poor transit service, the land use qualities will never provide sufficient influence to shift mode share to transit. In addition, one of the key factors of success for any transit system is high ridership, which allows for more comprehensive coverage and frequent service. High ridership is an indicator for TOD potential as TOD residents have high rates of transit use for their respective communities.[22] Also, high levels of transit ridership depend on the development of supportive land use and circulation around the station.[23] Hence, high ridership indicates TOD supportive area.

Ridership

For purpose of analysis, Average 7- Day week ridership of existing bus stops within identified potential nodes have been studied for year 2017. This data was obtained from GRTC. Higher the average ridership, higher scores the potential node gets. Broad St. node has the highest average 7-day week ridership followed by Willow Lawn node (see table 2.5).

Table no. 2.5. Ranking of potential nodes based on average 7-day week ridership

Potential Node	Total of Average 7-day bus stop ridership	Number of existing bus stops in the node	Average Stop ridership in potential nodes	Ranking scores
East Main St.	794	8	99	1
Broad St	60,966	94	649	5
Willow Lawn	4,371	8	546	4
Chamberlayne	3,239	11	294	3
Southside Plaza	3,688	14	263	2

Source – GRTC and Computed values

Frequency

Broad St. node has a BRT line going through it, in addition to one 15 min frequency route (Route 5- Cary/Main/Whitcomb). East Main St. has a BRT line along with two 15 min frequency routes (Route 4A- Orleans/Montrose and Route 4B Orleans/Darbytown). Willow Lawn node just has a

[21] Elapsed time between consecutive buses (or trains, or ferries) on a line, which determines the maximum waiting time (Walker, 2015).
[22] Lund, Cervero & Willson, 2004, p.iii.
[23] Arambula, n.d.

BRT line passing through it but no 15 min frequency route. However, Southside transfer plaza neither has BRT line nor any 15 min frequency route passing through it. Since Chamberlayne and Southside Plaza both got same scores, so they were ranked based on number of 30 min frequency routes passing through them. Chamberlayne node has two 30 min frequency routes while Southside Transfer Plaza has three 30 min frequency routes (Route 1A-Chamberlayne/Hull/Midlothian, Route 20 Orbital and Route 2C- North Avenue/Midlothian/Belt Blvd).

Scoring of potential nodes based on frequency nodes is done in such a way that BRT line gets a score of 6 and 15 min frequency route gets a score of 3. So, if there are two 15 min frequency route in the node, it gets a score of 6. The route with 30 min frequency gets a score of 1 and node with two 30 min frequency route gets a score of 2 (see table 2.6).

Table no. 2.6. Ranking of nodes based on frequency of routes

Route Frequency	**BRT (10 mins frequency)**	**15 min frequency**	**30 min frequency**	**Total Scores**	**Ranking scores**
Broad St	6	3	-	9	4
East Main St.	6	6	-	12	5
Willow Lawn	6	0	-	6	3
Chamberlayne	0	0	2	2	1
Southside Transfer Plaza	0	0	3	3	2

Source – GRTC and Computed values

2.2.2. Land use Mix of Identified Potential Nodes for TOD

Land use is the most important factor in evaluating TOD potential of any area. Infact, TOD is the practice of creating vibrant, walkable, mixed-use communities surrounding transit stations. Land use mix has been shown to have stronger explanatory power over travel behavior than urban density (Badoe and Miller 2000; Kockelman 1997). A mixture of land uses concentrated around a

transit station can increase off-peak ridership for non-work travel, foster sharing of parking spaces between uses and bring services closer to residents (Krizek 2003).[24]

Land use mix of identified potential nodes have been studied using Land use entropy index, i.e.

$$-\sum_{j=1}^{k} P_j \ln(P_j) / \ln(k)$$

So, in the following case land use entropy is based on 3 land use category equation - residential, commercial, and non-residential. Residential includes single family, multifamily and residential group quarters.

$$\frac{(-1) * [(b1 / a) \ln (b1 / a) + (b2 / a) \ln (b2 / a) + (b3 / a) \ln (b3 / a)] /}{\ln (n)}$$

where, a= total square feet of land for all three land uses present in quarter mile walkshed,;b_1 is area of residential in walkshed; b_2 is area of commercial land use in walkshed; b_3= area of non-residential land uses in walkshed and n = 3 (number of land uses in walkshed)

Table 2.7. Ranking of potential nodes based on Entropy Index

Potential Node	**Entropy Index**	**Ranking scores**
East Main St.	0.74	2
Broad St	0.94	3
Willow Lawn	0.43	1
Chamberlayne	0.98	4
Southside Plaza	0.99	5

Source- computed values

Land use percentages breakup within all the identified potential nodes is shown in table 2.8 (see p. 27), which informs about different land uses within each node. These percentages and land areas was utilized for land use entropy calculations.

[24] Lavoie, 2012, p.9.

Table 2.8. Percentages of each land use within potential TOD nodes

Land Use	East Main St.		Southside Transfer Plaza		Willow Lawn		Chamberlayne		Broad St.	
	Area (sq.ft)	Pct.	Area (sq.ft)	Pct.	Area (sq.ft)	Pct.	Area (sq.ft)	Pct.	Area (sq.ft)	Pct.
Commercial	704,227.93	7.43	3,477,812.06	33.68	3,412,666.117	42.46	2,010,828.01	31.58	10,911,109.40	24.28
Duplex (2 Family)	93,089.75	0.98	9,983.01	0.10		-	107,393.73	1.69	375,117.66	0.83
Government	72,819.77	0.77		-		-		-	1,016,996.49	2.26
Industrial	595,275.99	6.28	1,215,922.79	11.78	627,302.6137	7.81	572,998.66	9.00	842,221.54	1.87
Institutional	254,155.60	2.68	1,212,815.82	11.75			439,323.88	6.90	2,053,690.65	4.57
Mixed-Use	133,551.54	1.41		-	100,762.292	1.25		-	797,701.50	1.77
Multi-Family	5,533,765.03	58.36	512,239.70	4.96	20,178.06	0.25	218,160.75	3.43	21,406,209.58	47.63
Office	194,720.36	2.05	62,500.22	0.61	866,635.95	10.78	122,149.89	1.92	4,299,906.90	9.57
Public-Open Space	556,303.34	5.87	83,258.93	0.81	11,325.40	0.14	60,487.01	0.95	735,986.73	1.64
Single Family	666,993.80	7.03	3,378,936.50	32.73	2,350,682.89	29.25	1,275,095.13	20.02	1,012,334.47	2.25
Vacant	677,741.50	7.15	371,571.98	3.60	395,253.11	4.92	1,313,693.36	20.63	1,490,864.19	3.32
Semi-Public		-		-	249,860.67	3.11	116,291.61	1.83		-
Residential- Group Quarters		-		-	2,312.88	0.03		-		-
Public		-		-		-	131,569.74	2.07		-
Total	9,482,644.61	100.00	10,325,041.01	100.00	8,036,979.99	100.00	6,367,991.77	100.00	44,942,139.09	100.00

Source- Computed values

2.2.3. Vacancy levels in Potential nodes for TOD

Nodes with large vacancy levels have high potential for development. Hence, vacancy is an important factor when it comes to TOD potential. Chamberlayne node has the highest percentage of vacant land available, followed by East Main St. node. Table shows ranking of potential nodes based on vacancy levels. Nodes with higher vacancy levels get higher scores.

Table 2.9. Ranking of potential nodes based on vacancy levels

Potential Node	Vacant land (percentage)	Ranking scores
East Main St.	7.15	4
Broad St	3.32	1
Willow Lawn	4.92	3
Chamberlayne	20.63	5
Southside Plaza	3.60	2

Source- Computed values

2.2.4. Transit Propensity of Potential nodes

In order to evaluate TOD potential of the nodes, the transit propensity has been studied for census block groups which are contained in the node. Transit supportive and transit dependent populations tend to use public transit more as compared to other demographic groups. Hence, presence of transit dependent and supportive population increases the potential for TOD. Higher the transit propensity, higher score the potential node gets.

Transit propensity of each node has been calculated by multiplying transit propensity scores of each block group with respect to their areas contained in node. For instance, if block group A makes up 80 percent of the node area and has propensity score of 1; and block group B is 20 percent of the node area with propensity score 2, then transit propensity of the node will be [(.8*1)+(0.2* 2)] i.e. 1.2.

Table 2.10. Ranking of potential nodes based on transit propensity

Potential Node	Transit Propensity scores	Ranking scores
East Main St.	1.3118	5
Broad St	0.3099	4
Willow Lawn	-0.3630	1
Chamberlayne	0.0044	3
Southside Plaza	-0.0621	2

Source- Computed values

2.2.5. Walkability Index of Potential Nodes for TOD

According to EPA, walkability depends upon characteristics of the built environment that influence the likelihood of walking being used as a mode of travel. The National Walkability Index is a nationwide geographic data resource that ranks each block group ranks each block group relative to all other block groups in the United States.[25] The index has been calculated by weighted formula using results of indicator rank scores such street intersection density and road network density.[26] However, this index has a limitation that it does not indicate about the quality of sidewalks or their continuity.

For analysis, walkability index of each node has been calculated in a similar manner as transit propensity of each node, i.e. multiplying walkability index of block group with respect to its area contained in node. East Main St. has the highest walkability index closely followed by Broad St. Chamberlayne has the lowest walkability index in comparison to other nodes (see table 2.11).

Table 2.11. Ranking of potential nodes based on national walkability index

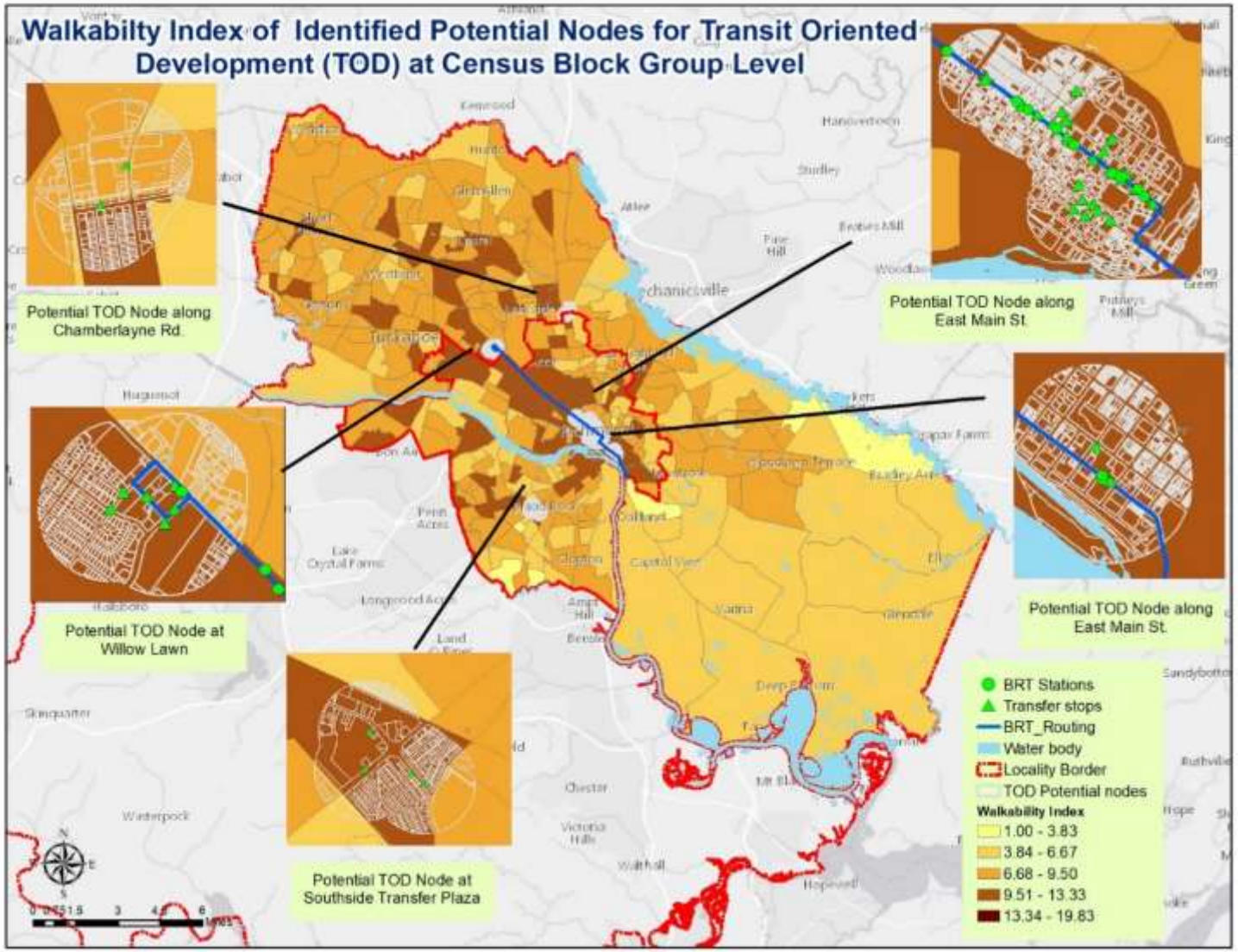
Potential Node	**Walkability Index of potential node**	**Ranking score**
East Main St.	11.94	5
Broad St	11.00	4
Willow Lawn	10.38	3
Chamberlayne	09.05	1
Southside Plaza	10.16	2

Source- Computed values

[25] Environmental Protection Agency. (n.d.).

[26] The Walkability Index dataset characterizes every Census 2010 block group in the U.S. based on its relative walkability. Walkability depends upon characteristics of the built environment that influence the likelihood of walking being used as a mode of travel. The Walkability Index is based on the EPA's previous data product, the Smart Location Database (SLD) that uses NAVTEQ streets data. For more information, see metadata (https://edg.epa.gov/metadata/catalog/search/resource/details.page?uuid=%7B251AFDD9-23A7-4068-9B27-A3048A7E6012%7D).

Map. 2.4. Walkability Index of Identified potential nodes for TOD



Source- Data from EPA National walkability index, designed and produced by author

2.2.6 Parking Inventory of Potential Nodes

Availability of parking[27] is another important factor when it comes to TOD readiness. More parking spaces near transit stations encourage park and ride trips. Broad St. Node has parking inventory of about 3,560,867.30 sq. ft.[28] Chamberlayne Node has parking space of about 2,185,696.68 sq. ft. Willow Lawn node has parking inventory of 2,839,507 sq. ft. Southside Plaza also has ample of parking available due to Southside Plaza and Circle Plaza shopping center. However, East Main St. has limited parking availability of about 459,884.47 sq. ft. which is 7.92 percent. Willow has the parking availability i.e. 35.33 percent followed by Chamberlayne node with 34.34 percent of parking available.

Table 2.12. Parking inventory (in percentage)

Potential Node	Parking percentage	Rank
East Main St.	4.85	5
Broad St	7.92	4
Willow Lawn	35.33	1
Chamberlayne	34.32	2
Southside Plaza	18.61[29]	3

Source- Computed values

2.2.7 Priority nodes for TOD

Potential TOD node along East Main St. has the highest potential for TOD, closely followed by Broad St. These nodes have both TOD readiness and potential due to upcoming BRT. Hence, these are established TOD nodes. Broad St has the highest average 7-day week ridership. However, East Main St. currently has lowest average ridership but it is anticipated to rise significantly due to upcoming BRT and proposed high frequency routes (under RTNP). Also, this node has the relatively highest transit propensity as compared to other nodes which shows support for transit. In addition, this node has highest walkability index desired for TOD neighborhoods. Furthermore, 7.51 percent of vacant land is available for development. Hence, this node has great potential for TOD.

[27] This parking inventory does not consider levelled parking or parking in basement.
[28] The parking data along Broad St. and East Main St. was obtained from City of Richmond GIS FTP website (ftp://ftp.ci.richmond.va.us/GIS) and GRTC.
[29] This percentage also includes parking of Southside transfer plaza and Circle Plaza shopping center.

Broad St. is another important node for TOD as it has the highest average 7-day week ridership, presence of proposed high frequency routes (under RTNP) and high walkability index. However, both East Main St and Broad st. node score low on landuse mix. This is because these are business centers/ downtown area and are expected to have significantly high number of jobs.

Next in ranking is Willow Lawn node, followed by Chamberlayne node and Southside transfer plaza nodes which are emerging TODs since large amount of parking and vacant land is available in these nodes for development. Willow lawn node has good potential to be TOD due to upcoming BRT and existing high ridership. Southside plaza is a good candidate for TOD investment since it has a perfect landuse mix of 0.99 (closest to 1). Also, there are plans for sidewalk improvements in this node. All of these nodes have great potential and readiness for TOD. Now, the next step is to place best practices for successfully implementation of TOD in these nodes.

Table 2.13. Evaluation Matrix for TOD Potential

Measure	**Broad St. Node (Scores)**	**East Main St. Node (Scores)**	**Willow Lawn Node (Scores)**	**Chamberlayne and Azalea Ave. (Scores)**	**Southside Plaza (Scores)**
Ridership	5	1	4	3	2
Frequency	4	5	3	1	2
Transit Propensity	4	5	1	3	2
Parking	1	1	5	4	3
Vacant land	1	4	3	5	2
Landuse Mix	3	2	1	4	5
Walkability Index	4	5	3	1	2
Total Scores	22	23	20	21	18

Source – Computed values

Strengths and weakness based on evaluation matrix has been summarized in table 2.14 (see p. 33). This summary forms the basis for recommendations.

Table 2.14. Strengths and weakness of potential nodes

East Main St. Node	
Strengths	**Weaknesses**
• High frequency routes • High transit propensity • High walkability index • Higher vacant land available for development	• Low parking inventory • Low ridership • Low land use mix
Broad St. Node	
Strengths	**Weaknesses**
• High ridership • High frequency routes • High transit propensity • High walkability index	• Low parking inventory • Limited vacant land available for development
Chamberlayne and Azalea Node	
Strengths	**Weaknesses**
• Large amount of vacant land available for development • Large parking inventory • Good land use mix	• Low walkability Index • Low frequency routes
Willow Lawn Node	
Strengths	**Weaknesses**
• High ridership • High parking inventory	• Low transit propensity • Low land use mix
Southside Transfer Plaza	
Strengths	**Weaknesses**
• Good land use mix • Good parking availability	• Low walkability Index • Low frequency routes • Low ridership

Source – Compiled by author

3. THE PLAN

Recommendations for the present plan have been informed from prior research and analysis. The plan has been developed to address issues identified in research and analysis such as gaps between underserved high propensity areas and new GRTC routes; and weaknesses of potential TOD nodes such as low land use mix, low walkability index etc. In addition, strategies to exploit strengths and opportunities of potential TOD nodes such as availability of vacant parcels, parking inventory etc. have been provided that would ultimately enhance ridership. Vision reflects purpose of the plan and GRTC's mission. Two goals emerge from the vision and suitable objectives and strategies have been developed to fulfill goals. Strategies include short term actions ranging from 3 months to 4 years. The plan also discusses in detail, various funding policies, programs and grants that are currently available to implement these strategies.

3.1. Vision Statement

The plan envisions the City of Richmond, and Henrico and Chesterfield Counties as comprising a region with increased mobility and accessibility through provision of efficient and reliable public transit in transit supportive and deficient areas; and by promoting transit oriented development. The plan offers to identify potential nodes in the region for transit oriented development to create diverse, mixed use and vibrant neighborhoods that support the use of transit and hence lead to higher transit ridership.

3.2. Goals, Objectives & Strategies

The plan aims to achieve the following goals and objectives:

Goal 1. Enhance mobility, accessibility and connectivity

Objective 1. Improve quality of transit service

Strategy 1.1 Implement high frequency routes in Southside Transfer Plaza and Chamberlayne node.

Strategy 1.2 Identify permanent transfer station within Broad St. node to improve on time performance and provide efficient transfer between routes.

Objective 2. Improve accessibility through Transit Coverage

Strategy 2.1 Provide opportunities for public transportation in transit deficient and supportive areas.

Objective 3. Integrate bike-transit

Strategy 3.1 Facilitate role of biker as feeder to bus transit by provision of bike lanes in potential nodes such as Willow Lawn and Southside transfer plaza node.

Goal 2: Promote Transit Oriented Development

Objective 1. Build mixed use and compact neighborhoods around transit stations

Strategy 1.1 Build housing units in Willow Lawn and Southside Transfer plaza node; and create more jobs in Chamberlayne node.

Strategy 1.2. Encourage infill development in Broad St node, Chamberlayne node and East Main St. node through utilization of vacant lots.

Strategy 1.3 Conversion of parking lots into mixed use projects for transit oriented development in Willow Lawn and Chamberlayne node.

Strategy 1.4. Encourage and support development practices that integrate land use with transportation; and development policies such as TOD overlays, mixed use zoning in potential TOD nodes.

Objective 2. Create more walkable neighborhoods by improving pedestrian infrastructure

Strategy 2.1 Provision of continuous sidewalks and decrease the number of existing gaps between sidewalks in Chamberlayne node and Southside Transfer Plaza node.

Strategy 2.2 Repair and maintenance of existing sidewalks in Chamberlayne node and Southside Transfer Plaza node.

4. RECOMMENDATIONS AND IMPLEMENTATION STRATEGIES

4.1. Recommendations

Goal 1. Enhance mobility, accessibility and connectivity

Most of the high transit propensity areas outside city limits and located in Chesterfield County and Henrico County are underserved by public transit. Hence, there is a dire need to extend services to these areas to enhance accessibility. In addition, high frequency routes should be implemented to increase mobility. Furthermore improving transit facilities by building and securing permanent transfer plaza ensures connectivity. This goal has been develop to fulfill GRTC's mission of providing efficient and reliable transit system; and thus increase ridership.

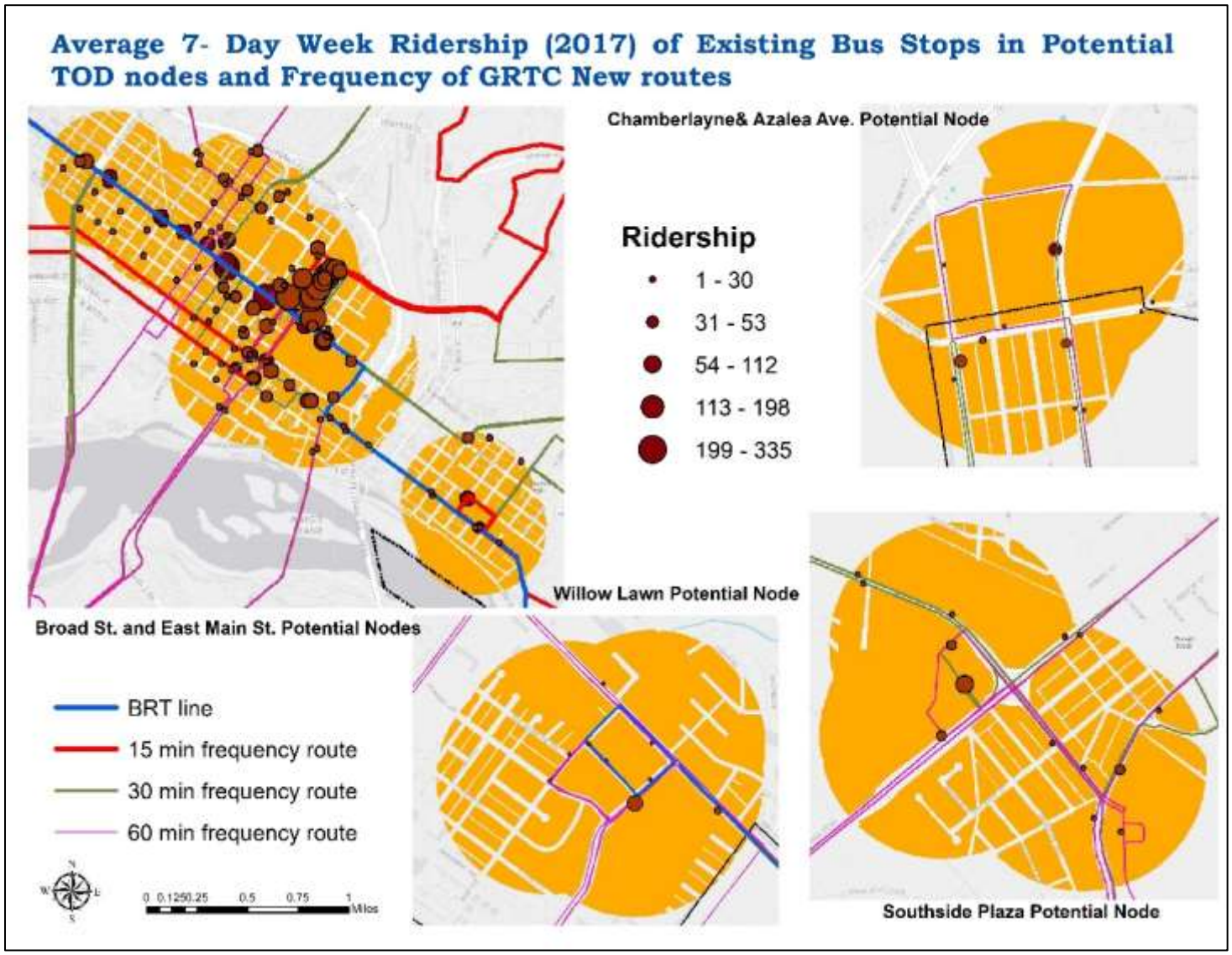
Objective 1. Improve quality of transit service

Strategy 1.1. Provide high frequency routes in potential TOD nodes such as Chamberlayne node and Southside Transfer Plaza node

According to a study conducted by Jeffrey R. Brown and Dristi Neog in 2012, "Central Business Districts and Transit Ridership: A Reexamination of the Relationship in the United States," variables such as transit coverage and frequency have statistically-significant relationships with transit commute mode share. As service frequency and coverage increase, so does the transit commute mode share. Furthermore, the elasticities indicate that service frequency has a stronger effect on commute mode share than service coverage.

As discussed in previous chapters, Southside plaza node and Chamberlayne nodes do not have any high frequency (15 min) routes (see map 4.1). Hence, provision of high frequency routes in potential TOD nodes; and high propensity block groups will significantly increase public transit ridership.

Map. 4.1 Average 7 day week ridership (2017) and frequency of new routes

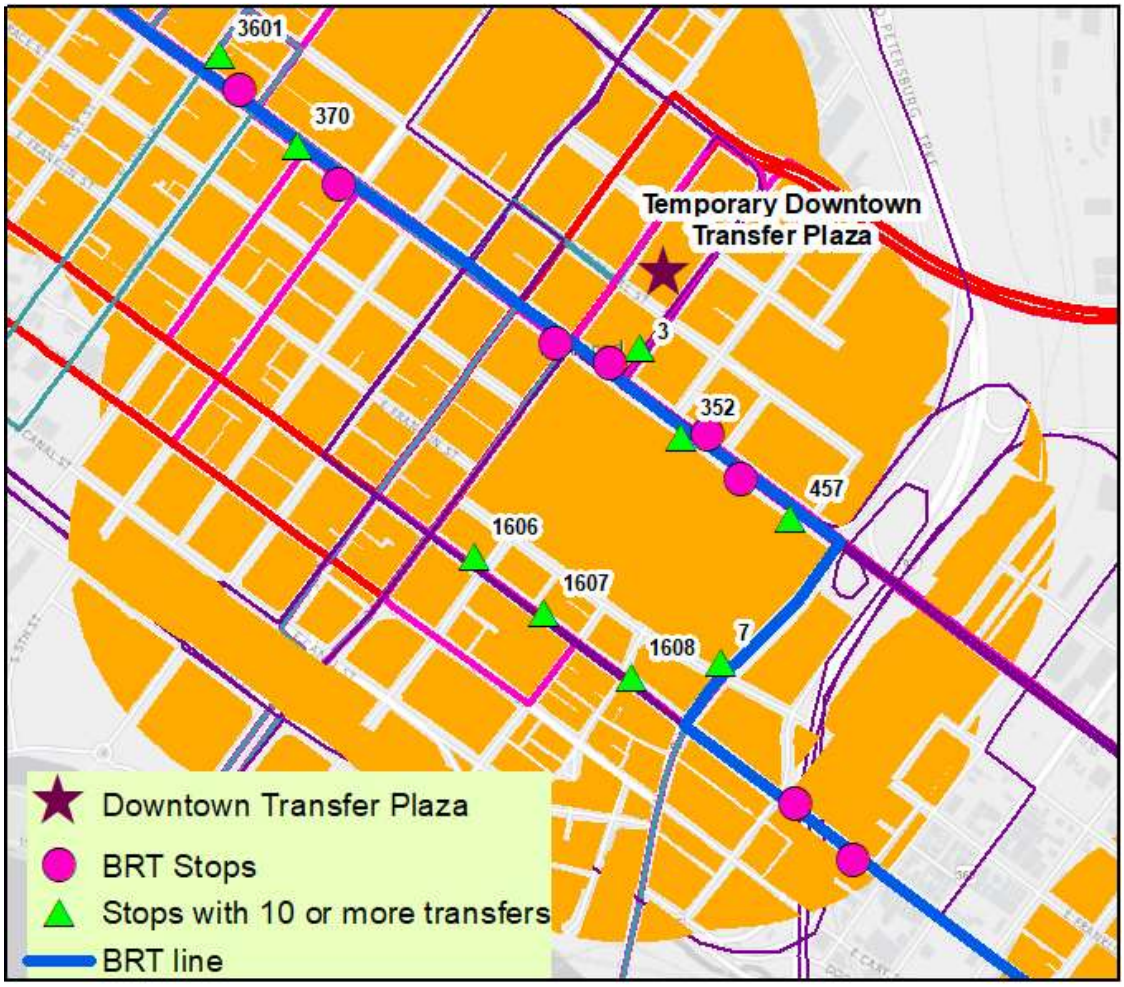


Source- Data from GRTC, designed and produced by author

Strategy 1.2 Identify permanent transfer station within Broad St. node to improve on time performance and provide efficient transfer between routes.

GRTC is currently working through the site selection process for a permanent transfer center. The site should be located in potential TOD node with highest number of transfers i.e. Broad St. node. All the bus stops where 10 or more routes meet (see table 4.1) are located in Broad St. node. GRTC envisions its permanent transfer plaza in Central Business District (CBD) of Richmond. Temporary transfer plaza is currently located at intersection of E. Marshall St. and N 9th St. which is within Broad St. node and in vicinity to BRT Pulse (see fig 4.1). Hence, temporary downtown transfer plaza can be converted into permanent transfer plaza with enhanced amenities or a suitable location should be found within the Broad St. node.

Fig 4.1. Temporary downtown transfer plaza



Source- GRTC, designed and produced by author

Table 4.1. Stops with 10 or more local routes connecting

Stop number	No. of local routes connecting
3	12
7	11
352	13
370	11
457	11
1606	10
1607	10
1608	10
3601	12

Source- GRTC

Objective 2. Improve accessibility through transit coverage

Strategy 2.1 Provide opportunities for public transportation in transit need and supportive areas that are underserved by new GRTC routes.

Some of the route extensions are discussed below:

2.1.1. Extension of route 19 (Pemberton) to Short Pump

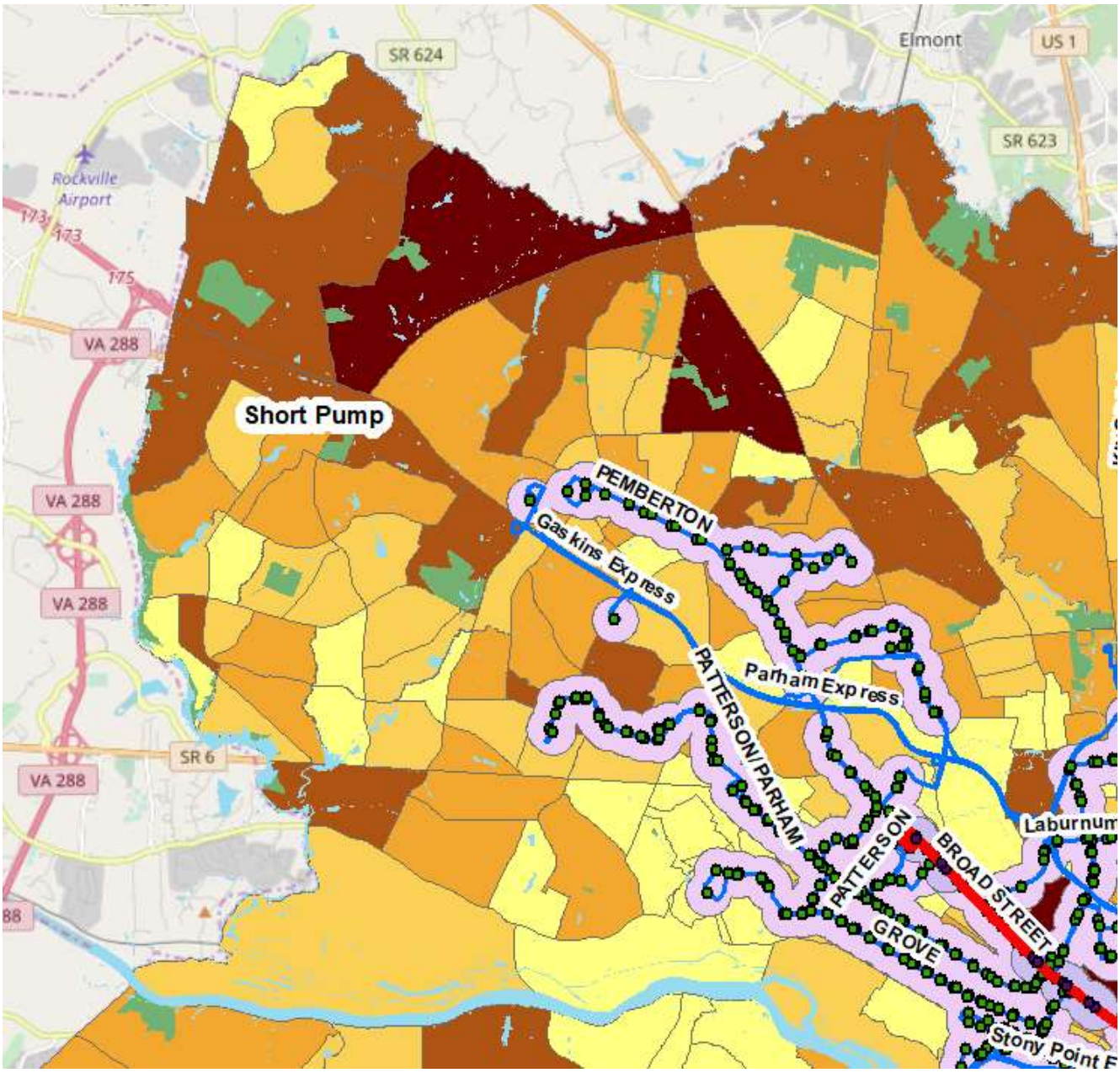
Census block groups 510872001291, 510872004131 in proximity to Short pump area indicate high transit propensity. Hence, route 19 should be extended to short pump. It is also suggested to build park and ride lot at near the proposed station at Short pump to ensure smooth transfer between modes of transportation. Furthermore, it is strongly recommended to extend Pulse BRT to short pump area as these areas are expected to have higher densities by 2040.[30] Hence, local route 19 (Pemberton) should be extended to short pump first, to build ridership prior extending BRT from Willow Lawn to Short pump.

Cost implementation

If route 19 is extended 10 miles to Short Pump area and 20 trips a day are made[31], then cost of extending and operating that route will be *8.59 X number of miles X number of trips*.[32] Hence the cost of running that route will be $1,718/day.

[30] RVA Transit Vision Plan 2017.
[31] Number of miles and trips are assumptions.
[32] Cost methodology followed by GRTC.

Fig no. 4.2. Underserved block groups near Short Pump

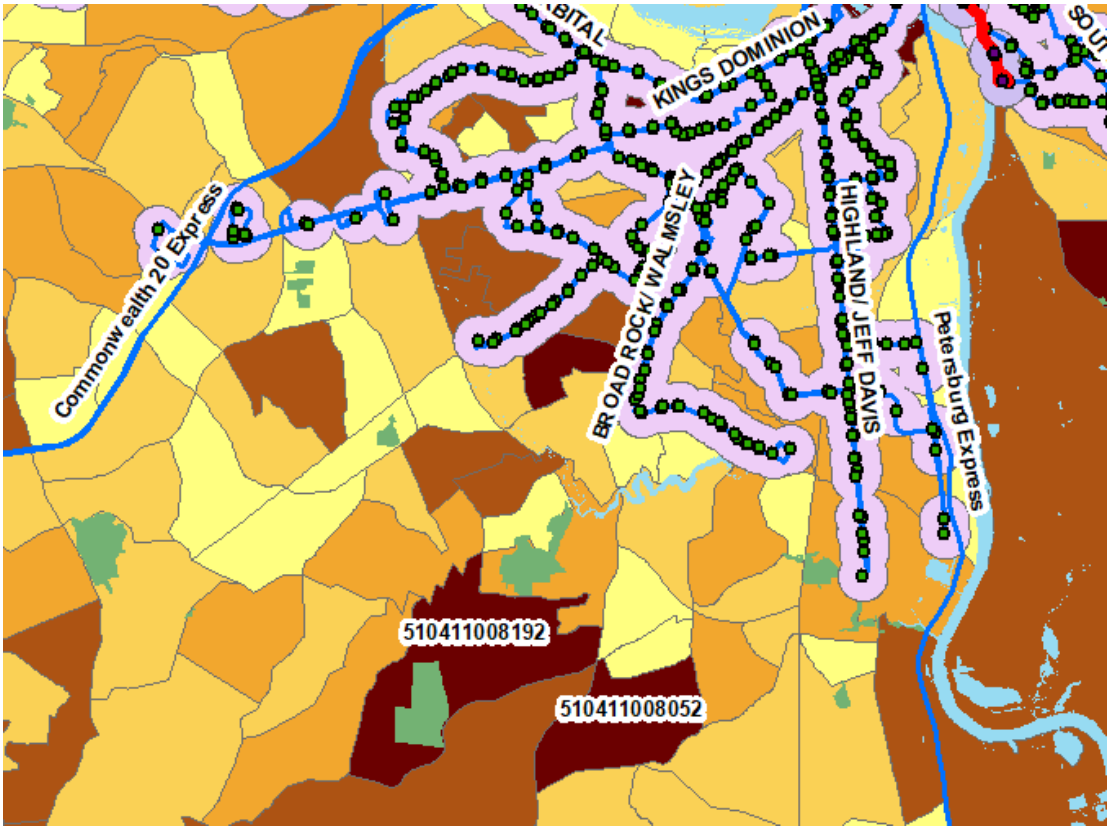


Source- Data from GRTC, designed and produced by author

2.1.2. Extension of Route 3B- Highland/Jeff Davis to Block groups (510411008192 and 510411008052) in proximity to Meadowbrook High School, along Cogbill road and near Iron gate shopping center

Block group 510411008192 and 510411008052 i.e. areas in proximity to Meadowbrook High School, along Cogbill road and near Iron gate shopping indicate high transit propensity. Hence, Route 3B- Highland/Jeff Davis should be extended to these block groups.

Fig 4.3. Underserved block groups in Chesterfield County

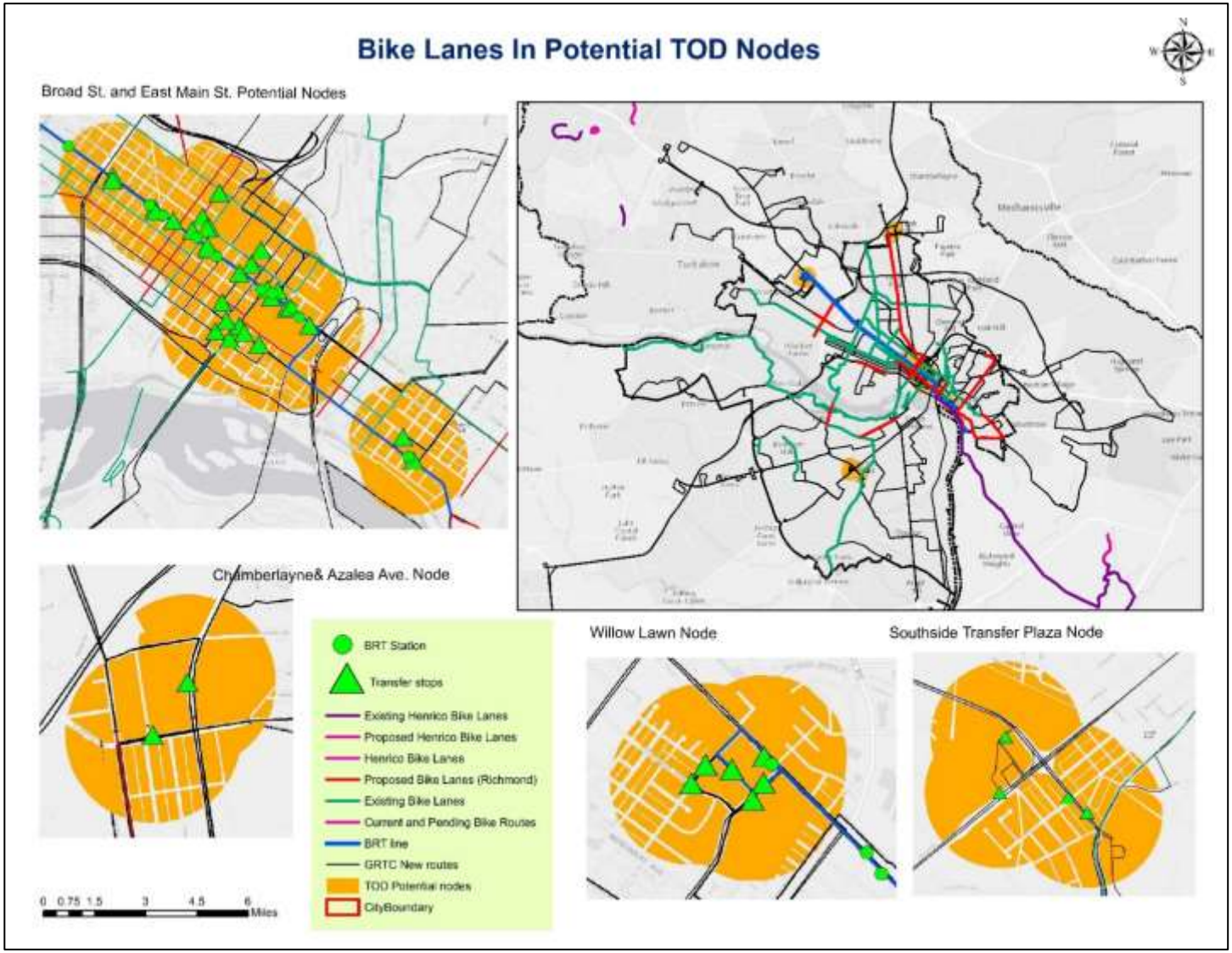


Objective 3. Integrate Bike-Transit

Strategy 3.1 Facilitate role of biker as feeder to bus transit by provision of bike lanes in potential nodes such as Willow Lawn and Southside transfer plaza node.

Bike transit integration is another important strategy to ensure smooth transition between different modes of transit. Hence, there should be provision of bike lanes in Willow Lawn node as they lack existing and proposed bike lanes (see map 4.2). In addition, Southside transfer plaza node has a single bike route passing through it. Hence, bike lanes should be extended to integrate well with the bus network.

Map 4.2. Bike lanes in potential TOD nodes



Source- Data from City of Richmond & Henrico County, designed and produced by author

Goal 2. Encourage transit oriented-development to create livable and sustainable communities

Transit-oriented development (TOD) is an important component of sustainable development. It is a significant way of improving the effectiveness of transit as well as supporting community goals and improving accessibility.[33] Hence, there should be an effective integration of land use and transportation planning to build communities that enjoy the benefits of TOD. The present plan ensures sustainability through TOD initiatives such as creating mixed use and walkable neighborhoods wherein residents have increased accessibility to jobs and other places.

Objective 1. Build mixed use and compact neighborhoods around transit stations

Strategy 1.1 Build more housing units in Willow Lawn node and Southside Transfer plaza; and create more jobs in Chamberlayne node to create job housing balance.

Job-housing balance analysis (see appendix 2) indicate that Broad St. node, Willow Lawn node and Southside transfer plaza does not have ideal job housing balance. Broad St. node is the business center/downtown as it has significantly higher jobs than housing (see table 4.2). It is already saturated and an established node as discussed in earlier sections. Also, Willow Lawn and Southside transfer plaza nodes have higher number of jobs than households. These nodes also have potential for further development. Hence, more housing should be provided in this node to create a job-housing balance. However, there is a need to create more jobs in Chamberlayne node.

Table 4.2 Job-housing balance ratio of potential nodes

Potential Node	**No. of households in potential node**	**No. of Jobs in potential node**	**Average Job-housing balance ratio**
East Main St.	4,327	2,772	0.94
Broad St	4,287	73,138	371.40
Willow Lawn	937	8,066	8.83
Chamberlayne	4,410	1,815	0.56
Southside Plaza	3,031	6,672	4.23

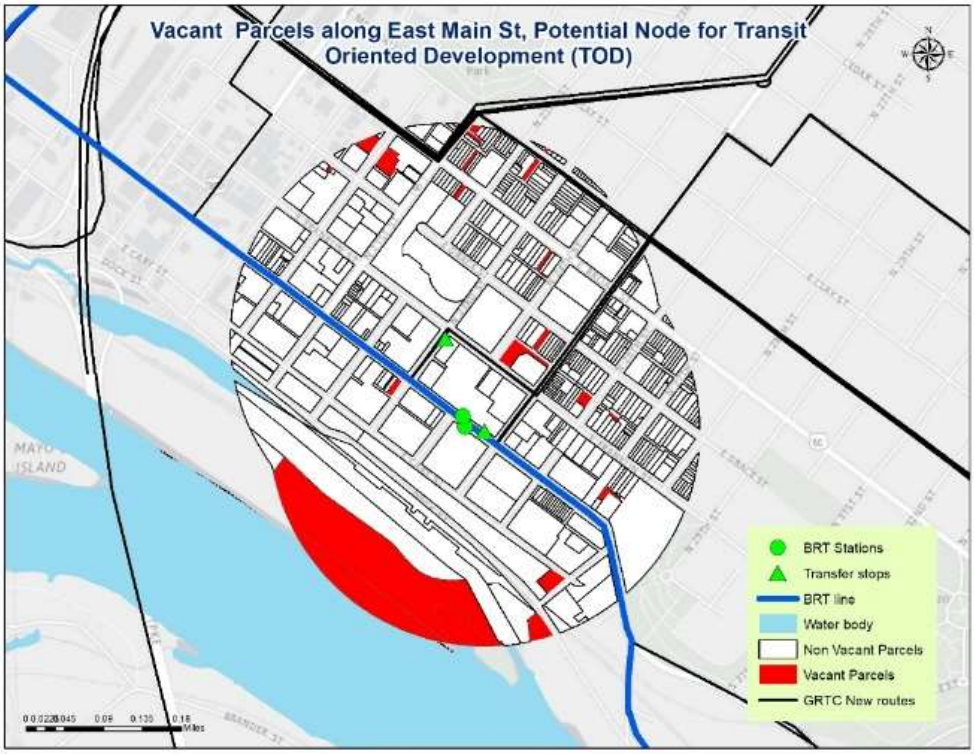
Source- Census data from American Community Survey 2015, 5-year estimates, Employment (jobs) data for 2015 – LEHD and computed values

[33] Currie, 2006, p.2.

Strategy 1.2. Encourage infill development in Broad St node, Chamberlayne node and East Main St. node through utilization of vacant lots

Infill development is the process of developing vacant or under-used parcels within existing urban areas that are already largely developed.[34] Infill development occurs on sites where there is existing infrastructure; thus, developers may not be subject to impact fees or incur additional costs of new infrastructure for these projects. Also, when infill development is transit-oriented, developers may save money on capital costs for parking. Despite higher capital costs required for infill development, developers may be able to command higher rent or sales prices to earn a profit.[35] Hence, infill development should be encouraged and prioritized in Broad St node, Chamberlayne node and East Main St. node through utilization of vacant lots. About 20.63 percent of land is vacant in Chamberlayne node that can be utilized for development. East Main St. has about 7.15 percent and Broad St. node has 3.32 percent of vacant land.

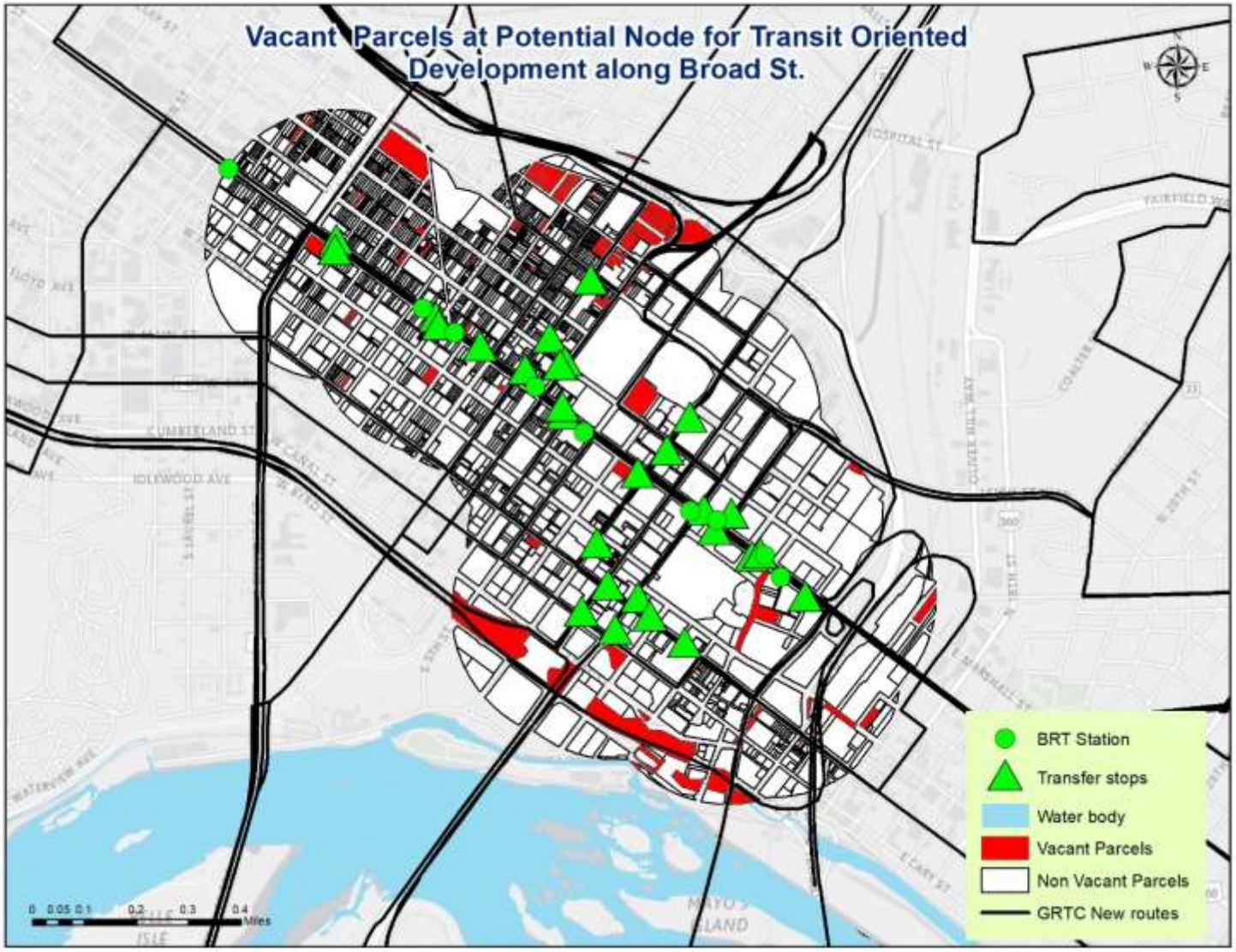
Map 4.3. Availability of vacant land at East Main St Node



Source – City of Richmond GIS data, designed and produced by author

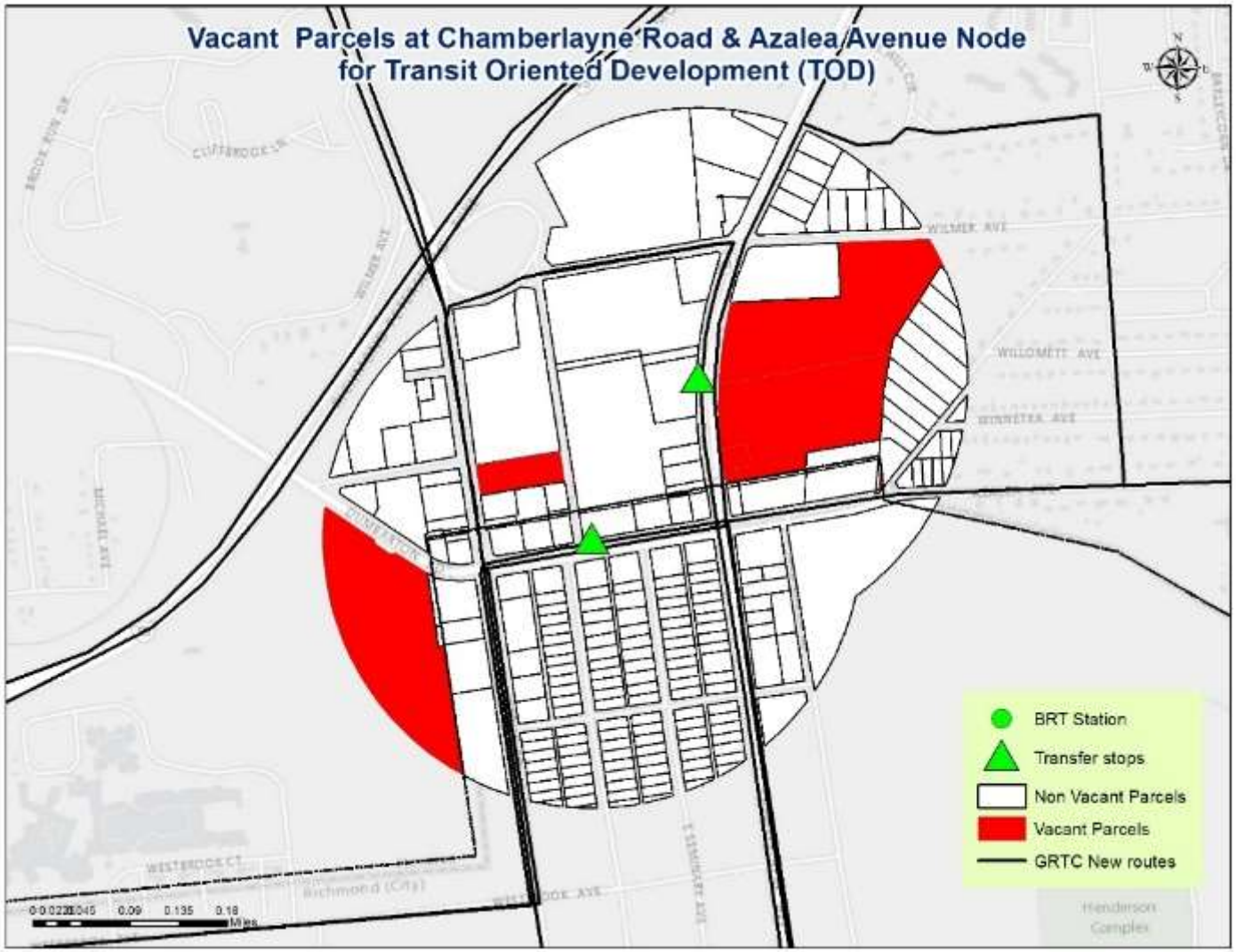
[34] Times of Oman, 2017.
[35] Infill Development Incentives, http://www.completecommunitiesde.org/planning/landuse/infill-development-incentives/).

Map 4.4. Availability of Vacant Land at Broad St Node



Source- City of Richmond GIS data, designed and produced by author

Map 4.5. Availability of vacant land at Chamberlayne node

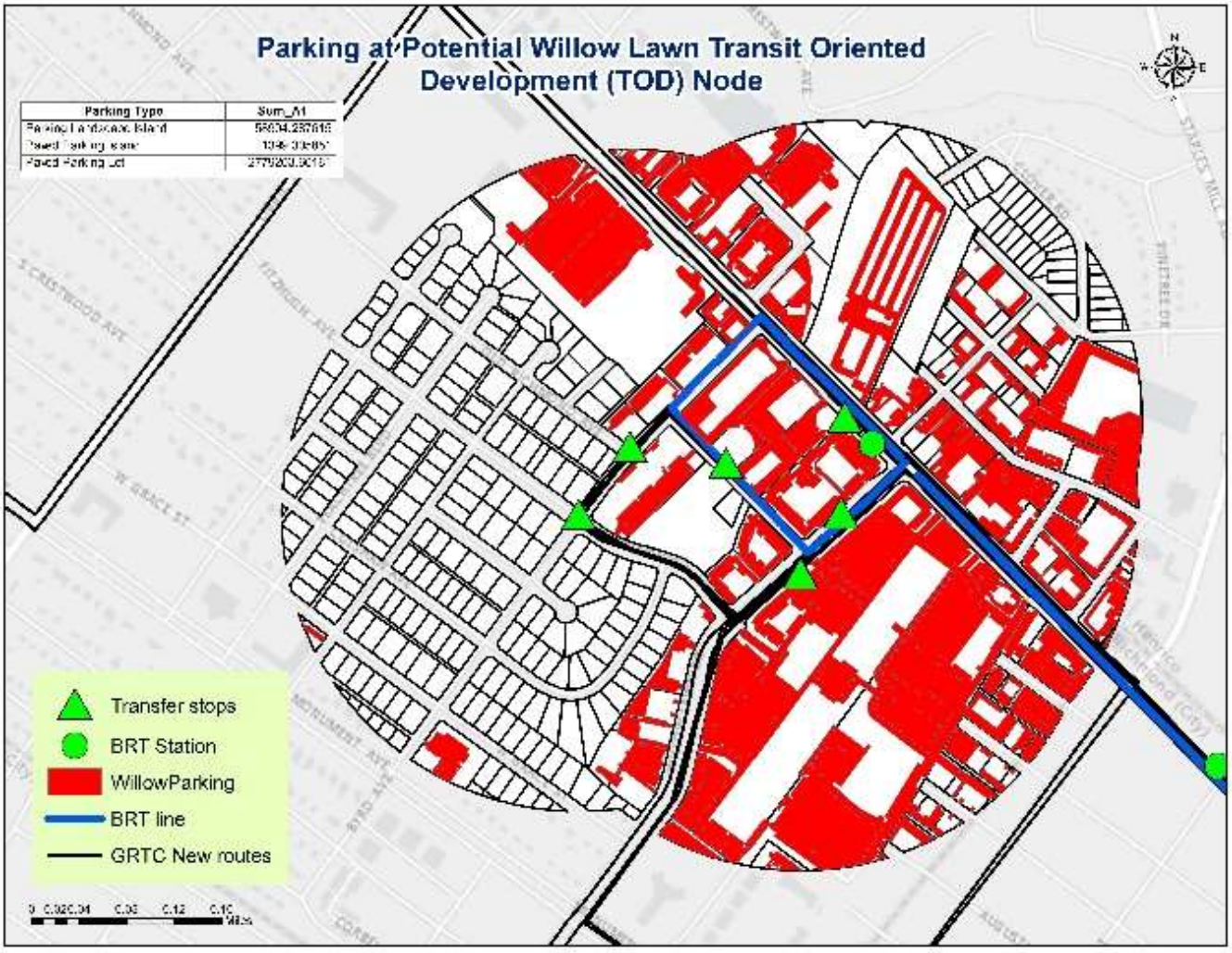


Source- City of Richmond GIS data, designed and produced by author

Strategy 1.3 Conversion of parking lots into mixed use projects for transit oriented development in Willow Lawn and Chamberlayne node

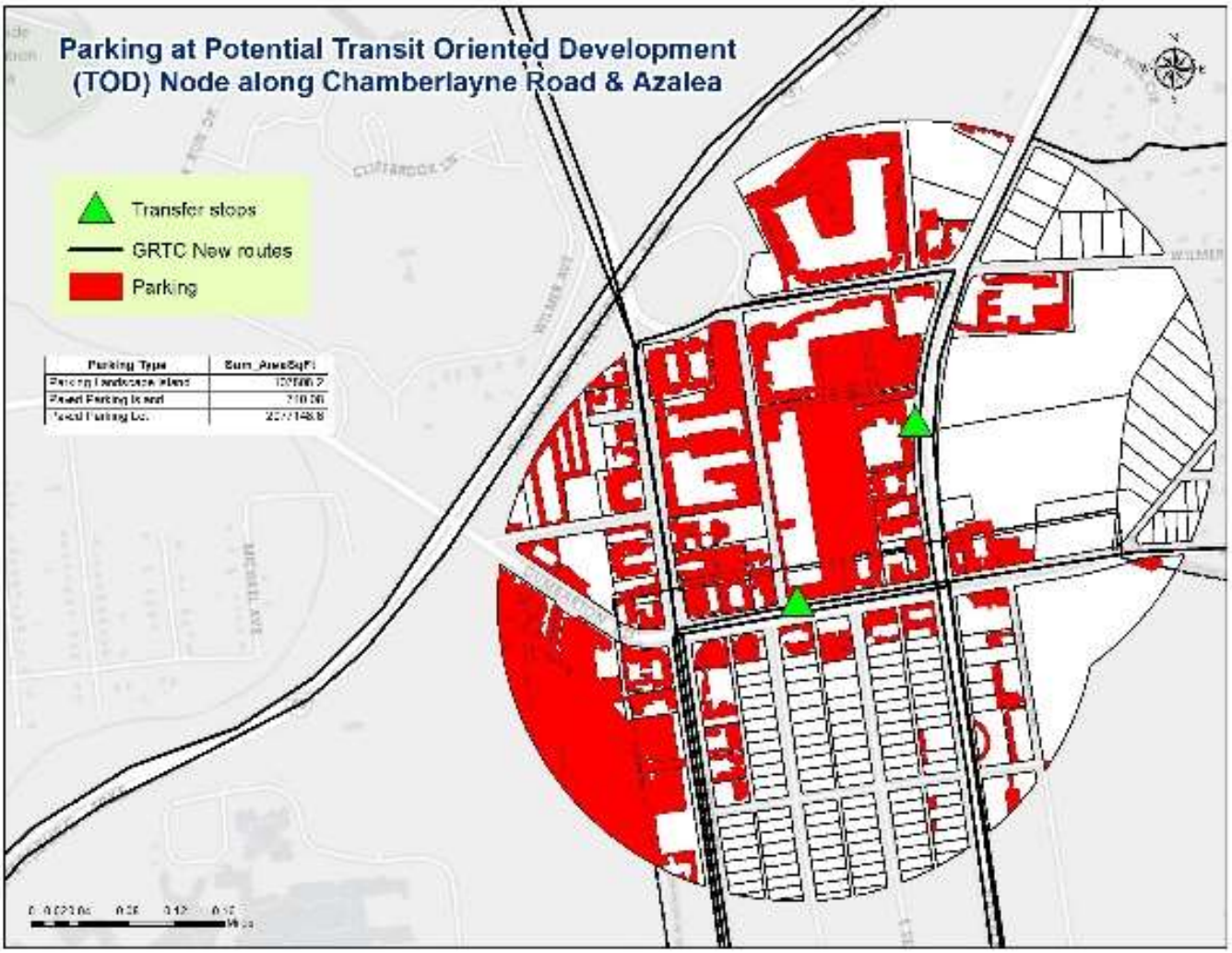
Large amount of parking structures are available in Willow Lawn and Chamberlayne node. Willow Lawn has parking inventory of about 34.32 percent and Chamberlayne has about 34.34 percent parking inventory. Hence, these can be converted into mixed use development to increase intensity of these areas. Surface parking lots can be converted in levelled or basement parking for compact development.

Map 4.6 Parking at Willow Lawn node



Source- City of Richmond GIS data, designed and produced by author

Map 4.7 Parking at Chamberlayne node



Source- City of Richmond GIS data, designed and produced by author

Strategy 1.4. Encourage and support development practices that integrate land use with transportation; and development policies such as TOD overlays and mixed use zoning.

TOD is creating mixed used communities. Hence, a mix of uses should be provided such as residential, commercial, recreational, public and semi-public in potential TOD which have low entropy index. For instance, Willow Lawn node has the lowest entropy index of 0.43 (see table 2.6) and is predominantly commercial. There is need to diversify land uses in this node. Multifamily- residential land use accounts for only 0.25 percent of the node area. In addition, only 1.25 percent of land under mixed use. Hence, more multifamily units should be created (see table 2.7). East Main St. node also has low entropy index i.e. 0.74 and mixed use accounts for just 1.41 percent in the following node. Hence, create more mixed use development in this node.

Objective 2. Create more walkable neighborhoods by improving pedestrian infrastructure

Strategy 2.1 Provision of continuous sidewalks and decrease the number of existing gaps between sidewalks in potential TOD nodes

Sidewalks are essential in TOD communities. Richmond has 832 miles of sidewalks but lacks in quality. A July 2012 citizen survey conducted by the City indicated significant concerns about the conditions of City sidewalks and roadways[36]. There is a need to created pedestrian connections that lead to transit stations, especially in potential TOD nodes such as Chamberlayne node and Southside Transfer Plaza which have relatively low walkability index.

Strategy 2.2 Repair and maintenance of existing sidewalks

As discussed above, Richmond sidewalks lack quality. Richmond is currently working on sidewalk improvements project under the Roadway Maintenance and Capital Improvement Sidewalk Operations. Hence, sidewalk improvements should be prioritized in identified potential nodes for TOD, especially in Southside transfer plaza and Chamberlayne node which have relatively low walkability index.

4.2. Funding Assistance

Funding is a critical part of any project when it comes to implementation. Hence, some of the available funding resources have been discussed that would help in successful implementation of various strategies discussed previously.

GRTC receives its funding from local jurisdictions which are subsidized by federal and state funds**.** Federal funds come from Department of Transportation (DOT).[37] The more a locality funds transit, the more state funds will come to the system.[38] For instance, if Richmond has 75 percent of passenger miles and Henrico County has 25 percent, then 75% of federal funds go to Richmond operations and 25% to Henrico County. Hence, if Henrico County needs route extension, then Henrico County will provide funds that are subsidized by state and federal funds. Other operating

[36] Richmond City Council, 2013.
[37] See Resources (http://ridegrtc.com/about-us/procurement/disadvantaged-business-enterprise-program).
[38] VTA, Transit Funding Structure (http://vatransit.com/content.php?page=Funding_Issues).

revenues include Passenger revenues (Farebox revenues which is about 20 percent) and Congestion Mitigation and Air Quality Improvement (CMAQ) Program.[39]

According to GRTC official, for building or securing permanent downtown transfer plaza, GRTC will utilize capital federal money and for park and ride lots Regional Surface Transportation (RSTP) funding can be utilized.

Funding Assistance for Bike Lanes Project

Funding for bike lanes project in City of Richmond comes from a variety of sources. Capital Improvement Program (CIP) budget is primarily used as a match source for various grant funding. This includes state revenue sharing[40] (50/50), and federal programs including Transportation Alternatives Program (80/20), Congestion Mitigation and Air Quality (80/20), and Highway Safety Improvement Program (100%, VDOT pays the 20% match for localities).[41]

Funding Assistance for Sidewalks Improvement

Sidewalk repairs, replacements and installations are done by two DPW divisions, Roadway Maintenance and Capital Projects Management. When the project area is smaller than ½ block (or 1800 square feet) Roadway takes care of it. When it is larger, it becomes a capital project.[42] Also, Richmond City Council panel has endorsed setting aside a portion of the city's still undetermined surplus from the previous fiscal year (2016) to pay for road and sidewalk improvements. The council's Finance Committee recommended the creation of a reserve fund balance to pay for up to $2 million in infrastructure improvements: $1.25 million for road projects and $750,000 for sidewalk repairs.[43] In addition, Henrico sidewalk improvements can be done using Revenue-sharing program. Improvement projects which is one of the eligible projects include installation of new sidewalks, upgrading sidewalks to meet ADA standards.[40]

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[39] See GRTC Transit System 2016 Transit Development Plan Update, p.33.
[40] For more information see Revenue Sharing Program Guidelines 2017, p.1. (http://www.virginiadot.org/business/resources/local_assistance/Revenue_Sharing_Program_Guidelines.pdf).
[41] This information was provided by VDOT official.
[42] See Street Maintenance (http://www.richmondgov.com/PublicWorks/StreetMaintenance.aspx)
[43] Robinson, 2017 (http://www.richmond.com/news/local/city-of-richmond/richmond-city-council-panel-supports-setting-surplus-funds-aside-for/article_7076d5ef-c317-5f53-9250-59784a539676.html).

Funding programs and sources

This section provides details of various funding policies and programs that are mentioned above or can be utilized otherwise:

Capital Improvement Program (CIP)

A project that is included in the City's capital budget is broadly defined as requiring the expenditure of public funds, for the purchase, construction, enhancement or replacement of physical infrastructure/assets. To be included in the CIP, the project should cost more than $25,000 and must have an expected useful life greater than the life-span of any debt used to fund the project. Projects include construction and major renovations of buildings; economic development activities; acquisition of property; improvements to roadways, bikeways, and sidewalks; and the efficient operation of the water, sewage and gas systems. Other costs associated with the capital budget include, but are not limited to, architectural and engineering fees and site development.[44]
In FY17 there is capital funding of $3.5 million for paving projects. 10.7 million USD in City capital funds is recommended over five years. Furthermore, 300,000 USD in city capital funds is proposed to address hazardous sidewalks and to provide new sidewalks in FY17. Also, approximately 2 million USD in City capital funds is recommended over five years.[44] aboveHence, these funds can be utilized for sidewalk improvements and bike lanes in potential TOD nodes.

Regional Transportation Funding

The RRTPO administers three regional transportation funding programs:

- the Regional Surface Transportation Program (RSTP);
- The Congestion Mitigation and Air Quality (CMAQ) program; and
- Transportation Alternatives Set-Aside.[45]

Regional Surface Transportation Program (RSTP)

The Surface Transportation Block Grant (STBG)[46] provides states and regions with flexible federal funding that may be used for a wide variety of highway and transit projects. The funds can

[44] See Adopted Capital Improvement Program for Fiscal Year 2017-2021, p. vii, 1.
[45] See Regional Transportation Funding (http://www.richmondregional.org/TPO/RSTP-CMAQ/).
[46] The FAST Act converts the long-standing Surface Transportation Program into the Surface Transportation *Block Grant* Program acknowledging that this program has the most flexible

be used to preserve and improve the conditions and performance on highways, bridges, tunnels, pedestrian facilities, bicycle infrastructure, and transit capital projects.

Congestion Mitigation and Air Quality Improvement (CMAQ) Program

CMAQ is administered by FHWA and is implemented to support surface transportation projects and other related efforts that contribute air quality improvements and provide congestion relief. The CMAQ program has provided more than $30 billion to fund over 30,000 transportation related environmental projects for State DOTs, metropolitan planning organizations, and other sponsors throughout the US. The FAST Act (Fixing America's Surface Transportation Act) provides from $2.3 to almost $2.5 billion in CMAQ funding for each year of the authorization-2016 through 2020.[47]

Transportation Alternatives Set-Aside

The Transportation Alternatives Set-Aside[48] provides funding for programs and projects defined as transportation alternatives, including pedestrian facilities, bicycle facilities, recreational trails, safe routes to school, and infrastructure projects for improving non-driver access to public transportation. Federal Transportation Alternatives Set-aside funding can reimburse up to a maximum 80% of eligible project costs. A local match contribution of 20% or more is required to pay for the remaining project costs.[49]

Highway Safety Improvement Program (HSIP)

The Highway Safety Improvement Program (HSIP) is a core Federal-aid program with the purpose to achieve a significant reduction in traffic fatalities and serious injuries on all public roads, including non-State-owned roads and roads on tribal land. HSIP funds be used for safety projects

eligibilities among all Federal-aid highway programs and aligning the program's name with how FHWA has historically administered it. [FAST Act § 1109(a)].

[47] For further information, see Congestion Mitigation and Air Quality Improvement (CMAQ) Program (https://www.fhwa.dot.gov/environment/air_quality/cmaq/).

[48] TA Set-Aside is an allocation set-aside within the Surface Transportation Block Grant funding allocation. This is no longer an independent program as it has been in the past. Starting Fiscal Year 2018, Virginia's TA Set-Aside application cycle is moving to a biannual cycle.

[49] Transportation Alternatives Program Guide Aug 2017 Interim Update, p.8.

that are consistent with the State's strategic highway safety plan (SHSP) and that correct or improve a hazardous road location or feature or address a highway safety problem.[50]

Transit-Oriented Development Technical Assistance Initiative

The National Public Transportation/Transit-Oriented Development Technical Assistance Initiative is a four-year project that focuses on supporting the efforts of local communities across the country to build compact, mixed-use, equitable development around transit stations. Richmond, VA also was chosen for technical assistance to further the city's work to spur TOD along its planned 7.6-mile bus rapid transit (BRT) line. Richmond's "Pulse" BRT project received a $24.9 million TIGER grant in 2014. Last year, Richmond was named a Ladder [STEP] city, part of USDOT's initiative that focuses on revitalization as part of future transportation projects.[51]

Sustainable Communities Initiative (SCI)

Since 2010, 143 communities have received funding to support the creation of sustainable communities through the Sustainable Communities Initiative (SCI) grants provided by the U.S. Department of Housing and Urban Development. Additionally, through the collective interagency efforts of HUD, the U.S. Department of Transportation (DOT) and the U.S. Environmental Protection Agency (EPA), an additional number of communities received funds through programs such as TIGER (DOT) and EPA Sustainable Community Technical Assistance and Brownfield Area Wide Planning grants (EPA). The grants provided opportunities for cities and regions of various sizes to coordinate long range comprehensive plans, support transit-oriented development, create revitalized main streets, foster economic growth, create and preserve affordable housing, improve health and well-being, increase access to fresh foods, and create quality jobs and educational opportunities.[52]

Federal Joint Development Program

FTA supports Equitable Transit Oriented Development (eTOD) through technical assistance programs to local communities, a TOD discretionary planning grant program, and through the federal Joint Development Program available to all communities that receive FTA funds. The

[50]Eligible activities (https://www.fhwa.dot.gov/fastact/factsheets/hsipfs.cfm).
[51] Federal Transit Administration (FTA), n.d.
[52] Reconnecting America, p. vi.

federal interest in eTOD stems from many reasons, including encouraging transit agencies and communities to adopt transit-supportive land uses and housing policies that support transit ridership and create the potential for value capture strategies that can support transit operations.[53]

Pilot Program for Transit-Oriented Development Planning - 5309

The Pilot Program for TOD Planning helps support FTA's mission of improving public transportation for America's communities by providing funding to local communities to integrate land use and transportation planning with a transit capital investment that is seeking or recently received funding through the Capital Investment Grant (CIG) Program.[54] Comprehensive planning funded through the program must examine ways to improve economic development and ridership, foster multimodal connectivity and accessibility, improve transit access for pedestrian and bicycle traffic, engage the private sector, identify infrastructure needs, and enable mixed-use development near transit stations.[55]

In addition, there are organizations and developers that support TOD initiatives such as

- **LOCUS**, a national network of real estate developers and investors who advocate for sustainable, walkable urban development in America's metropolitan areas. This is a program of Smart Growth America.[56]
- **Natural Resources Defense Council (NRDC)**, a non-profit organization dedicated to developing and advocating for sustainable solutions to the challenges facing our planet. NRDC's Urban Solutions program collaborates with national, state, and local leaders to find, finance and implement strategies for enhancing transportation and mobility choices, public health, green infrastructure, sustainable food systems, climate resilience, green and equitable neighborhoods, affordable housing and access to sustainable jobs.[56]

[53] MZ Strategies, LLC, 2016, p. 13.
[54] For more information about CIG, see https://www.transit.dot.gov/funding/grant-programs/capital-investments/capital-investment-grants-program
[55] Federal Transit Administration (https://www.transit.dot.gov/TODPilot)
[56] See USDOT, U.S. Transportation Secretary Foxx Announces LadderSTEP Technical Assistance Program

Table 4.3. Implementation Strategies

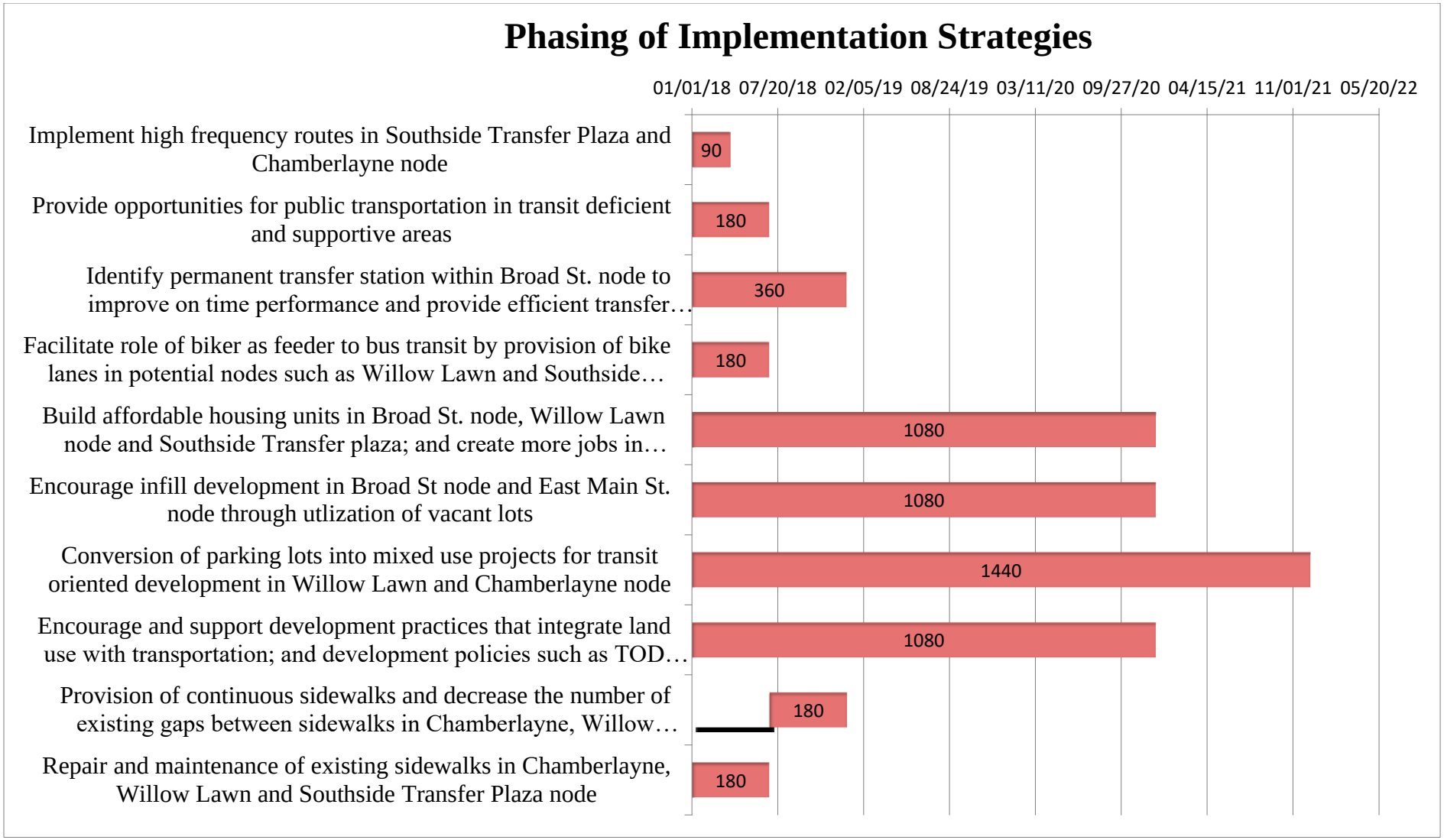
Goal 1: Enhance mobility, accessibility and connectivity				
Objectives and Strategies	**Priority level**	**Time frame**	**Actors**	**Funding Assistance**
Objective 1. Improve quality of transit service				
Strategy 1.1 Provide high frequency routes in identified potential TOD nodes and high transit propensity areas.	High	3 months (until next booking)	GRTC	Local, State and Federal Funds, CMAQ
Strategy 1.2 Identify permanent transfer station within Broad St. node to improve on time performance and provide efficient transfer between routes.	Medium	Within 1 year	GRTC	Capital Federal fund
Objective 2. Transit Coverage to improve accessibility				
Strategy 2.1 Provide opportunities for public transportation in transit deficient and supportive areas	High	6 months	GRTC	Local, State and Federal Funds, CMAQ
Objective 3. Bike Transit Integration				
Strategy 2.1 Facilitate role of biker as feeder to bus transit by provision of bike lanes in potential nodes such as Willow Lawn and Southside transfer plaza node.	Medium	6 months	Richmond PDR and DPW, Henrico County	CIP, RSTP, CMAQ, HSIP, Revenue Sharing Program

Goal 2: Encourage transit oriented-development to create livable and sustainable communities				
Objective 1. Build mixed use and compact neighborhoods around transit stations				
Strategy 1.1 Build housing units in Willow Lawn and Southside Transfer plaza node; and create more jobs in Chamberlayne node	High	Within 3 years	City of Richmond, Henrico County	Transit-Oriented Development Technical Assistance Initiative, SCI, LOCUS, NRDC, Federal Joint Development Program
Strategy 1.2. Encourage infill development in Broad St. node and East Main St. node through utilization of vacant lots	High	Within 3 years	City of Richmond	Transit-Oriented Development Technical Assistance Initiative, SCI, LOCUS, NRDC
Strategy 1.3 Conversion of parking lots into mixed use projects for transit oriented development	Medium	4 years	Henrico County	Transit-Oriented Development Technical Assistance Initiative, SCI, LOCUS, NRDC
Strategy 1.4. Encourage and support development practices that integrate land use with transportation; and development policies such as mixed use zoning.	High	Within 3 years	City of Richmond, Henrico county	Transit-Oriented Development Technical Assistance Initiative, SCI, LOCUS, NRDC, Federal Joint

				Development Program, HSIP
Objective 2. Create more walkable neighborhoods by improving pedestrian infrastructure				
Strategy 2.1 Provision of continuous sidewalks and decrease the number of existing gaps between sidewalks in Chamberlayne node and Southside transfer plaza node	High	6 months	City of Richmond (DPW), Henrico county	CIP, RSTP, CMAQ. Revenue Sharing Program
Strategy 2.2 Repair and maintenance of existing sidewalks in Chamberlayne node and Southside transfer plaza node	High	6 months	City of Richmond (DPW), Henrico county	CIP, RSTP, CMAQ, Revenue Sharing Program

Source- Compiled by author

Fig. 4.4. Phasing of implementation strategies



Source – Prepared by author

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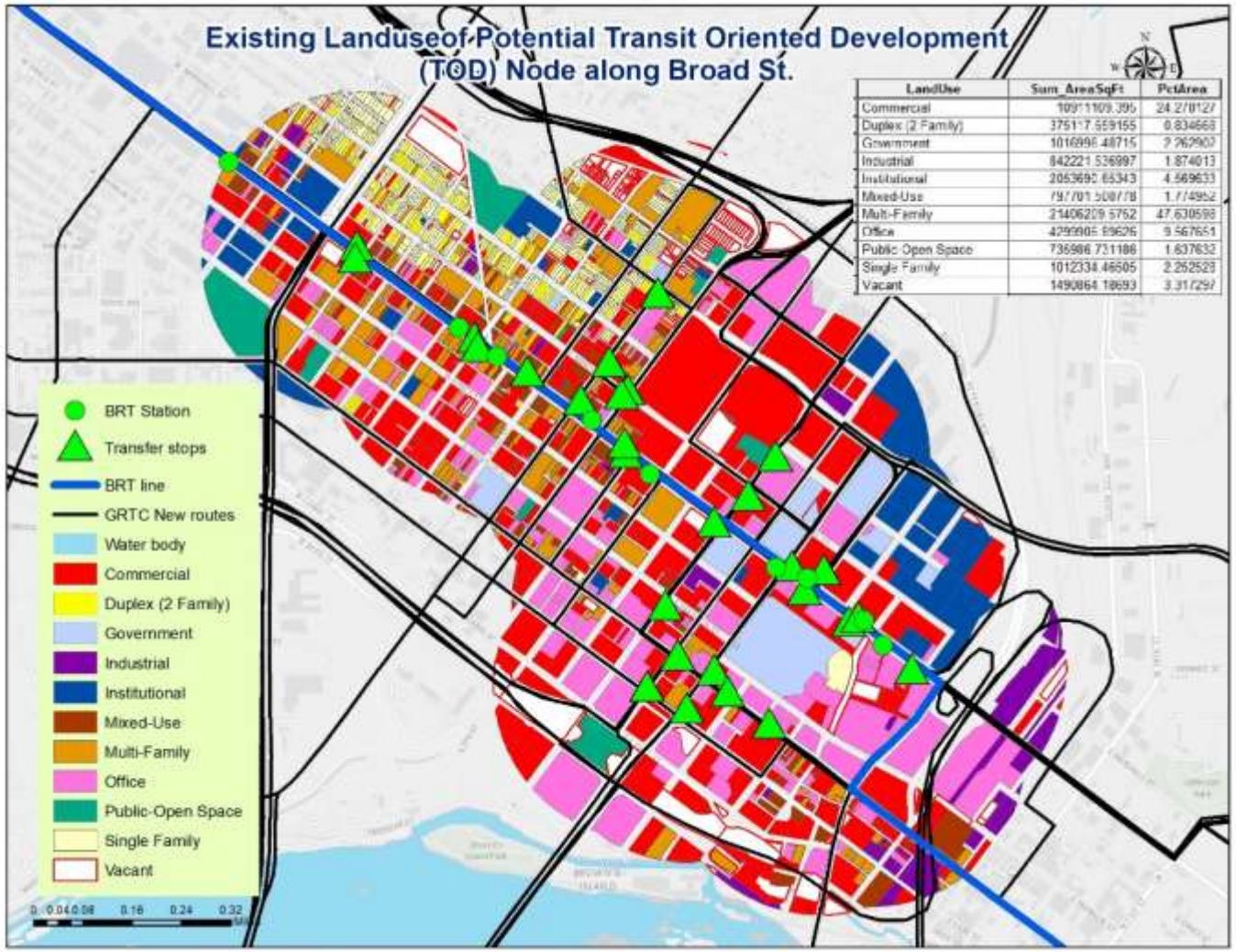
Appendix 1 – Land use of Potential Nodes

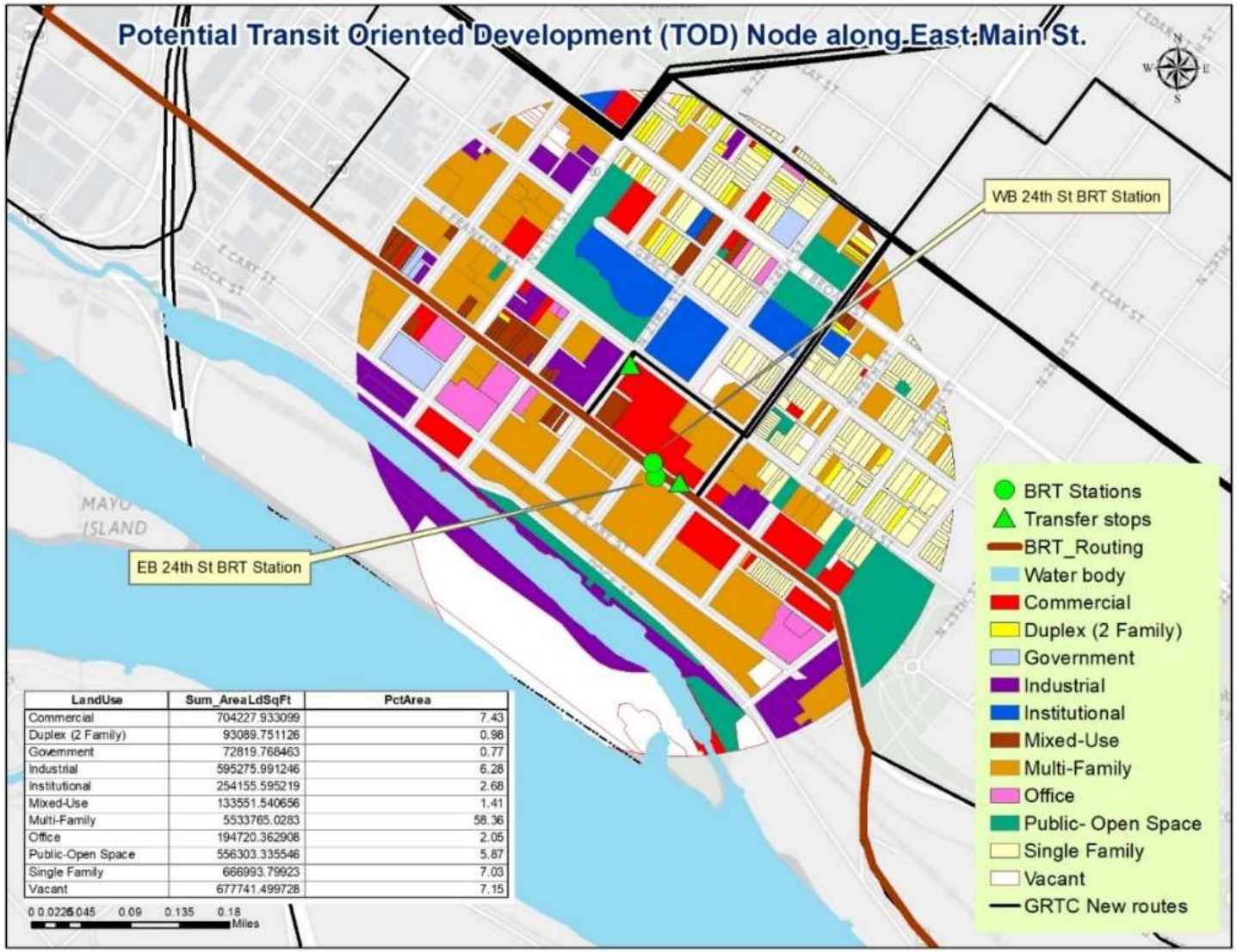
Existing land use of potential TOD node along Broad St.



LandUse	Sum_AreaSqFt	PctArea
Commercial	10911109.395	24.270127
Duplex (2 Family)	375117.559155	0.834668
Government	1016996.48715	2.262907
Industrial	842221.536997	1.874013
Institutional	2053690.65343	4.569633
Mixed-Use	797701.508778	1.774952
Multi-Family	21406209.5752	47.630598
Office	4299805.89626	9.567651
Public-Open Space	736986.731186	1.639632
Single Family	1012334.46505	2.252523
Vacant	1490864.18693	3.317297

Source- City of Richmond GIS data, designed and produced by author

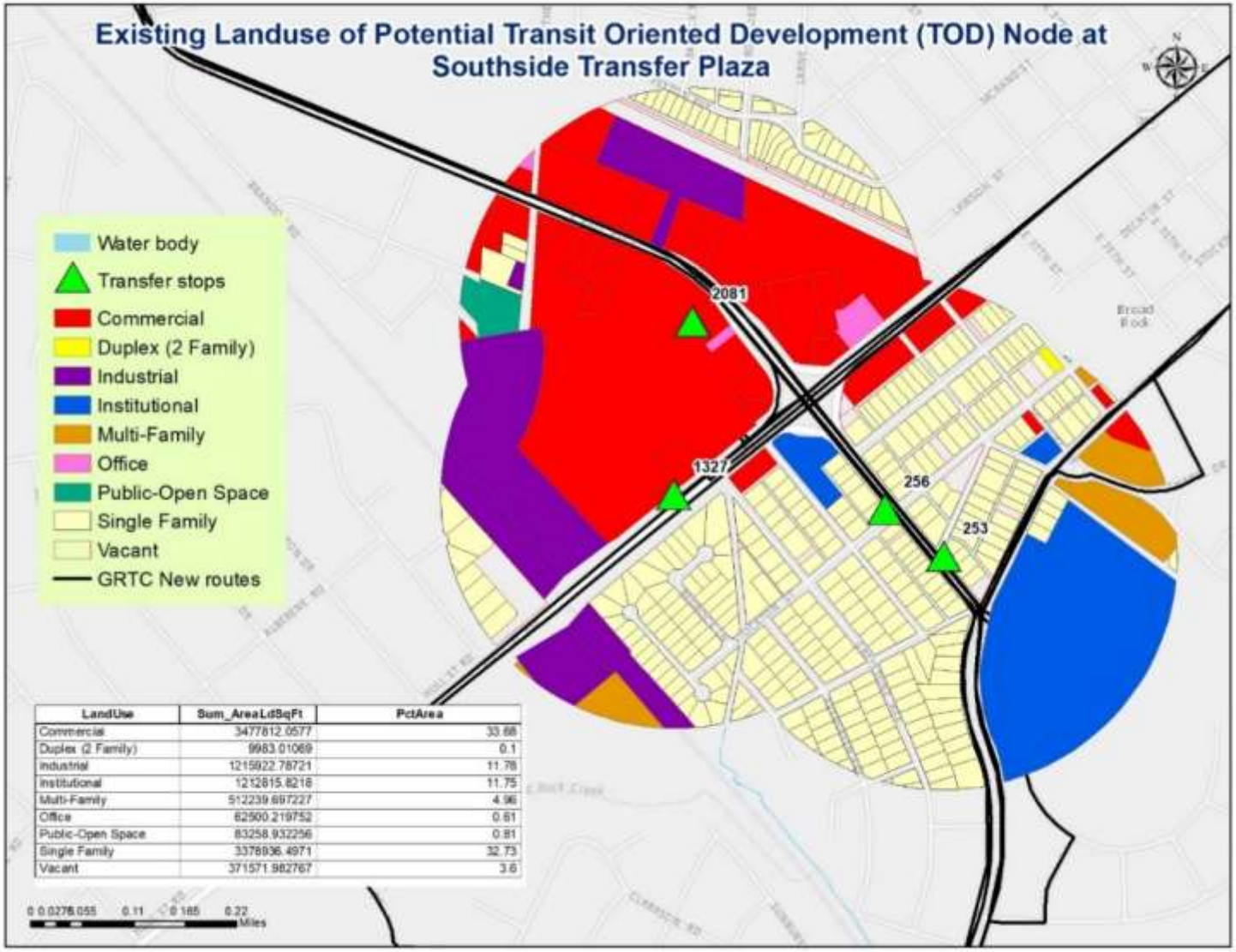
Existing land use of potential TOD node along East Main St.



LandUse	Sum_AreaLdSqFt	PctArea
Commercial	704227.933099	7.43
Duplex (2 Family)	93089.751126	0.98
Government	72819.768463	0.77
Industrial	595275.991246	6.28
Institutional	254155.595219	2.68
Mixed-Use	133551.540656	1.41
Multi-Family	5533765.0283	58.36
Office	194720.362908	2.05
Public-Open Space	556303.335546	5.87
Single Family	666993.79923	7.03
Vacant	677741.499728	7.15

Source- City of Richmond GIS data, designed and produced by author

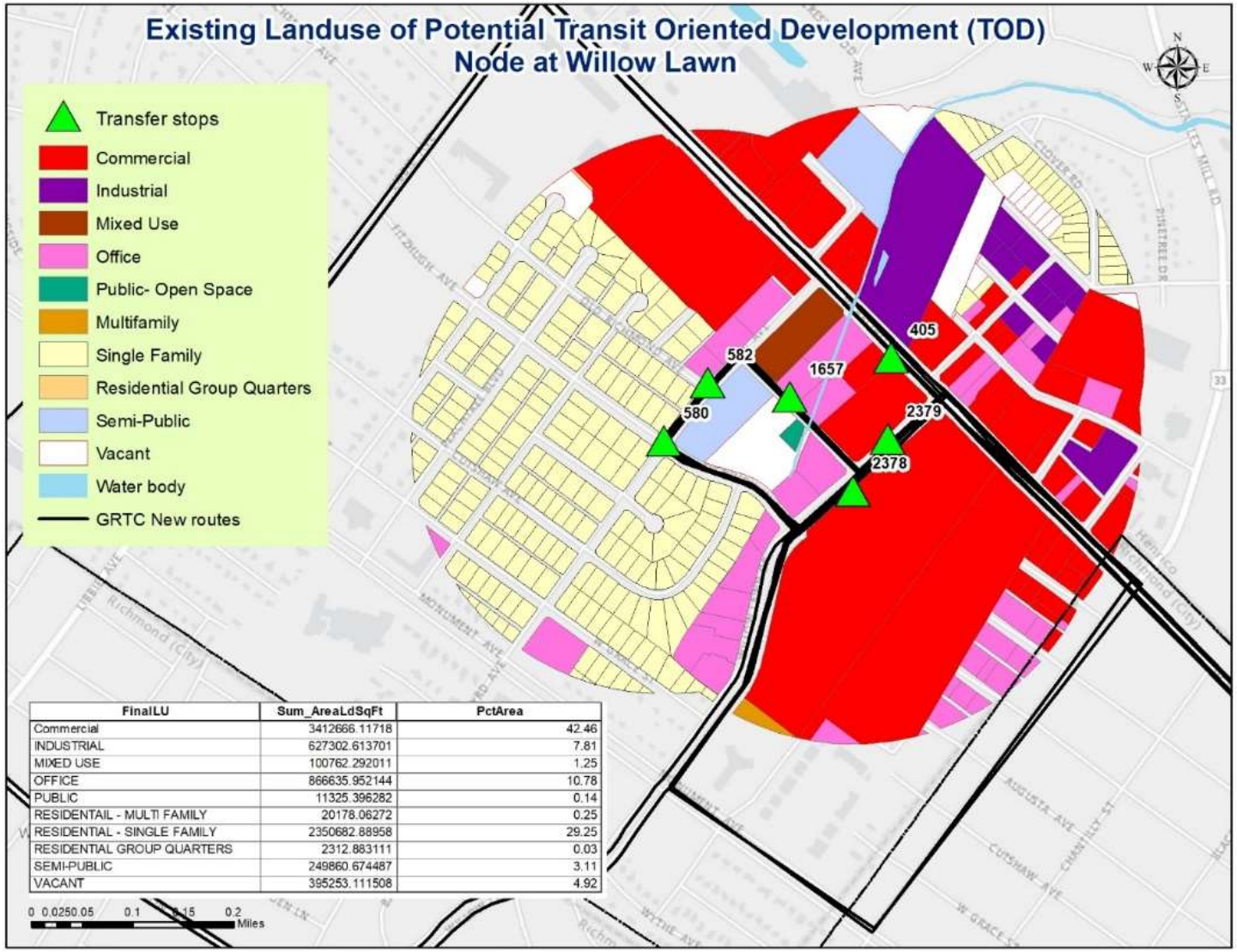
Existing land use of potential TOD node along Southside Transfer Plaza



LandUse	Sum_AreaLdSqFt	PctArea
Commercial	3477812.0577	33.68
Duplex (2 Family)	9983.01069	0.1
industrial	1215922.78721	11.78
Institutional	1212815.8218	11.75
Multi-Family	512239.697227	4.96
Office	62500.219752	0.61
Public-Open Space	83258.932256	0.81
Single Family	3378936.4971	32.73
Vacant	371571.982767	3.6

Source- City of Richmond GIS data, designed and produced by author

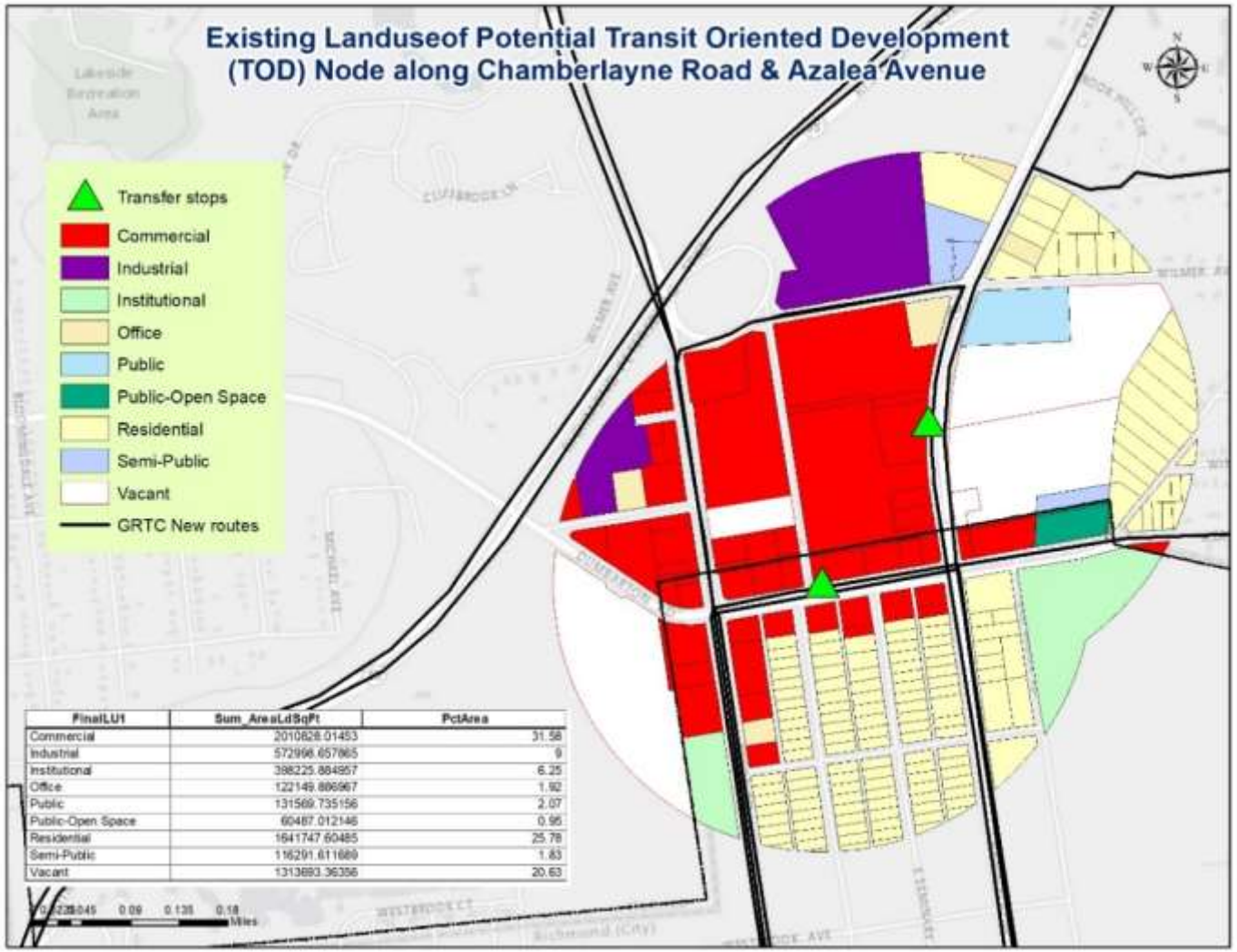
Existing land use of potential TOD node at Willow Lawn



FinalLU	Sum_AreaLdSqFt	PctArea
Commercial	3412666.11718	42.46
INDUSTRIAL	627302.613701	7.81
MIXED USE	100762.292011	1.25
OFFICE	866635.952144	10.78
PUBLIC	11325.396282	0.14
RESIDENTAIL - MULTI FAMILY	20178.06272	0.25
RESIDENTIAL - SINGLE FAMILY	2350682.88958	29.25
RESIDENTIAL GROUP QUARTERS	2312.883111	0.03
SEMI-PUBLIC	249860.674487	3.11
VACANT	395253.111508	4.92

Source- City of Richmond GIS data, designed and produced by author

Existing land use of potential TOD node at Chamberlayne



Source- City of Richmond GIS data, designed and produced by author

Appendix 2- Job- Housing Balance

To study census data, geography of the entire census block group that touches or intersect with quarter mile walkshed of identified potential nodes is included for calculations. For purpose of analysis, Jobs-households ratio (also known as jobs-occupied housing units ratio) has been used to determine job-housing balance for various nodes. It is ratio of number of jobs to number of households in a given census block group. Households data was obtained from Census data from American Community Survey 2015, 5-year estimates and Employment (jobs) data from 2015 – LEHD. Job housing balance of each node has been developed by multiplying job-housing balance ratio of block group with their respective areas contained in the node.

Job housing balance of Broad St Potential Node

Block Group	No. of households	No. of jobs	Job-housing ratio	Area (in sqft)	Area (in pct)	Job-housing ratio (wrt area)
517600402001	623	203	0.33	1069175.73	0.03549	0.011711
517600305002	993	1717	1.73	2342761.15	0.07776	0.134521
517600301001	454	5	0.01	137548.16	0.00457	4.57E-05
517600302001	899	1414	1.57	5507104.35	0.18278	0.286972
517600302002	17	26997	1588.06	6731546.80	0.22342	354.8122
517600403001	355	10302	29.02	1133781.83	0.03763	1.092053
517600305001	946	32500	34.36	11402806.53	0.37847	13.00414
517600301002	645	52	34.36	75882.93	0.00252	0.086539
517600205001	761	244	34.36	728298.97	0.02417	0.830577
517600205002	2033	2107	34.36	999988.49	0.03319	1.14042
				30128894.94		371.40

Source- ACS 2015, 5 year estimates and computed values

Job housing balance of East Main St Potential Node

Block Group	No. of households	No. of jobs	Job-housing ratio	Area (in sqft)	Area (in pct)	Job-housing ratio (wrt area)
517600208001	760	88	0.12	461432.2	0.065283281	0.007834
517600206002	262	112	0.43	413638.1	0.058521386	0.025164
517600205002	2033	2107	1.04	6122407	0.866196115	0.900844
517600206001	511	221	0.43	70676	0.009999218	0.0043
	3566	2528	0.40			0.94

Source- ACS 2015, 5 year estimates and computed values

Job housing balance of Southside Transfer Plaza Potential Node

Block Group	No. of households	No. of jobs	Job-housing ratio	Area (in sqft)	Area (in pct)	Job-housing ratio (wrt area)
517600604003	558	8	0.01	567859.8	0.047903296	0.000479
517600706013	417	7	0.02	306304	0.025839072	0.000517
517600706021	359	1581	4.4	9011381	0.760178543	3.344786
517600709001	291	294	1.01	170053.7	0.014345321	0.014489
517600709002	671	4723	7.04	1453184	0.122587151	0.863014
517600706012	735	59	0.08	345512.6	0.029146617	0.002332
	3031	6672	2.093333333			4.23

Source- ACS 2015, 5 year estimates and computed values

Job housing balance of Willow Lawn Potential Node

Block Group	No. of households	No. of jobs	Job-housing ratio	Area (in sqft)	Area (in pct)	Job-housing ratio (wrt area)
510872005011	357	2639	7.39	2686356.887	0.267499425	1.976821
510872003011	580	5427	9.36	7356120.346	0.732500575	6.856205
	937	8066	8.38			8.833026

Source- ACS 2015, 5 year estimates and computed values

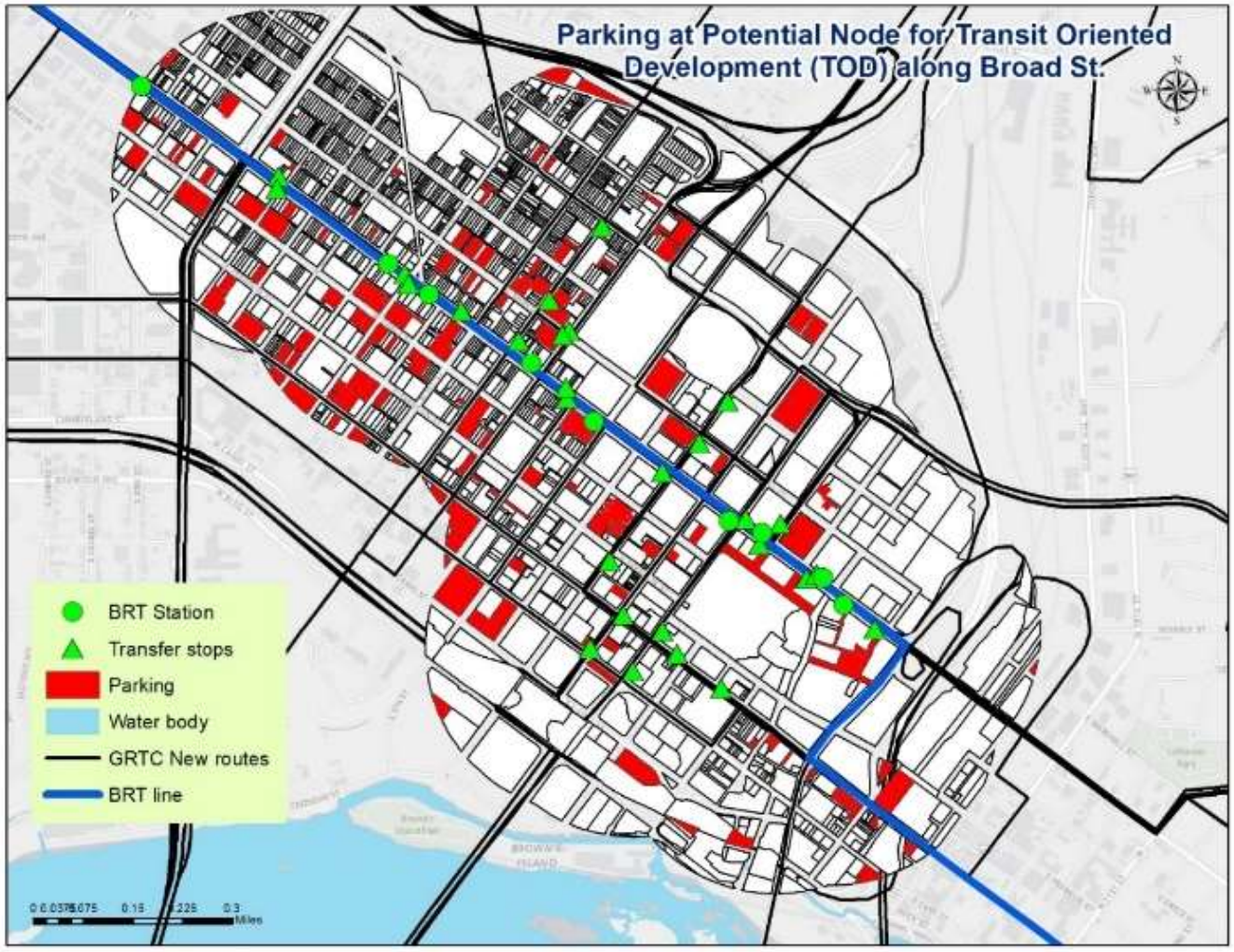
Job housing balance of Chamberlayne Potential Node

Block Group	No. of households	No. of jobs	Job-housing ratio	Area (in sqft)	Area (in pct)	Job-housing ratio (wrt area)
510872007002	776	281	0.36	1018629	0.128728142	0.046342131
510872008021	851	1111	1.31	2456639	0.310455166	0.406696267
510872008041	599	55	0.09	1378460	0.174201385	0.015678125
510872008042	718	94	0.13	282386	0.035686228	0.00463921
517600103001	593	99	0.17	308748	0.039017703	0.006633009
517600102001	459	131	0.29	2170646	0.274313078	0.079550793
517600102002	414	44	0.11	297516	0.0375983	0.004135813
	4410	1815	0.35			0.56

Source- ACS 2015, 5 year estimates and computed values

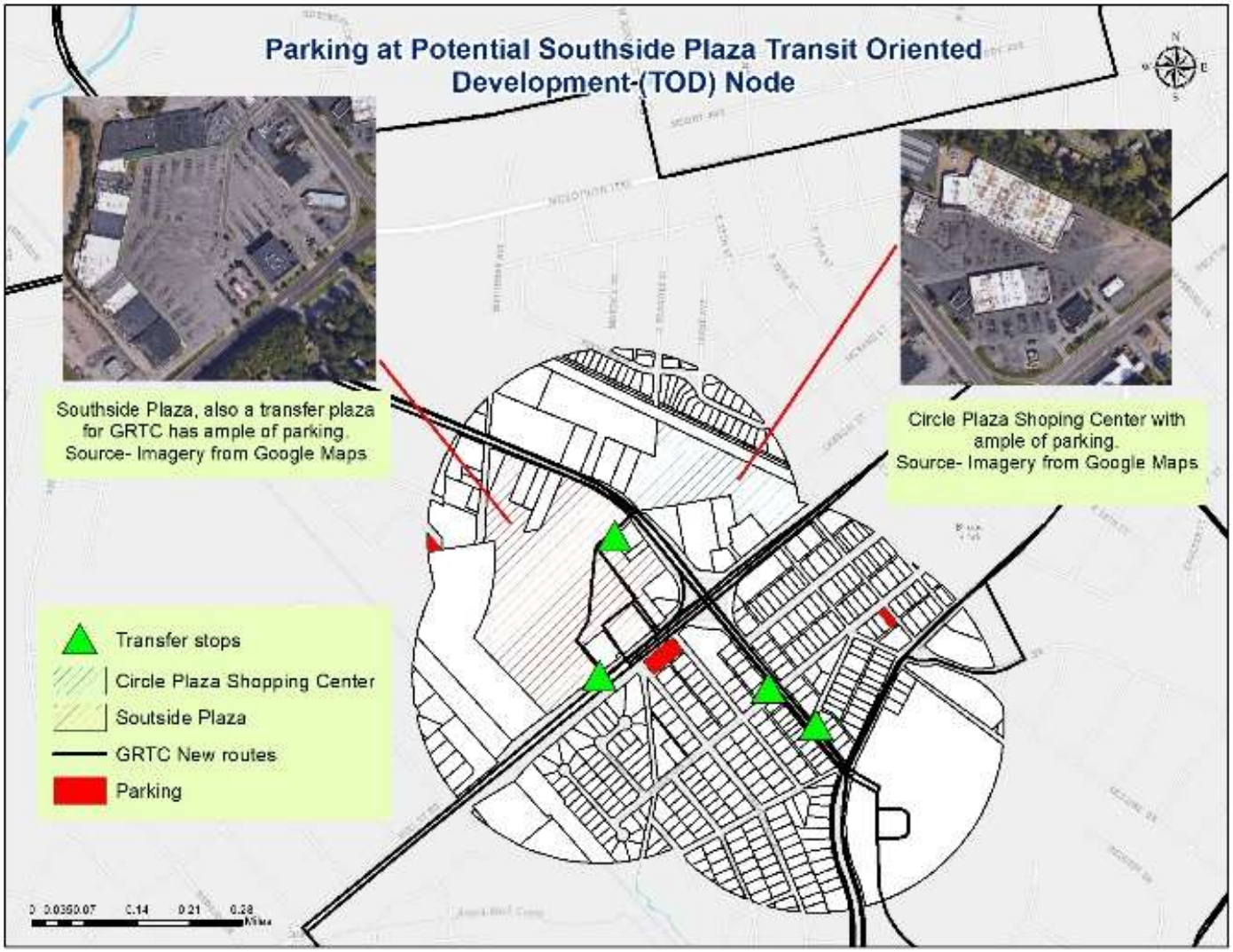
Appendix 3 - Parking Inventory of Potential Nodes

Parking availability at Broad St. Node



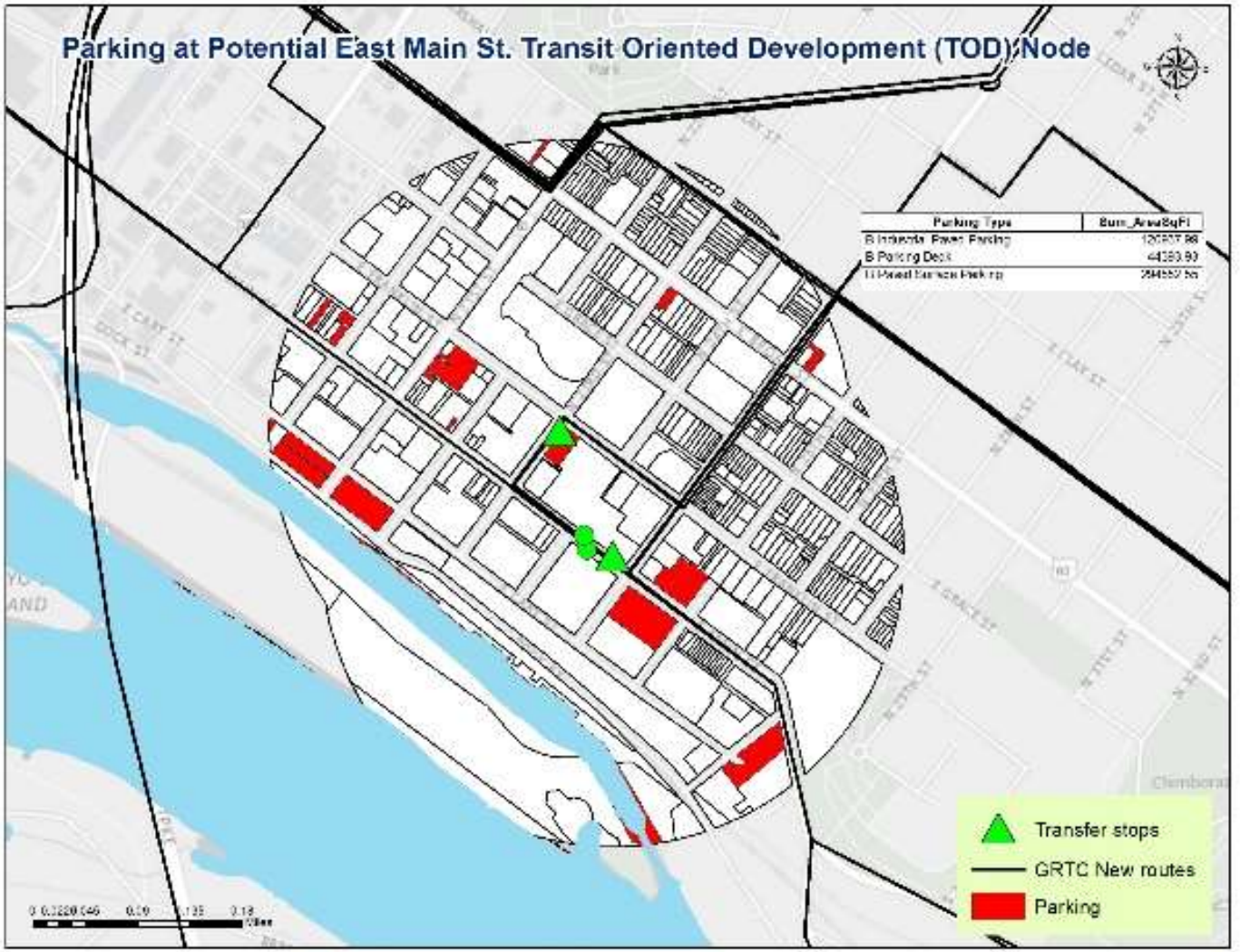
Source- City of Richmond GIS data, designed and produced by author

Parking availability at Southside Transfer Plaza. Node



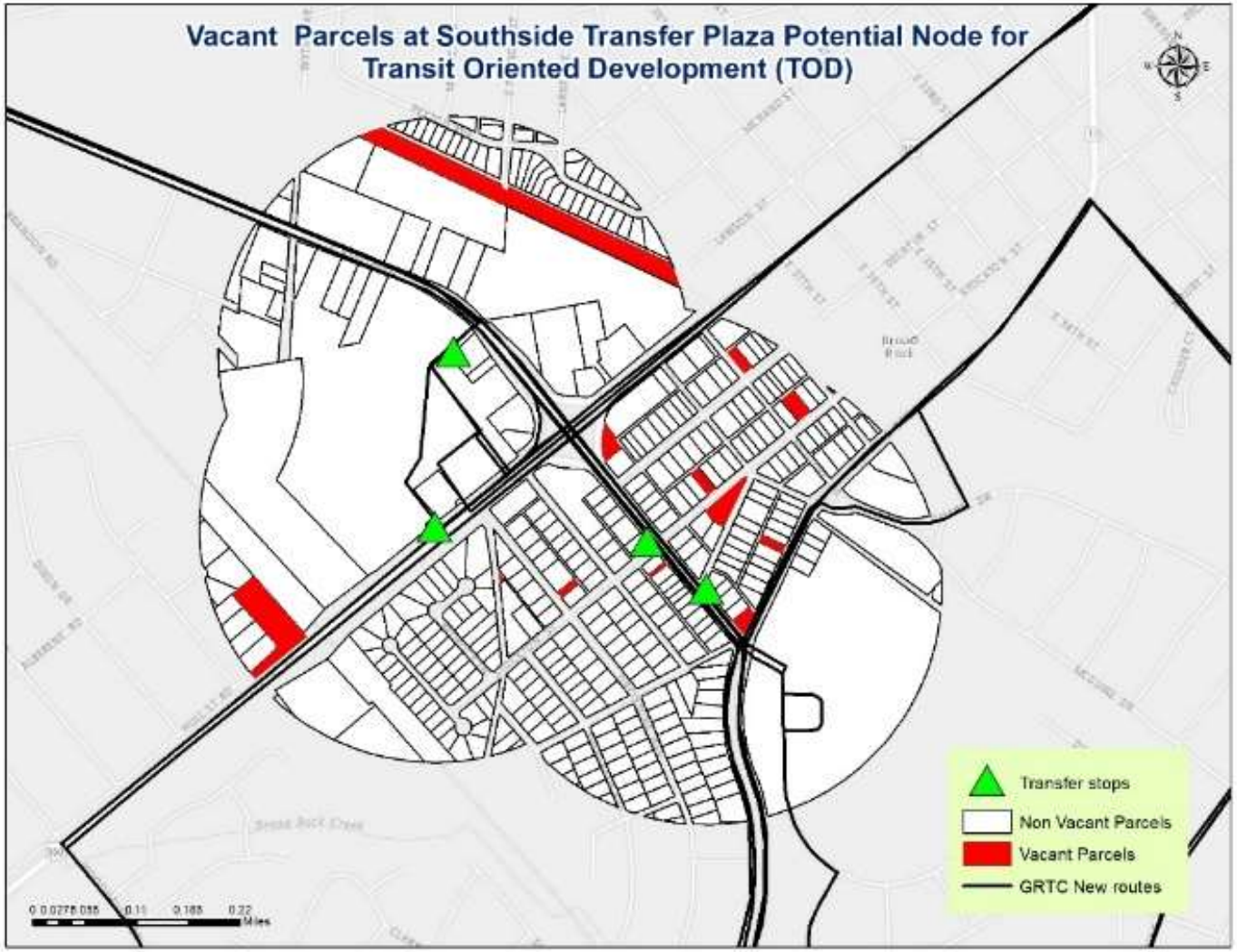
Source- City of Richmond GIS data, designed and produced by author

Parking availability at East Main St. Node



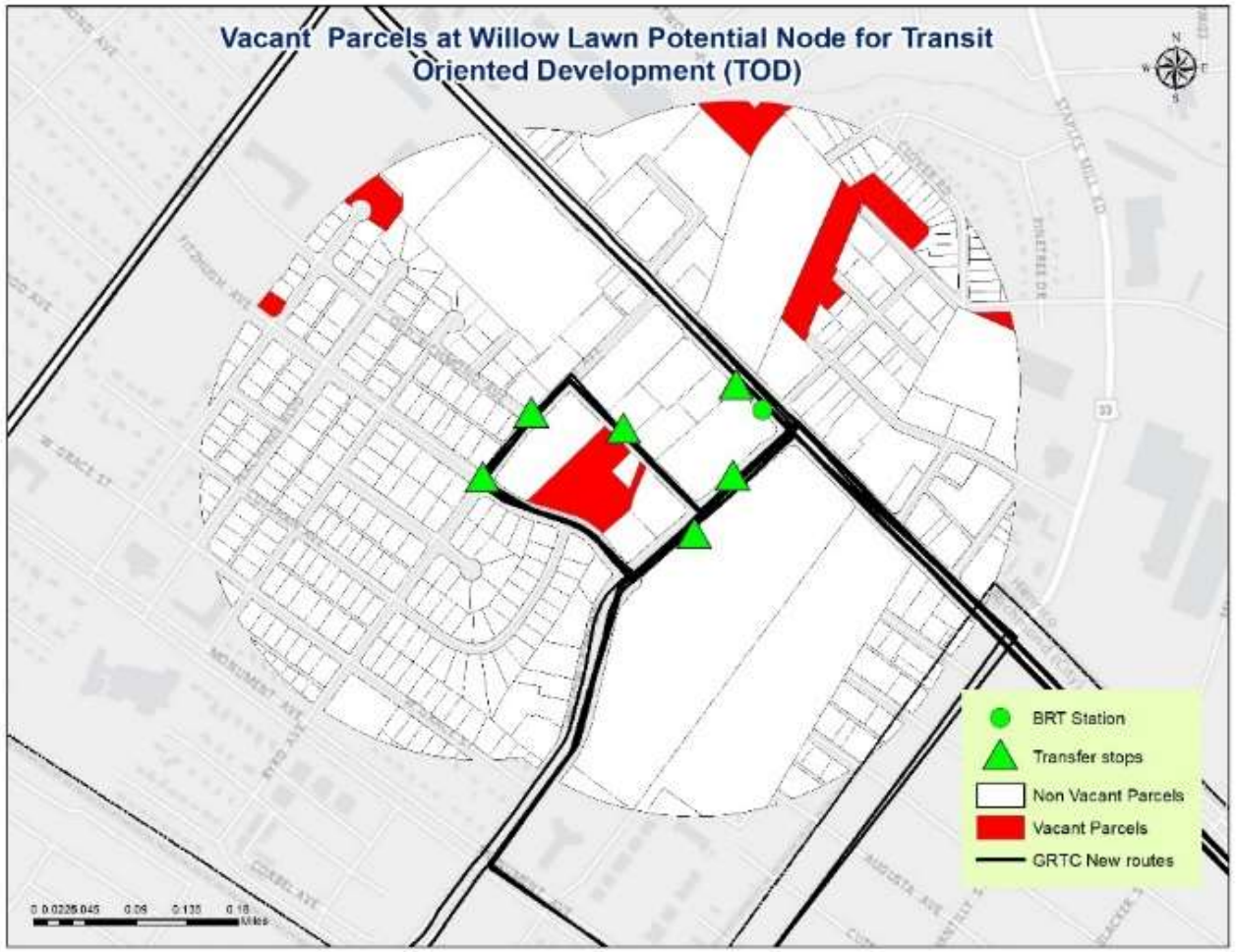
Source- City of Richmond GIS data, designed and produced by author

Appendix 4 – Availability of Vacant Land of Potential Nodes



Source- City of Richmond GIS data, designed and produced by author

Availability of Vacant Land at Willow Lawn Node



Source- City of Richmond GIS data, designed and produced by author

Appendix 5 Walkability Index

Walkability Index of Broad St. Node

Block Group	National Walkability Index	Area (in sq.ft)	Area (in pct)	Walkability Index of block group (wrt area)
517600305002	10.50	2342761.00	0.077757952	0.816458
517600305001	10.33	11402807.00	0.378467466	3.910704
517600402001	10.83	1069176.00	0.035486722	0.384428
517600301001	7.50	137548.20	0.004565324	0.03424
517600403001	11.17	1133782.00	0.037631046	0.420226
517600302001	12.83	5507104.00	0.18278481	2.345677
517600302002	10.83	6731547.00	0.223424949	2.420362
517600301002	8.67	75882.93	0.00251861	0.021829
517600205001	10.17	728299.00	0.024172774	0.245765
517600205002	12.17	999988.50	0.033190347	0.403827
		30128895.00		**11.00**

Source- National Walkability Index (EPA) & computed values

Walkability Index of East Main St. Node

Block Group	National Walkability Index	Area (in sq.ft)	Area (in pct)	Walkability Index of block group (wrt area)
517600208001	10.50	461432.2	0.065283281	0.685474
517600206002	10.50	413638.1	0.058521386	0.614475
517600205002	12.17	6122407	0.866196115	10.53901
517600206001	9.83	70676	0.009999218	0.098322
		7068153		11.94

Source- National Walkability Index (EPA) & computed values

Walkability Index of Southside Transfer Plaza Node

Block Group	National Walkability Index	Area (in sq.ft)	Area (in pct)	Walkability Index of block group (wrt area)
517600604003	6.50	567859.84	0.047903296	0.311371
517600706013	4.50	306303.99	0.025839072	0.116276
517600706021	11.17	9011381.24	0.760178543	8.488914
517600709001	8.83	170053.67	0.014345321	0.126712
517600709002	7.33	1453184.34	0.122587151	0.898932
517600706012	7.33	345512.68	0.029146617	0.213732
		11854295.7		10.156

Source- National Walkability Index (EPA) & computed values

Walkability Index of Willow Lawn Node

Block Group	National Walkability Index	Area (in sq.ft)	Area (in pct)	Walkability Index of block group (wrt area)
510872005011	8.67	2686356.90	0.27	2.318418
510872003011	11	7356120.34	0.73	8.057506
		10042477.23		10.38

Source- National Walkability Index (EPA) & computed values

Walkability Index of Chamberlayne Node

Block Group	National Walkability Index	Area (in sq.ft)	Area (in pct)	Walkability Index of block group (wrt area)
510872007002	8.33	1018629	0.128728	1.072692
510872008021	9.50	2456639	0.310455	2.949324
510872008041	8.67	1378460	0.174201	1.509803
510872008042	6.33	282386	0.035686	0.226001
517600103001	6.50	308748	0.039018	0.253615
517600102001	10.33	2170646	0.274313	2.834477
517600102002	5.50	297516.3	0.037598	0.206791
		7913024		9.05

Source- National Walkability Index (EPA) & computed values