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Exploring the ability of balance between land use and transportation infrastructure to explain success of transit-oriented development projects in suburban Washington D.C.

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Summary

Suburban transit-oriented development is understudied in the American context and is more difficult to develop than urban projects due to a heavier reliance on vehicle trips and community preference for lower density infrastructure. (Mathur & Ferrell, 2009) Models are one tool that developers and policy makers use to understand the historical and contemporary context of a site and how best to improve it. (Jacobson & Forsyth, 2008) This research aims to test assessing the balance between transportation infrastructure and land use as an explanatory and predictive tool for developing and evaluating suburban transit-oriented development projects. This relationship was tested by putting 9 suburban Washington D.C. metro stations through a Dutch model that employs 6 different overall factors of TOD success: active transport, public transit network, car and road infrastructure, design of land use, density of population, and diversity of land use, which are grouped into the larger categories of transportation and land use.

The model is intended to test the balance between these factors with more balanced models indicating higher levels of success. The model results were evaluated for each station and compared to the context of other TOD models for these stations and a Belgian use case of the Dutch model that also evaluated suburban metro stations. Additionally, two industry professionals were consulted for specific context on how development decisions about these stations are made.

The study found that the Dutch model mostly accurately captures the conditions of the 9 case study stations. The closer stations to D.C. were the most balanced, and their dense populations and high access to transit were reflected in the models. None of the nodes were perfectly balanced, which is reflective of the stations' continued need for development and improvement. However, the model results leave out an important context of how the stations were intentionally developed differently based on their functions as part of a larger corridor. Imbalance isn't always an indicator of failure, but rather could suggest success depending on the intended purpose of the node.

The results suggest potential for the overall relationship between transportation and land use to be important in evaluating TOD, but that balance might not be the most crucial outcome for every station. Rather, evaluating the 6 prongs that make up the model individually and developing a more nuanced model that can capture corridor level planning could be even more valuable for planners.

Keywords

Transportation, Land Use, Balance, Development, Decision-making

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Abbreviations

TOD	Transit Oriented Development
D.C.	District of Columbia
RER	Réseau Express Régional (Brussels Regional Express Network)
WMATA	Washington Metropolitan Area Transit Authority
US	United States

1: Introduction

1.1 Background

Public transportation is a vital component of the future of mobility. The benefits of a functional transit network are abundant and undeniable, across the health, sustainability, economic, and social equity sectors. Public transit has been linked with improved air quality, increased rates of daily physical activity, and reduced traffic congestion. (Litman, 2010) Collective economic benefits like job creation, and increased property values around transit lines and station development areas increases the demand for transportation infrastructure. (Bautta & Drennan, 2003) Social equity is another vital benefit of transportation as it provides alternative transit methods for those who do not own a car. It also provides access to increased opportunities for economic and social mobility. (Yeganeh et al., 2018) The benefits of transportation cannot be fully realized, however, if the surrounding environment is not conducive to its use.

Implementing transit options successfully requires appropriate supporting infrastructure and demand from the public. Transit-oriented development (TOD) is one strategy to increase ridership by promoting smart growth and lifestyle choices. (Cervero, 2004) TOD is defined differently across the world but is centred around inclusivity, accessibility, and connectivity. The Institute for Transportation & Development Policy defines TOD as "integrated urban places designed to bring people, activities, buildings, and public space together, with easy walking and cycling connection between them and near-excellent transit service to the rest of the city". (ITDP, 2023, p. 1) TOD has continued to gain popularity to address urban sprawl, reduce automobile dependence, and promote sustainable development. While TOD has traditionally been associated with urban areas, there is growing interest in its application in the suburbs, where low-density development and automobile dependency are major challenges. These unique conditions of the suburbs make implementing TOD tricky but necessary.

It is thus important to understand what makes TOD projects successful in different contexts. A successful TOD project requires a comprehensive approach that integrates land use, transportation, and community development strategies. (Bertolini et al., 2005) However, the specifics of the success threshold are hard to define.

1.2 Background - Model

Multiple models have been created to try to explain the relationship between transportation infrastructure and land use and how each factor contributes to the success of a TOD project. One model that captures this relationship well is the Butterfly model, developed in the Netherlands as a decision-making tool for policymakers for better integration of multimodal transportation planning and land use planning on the node level. (Deltametropool, 2013)

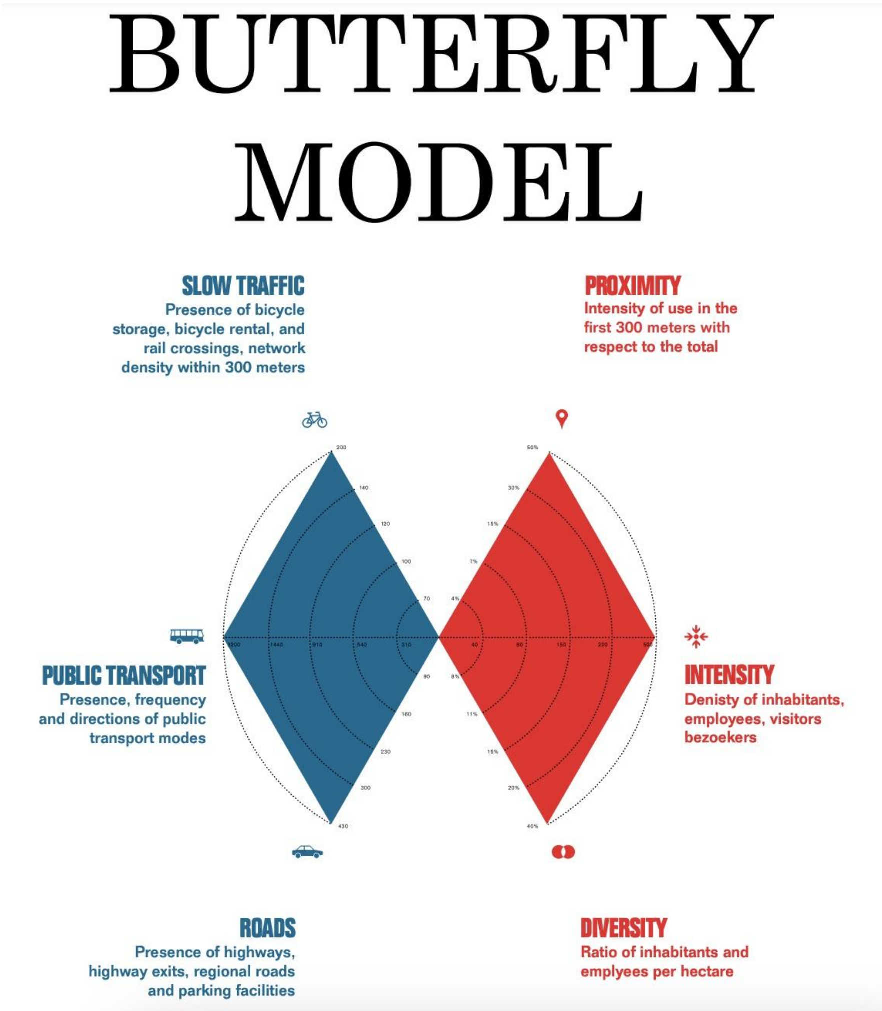

Figure 1: The "butterfly" element is the shape of the model, which comprises two wings, the first encompassing transportation infrastructure and the second depicting elements of land use and population. (Pretorius, 2021)

Each of the 6 points of the wings is informed by a set of indicators. Slow traffic includes bike infrastructure, walking paths, and micro-mobility hubs. Public transportation includes present infrastructure, frequency and level of service. Roads and car infrastructure make up the third transportation point. On the land use side, there are points for design of the built environment, density of the population, and diversity of land use. The way this model has been applied has been adjusted in each existing study to adjust the indicators for the context. (Pretorius, 2021). It is a general enough model to be able to adjust the indicators without significantly altering the structure or efficacy of the model. (Deltametropool, 2013)

1.3 Problem Statement

Suburban transit-oriented development is not well studied in the United States. It can be difficult to implement TOD projects in areas that are not already well connected to densely populated areas with existing infrastructure and a population with an inherently strong desire to take transit. Due to the suburban population generally being deeply reliant on cars and road infrastructure, there is often significant community opposition to proposed TOD projects in the American suburbs. (Mathur & Ferrell, 2009) This resistance can be explained by a lack of familiarity with integrating transit use into their daily lives, and a fear of the community changing in unfamiliar ways that do not serve their interests. (Padiero et al., 2019) When policy makers and community planners wish to implement more TOD, it is extremely important to evaluate what has worked and has not and why, to understand what critical factors, need to be considered for a higher chance of success.

Understanding the specifics behind previous triumphs and failures across different cases is crucial for learning from these precedents to design and implement new TOD. Most noteworthy positive projects have transformed the land around stations within city boundaries. When working within a city, the population around the station is already denser, and more likely to use active transport and public transport methods to move around. (Al-Kodmany, 2018) It can be far more challenging to get suburban residents to adopt a lifestyle that is compatible with denser transit-oriented development. To implement suburban TOD on a larger scale across the country it would be useful for planners to have a model or tool that can be applied to transit nodes to understand what existing infrastructure is proficient or lacking and how that might explain the performance of different types of developments. There is currently no universal model for evaluating TOD, particularly in the suburbs and the American context.

The Dutch Butterfly model is an innovative, concise, comprehensive visual representation of the balance between these two "wings" of TOD. It has never been applied in the United States context before and could prove very useful for policy makers to have such a tool to use for comparison and improvement of different sites.

1.4 Case Study & Research Gap

For the purposes of this study and applying the Dutch Butterfly model in the United States, it is important to have a control example of a widely accepted successful project. The Rosslyn-Ballston corridor in Arlington, Virginia outside of Washington D.C. is highly regarded as one of the most successful examples of suburban TOD in the country. However, attempts at replicating the type of development that occurred there have largely been unsuccessful. It is difficult to pinpoint exactly why in a way that would allow for correction and replication, particularly when comparing these 5 station areas with similar analogues. There are many explanations offered in studies over the last couple decades, with factors such as land use decisions, existing zoning restrictions, population demographics, accessibility, project management structure, funding sources, and many others. (Jennings, 2014) The Dutch model captures the relationship between many of these factors and is a comprehensive way of evaluating the project. The model puts a crucial emphasis on the balance between these land use and transportation indicators to evaluate overall success. Understanding how active transportation and design interplay to create more liveable spaces, how public transit and density depend on each other for further development and managing demand, and car and road infrastructure has developed differently depending on the diversity of land use around a station can all help evaluate the success of the development around the node. Evaluating the known success of the Rosslyn-Ballston corridor, along with 4 other suburban orange line stations on the Washington Metropolitan Area Transit Authority's (WMATA) metro system with the model will be the first test of the usefulness of the Dutch model in explaining and evaluating the success of the project and lack of success around other stations. There is limited research in the United States on the connections between all the factors captured in the model, and the overall factors of success for transit-oriented development.

1.5 Research Objectives

The objective of this study is to evaluate the extent to which the balance between transportation infrastructure and land use factors can be used in determining success. In doing so, it will apply a potential framework for explaining and understanding successes and failures of suburban TOD. This study will compare accepted successful project areas to other areas with less effective development to best understand how well this balance can explain success and evaluate how it can be used as a tool in the future.

1.6 Research Questions

The main research question is to what extent can the balance between transportation infrastructure and land use be used to explain the success of suburban transit-oriented development in Arlington and Fairfax County, Virginia? The sub questions include: 1) How can the balance between transportation and land use be applied to the successful TOD project of the Rosslyn-Ballston corridor as a control, and other similar projects along the same metro line as a further test? 2) Does one element or indicator have a larger influence than others on the balance between transportation and land use in TOD projects? 3) What are the underlying assumptions used in the Dutch butterfly model and how do they differ from US assumptions for evaluating TOD? 4) Are the indicators included in the Dutch model the most appropriate and effective way to employ the model in the US context?

1.7 Significance of the Study

Most of the United States research has predominantly focused on TOD projects in urban areas, while suburban projects have been comparatively underrepresented. American city planners thus lack a standardized model for explaining the success and failure factors of TOD projects, and the models that are used tend to not apply as well to suburban conditions. (Jacobson & Forsyth, 2008) Suburban infrastructure varies significantly across the country, making a model that captures the most important development factors accurately across many conditions especially difficult to create. (Swenson & Dock, 2004) Additionally, suburban TOD has not been well studied in the United States in general, and this research study will help contribute to the body of research done on its implementation. It will also advocate for why suburban development is advantageous, has faced many historical barriers, and should be studied more thoroughly. (Hrelja et al., 2020) This study also aims to shed light on why future TOD might focus on balance between different types of infrastructure as an explanation for why certain projects succeed or fail.

Evaluating the selected different nodes through the balance between land use and transportation infrastructure by applying the Butterfly model to the U.S. context for the first time will provide valuable information on whether it could be useful as a decision-making tool in the United States.

1.8 Scope and Limitations

To focus the study, the stations chosen are limited to 5 successful stations and four less successful stations, all along the same metro line that were all opened and developed in similar time frames with similar characteristics. This study will not cover other areas around the Washington D.C. metro system, or other similar projects across different areas of the United States. This study also will not go into extreme detail about other factors that could have influenced the success of these projects that are not covered by the model.

2: Literature review and conceptual framework

2.1 Introduction

This chapter will focus on the body of existing literature and research that currently exists on TOD and its implementation in the United States. An emphasis will be placed on the frameworks that have been developed previously for understanding the different factors and relationships that inform transit and land use planning and the current understanding of the integration between these two elements.

2.2. What is Transit Oriented Development?

In 1993, Peter Calthorpe coined the term transit-oriented development to describe an optimal mix of development around a transit node, including residential, commercial, office, and public space that is conducive to multiple modes of mobility, particularly walkability and bikeability. (Calthorpe, 1993) While dense, walkable mixed-use communities are not a new concept for most of the world, it represented a shift in the individualistic United States development mindset that had been present since the end of World War 2. City development was centered around a strong preference for using a car for most trips, leading to prolific urban sprawl in most major metropolitan areas. (Beske & Dixon, 2018) Washington D.C. was no exception, with most of the employees working in the city living in the low-density suburbs and commuting long distances each day. With the introduction and expansion of the Washington D.C. metro system in the 1970s, a new call for denser communities around the station areas led to the development of transit-oriented communities within the city. As the system was expanded into the suburbs, the density of development was slow to follow. (Beske & Dixon, 2018) Now, transit-oriented development has become a way of catching up to the density of the city, allowing more people to live within walking and biking distance of transit stations, and thus encouraging higher rates of transit use.

TOD uses the 6 "Ds": density, diversity, design, distance to transit, destination accessibility, and demand management. (Cervero & Sullivan, 2010) Density encompasses both residents and employees and helps ensure that a high enough volume of people live and work around the transit node. When developing new projects, density is a major factor that makes expensive mixed-use development more attractive, as a higher population is more likely to make better use of new amenities. (Hrelja et al., 2022) Diversity is the heterogeneity of land use around the transit node, defined as a wide range of amenities, activities, and space usage. Having a balance between residential, commercial, service and leisure tends to have the best outcomes, but ideal ratios are dependent on the individual conditions at the node. (Hasibuan & Mulyani, 2022) Design includes walkability, bikeability, and safe access to transit stations, with additional amenities like benches and parks to make the environment more comfortable. A focus of the design element is liveability and improving the overall experience and quality of living within this development project and the surrounding area. (Salat & Ollivier, 2017) Distance to transit partly determines likelihood of transit use and helps policymakers evaluate level of service. One of the main goals of TOD is increased ridership on the transportation modes the developments are built around, so ensuring a short distance to transit and thus encouraging its use is an important component of planning TOD. (Ann et al., 2019) Destination accessibility is a metric to understand how well connected the transit node is and how easy it is for travellers to get to where they need to be using that transit mode. In theory, well designed TOD should make traveling to different types of destinations easier and more efficient and incentivize people to use transit, walk, or bike more to their destinations. (Lye et al., 2020) Finally, demand management is the psychological factor of whether users are willing to make modal shifts and take fewer vehicle trips. This is dependent on many factors, including how easy or convenient it is to use alternative modes, the relative cost of switching modes, and cultural perception of each mode. (Ogra & Ndebele, 2014)

Many planners agree that there isn't a universally accepted optimal level of any of these factors because the conditions at each node are context dependent. For instance, if a node was intended to be a business center, there might be purposefully less diversity in land use. However, overall, there are strong links between compact, pedestrian friendly design with reduced vehicle mile trips and reduced single occupancy vehicle trips. (Cervero & Kockelman, 1998) Reducing vehicle trips and increasing transit ridership is one potential way of measuring success of TOD, but it only tells one piece of the story. Incorporating scores and evaluations of land use and the quality of mobility network access paints a more comprehensive picture of the true conditions of the development project. (Deltametrapool, 2013)

2.3 Corridor Planning for TOD

Most TOD planning is done at the node level because it is easier to understand the needs of one node at a time and most projects are not funded at a higher level. (Singh et al., 2017) However, planning TOD at the corridor level is becoming a more popular development strategy due to the ability to problem solve for shorter- and longer-term issues affecting a whole region or group of stations, relating to transportation access, land use, future growth management and environmental concerns. (Smith, 1999) It is also more cost effective and efficient when adjacent stations face similar development opportunities and have similar demographics. It can help build local excitement and improve stakeholder engagement in earlier stages of the project as there is a stronger feeling of real change and improvement of the area. (Reconnecting America, 2010) A large part of corridor planning is focused on sustainability and liveability standards for the whole region, which is often easier to arrange and coordinate at this scale as opposed to the node scale. (Ferrell et al., 2016) Additionally, each node may not be the most successful on its own, but it may be an important factor in its neighbour's successes, as a potential feeder node for an abundance of employment opportunities at a similar node. (Huang et al., 2018) It is crucial to integrate the planning for a corridor, instead of simply linking individual node plans together. This ensures a more cohesive and stronger corridor for the future and relies on interdependencies and compatible differences across the nodes. (Rooney et al., 2010)

2.4 Evolution of TOD Models

Alfred Weber was one of the first to begin the discussion of optimal locations when planning for development. He developed a Location Triangle model that attempted to explain the best location for a firm to locate when considering the locations of raw materials needed in the factory production process, and the marketplace to sell the goods produced in the factory. Ideally the factory would be located within a reasonable distance of each of these other locations to be the most efficient. (Weber, 1929) This same principle can be applied to transportation, and TOD. It is logical to build TOD where the site has access to people that will live and work in the new development, and proximity to transit, both to better serve the needs of the people and to encourage transit use. An extension of this logic came through the

Node Place model, developed by Bertolini in 1996. The Node Place model was the first robust attempt at directly explaining the relationship between a transportation node and the intensity of the land use around it. When the two factors were not in balance with each other, it led to either an unsustained node or an unsustained place. Accessibility was the ideal balanced midpoint of the model, particularly around areas with high public transit access, as opposed to areas only focused on car infrastructure or pedestrian and bike infrastructure. (Bertolini, 1999) This model is considered foundational in understanding this relationship but is somewhat difficult to use and compare sites with, especially with variation in TOD that has evolved since the model's conception.

The Butterfly model is an extension of the Node Place model and was developed with the Delta Metropool association in collaboration with the province of North Holland. The 6-pronged approach is an extension of the relationship model the Node Place model provided to understand how best to explain the balance and imbalances between land use and transportation factors. By examining these factors from a high-level perspective of balance, rather than seeing each element as its own separate problem, it is easier to understand the challenges and opportunities each node faces. It allows systematic spatial and mobility analysis of each node in a transit system and provides a visual representation of opportunities for improvement to make the node function more optimally. The Butterfly model was developed as a first step tool to help stakeholders understand the current situation a node faces and have empirical data informing gaps in development and potential areas of growth. (Hengstmengel, 2022) The overarching idea is that the greater the position in the transit network, the denser the population should be around the station. In less advantageous parts of the transit network, the population should be lower. This balance ensures that the liveability of the development is as high as possible and the demand for transit and housing and employment opportunities are in balance. (Deltametropool, 2013)

They also developed 12 ideal archetypes of butterflies to analyse the results of the indicators. Most places are not at the ideal potential 12, but seeing how nodes compare to the 12 types can help policy makers understand where nodes are lacking and help inform future decision making. (Deltametropool, 2013) These archetypes are specific to the Dutch context. They separate and categorize stations based on what types of train transportation run through the node (high speed, inner city, sprinter), and based on significant characteristics of the area, and the relative size of the cities. Due to the Netherlands being a geographically small and dense country with high connectivity of transit, this separation is effective and meaningful in understanding why developments in different regions and different cities may require differing development strategies. For example, one of the archetypes is the "world city" where important governmental and international relations activities happen. (Deltametropool, 2013) This sort of separation is not possible in the same way in other places due to a lack of regional and corridor planning where nodes more naturally have different functions from each other as they are all co-located in relatively close proximity. Nodes are typically developed in isolation in the US as they are geographically further away from each other and the lack of the variation of train types that separate the Dutch nodes also make these twelve archetypes less applicable in the US context. Thus, in other uses of the model, interpretations have been adjusted to be more widely applicable.

The model rests on this balance between the two wings. The left wing is the aggregated node value of the place that "evaluates the quality of the network" by assigning higher scores to places that are well located within the transportation networks. (Deltametropool, 2013) Each dimension of the network is carefully aggregated by including multiple metrics. Active transportation is measured by assessing bike parking, bike and walking path network accessibility, and presence of bike and micro mobility sharing stations. Bike parking capacity is a measure that determines how many designated bike rack spaces there are within 1000 feet of the station, which helps indicate how convenient it is for commuters to leave their personal bicycles at the station. Whether or not the station is accessible by dedicated biking and walking paths also is a crucial factor in determining the feasibility of a commuter biking or walking to the station from another location. Additionally, the micro mobility factor indicates the presence of bike share at the station, further providing insight on which options commuters must get to and from the station.

Public transportation includes indicators inspired by Bertolini's node place research, including number of trains serving the station per day and number of stations reachable within twenty minutes, as well as measures of centrality to better understand the station's position in the network. Understanding how many end stations are reachable by train puts the station into context of the larger metro system, placing it on either a well-connected line or a more out of the way location that may be less incentivizing to commuters as they need to transfer or ride longer distances to reach their destination. Similarly, measuring how many stations a commuter could reach within 20 minutes, how many trains serve the station daily, and the number of bus lines that stop at the station each also contribute to an overall understanding of the "usefulness" of the public transportation that is available at this node.

Car and road infrastructure is measured by parking capacity, presence of car sharing services and closeness to the highway. Car parking capacity is measured in a similar way to bike parking capacity, with a 1000 ft radius around the station. Measuring car access is particularly important in the American suburbs, where most residents rely on a car for at least one part of their commute. Presence of car sharing services can be measured through presence of designated pick up and drop off spots, and coverage areas for different transportation network companies. Closeness to the highway is also an important indicator that allows for connectivity to the road network to be measured appropriately.

The other wing measures place characteristics. Design is informed by pedestrian shed analysis, and transversable network analysis. The pedestrian shed analysis is a ratio of walkability within a certain time frame and the area of the buffer circle of half a mile. If this value is large, walkability is high. This provides insight on the actual on the ground design around the station and how easy it is for pedestrians to move around. Transversable network analysis is the general measure in miles of how many paths there are around the station that could be considered walkable. The density indicator shows the number of residents in the area and the number of workers in different sectors to better understand how many people and what types of people use the station and the area around it. The indicator is divided into four main industry types to ensure that the diversity of the economy is captured within the density metric. This also provides further insight into the result of the model when examining which factors have the most pull on the wings. Diversity uses a degree of functional mix and zoning to understand the makeup of land use around the station and how that may influence use of the TOD infrastructure. (Caset et al., 2018)

The idea behind the model is that each of these factors alone may not be able to say much about the node, but when the balance is calculated and seen through the model, decisions can be made based on the relationship of the variables to each other. Each of these indicators for each point of the wings helps tell a data driven story about the node and the place, and how that balance can be evaluated. The more balanced the wings, the more successful the node. Unbalanced nodes have the most room for improvement to achieve the balance and depending on where the imbalance is coming from different interventions and recommendations will be made.

2.5 Previous Research with the Butterfly Model

The Butterfly model is a relatively new framework for this type of analysis. After its development in 2013, it has been used in Dutch studies and a handful of other countries, most notably in Belgium and New Zealand.

The Brussels study looked at these indicators within this model to understand the accessibility of rail stations in the regional express network (RER). The Butterfly model was used to help explain how the RER network had integrated with other infrastructure and if land use around those stations corresponded with the connectivity of the transportation network. This study found that the advantage of using these types of models is their ability to compare nodes to each other, assessing “relative functioning of nodes…instead of absolute accessibility”. (Caset et al., 2018, p. 521) Analysing nodes in a vacuum is less useful for understanding how a project has succeeded or failed, as it lacks comparison with other similar projects. Various metrics that are typically used to analyse success of TOD, including increased transit ridership or increased population, are less meaningful in isolation, and more useful to developers and city officials when put in context with other similar development attempts. This research also led to the development of 7 cluster typologies of the 144 stations analysed in the network, which became a useful quick comparison tool when exploring how the different metrics and parts of the wings affected the success of the node overall. Some of the cluster types included “unbalanced large nodes” with low density scores but high design scores and transportation scores, and “high density stations” with very high-density scores but variable scores on other categories. Each of these categories was named based on what the researchers decided was the major pain point of the station. For the unbalanced large nodes, they have advantageous design and good transit connectivity, but they don’t have the matching high population to take advantage of the design and public transit access, visually showing an obvious area for improvement of the node. By categorizing stations into these typologies, it is easier to come up with a plan or assessment for groups of stations or corridors. (Caset et al., 2018)

In New Zealand, the Butterfly model was reviewed as a decision support tool in the New Zealand context to see if it could be useful for policymakers. They worked to apply the model at three levels of planning: station, corridor, and strategic. Primarily used at the station level, the wings were the same for each level and showed some promise in understanding the broader levels as well. However, one of the main concerns with the New Zealand case was the indicators and how they might need to be adjusted to better reflect conditions at stations. One of the biggest differences between the Netherlands and New Zealand is that the Netherlands has substantially more safe bike infrastructure, whereas New Zealand’s active transport metrics had to be adjusted to only include safe bike paths, which are far less prevalent. The wings would also benefit from adjustment when trying to conceptualize clusters of stations at the corridor and regional level. This study concluded that the butterfly model could prove very useful in understanding the relationship between the transport network and land use and offer insight for future planning endeavours focused on decarbonizing transport, and creating synergistic and integrated plans. (Pretorius, 2021)

2.6 Conceptual Framework

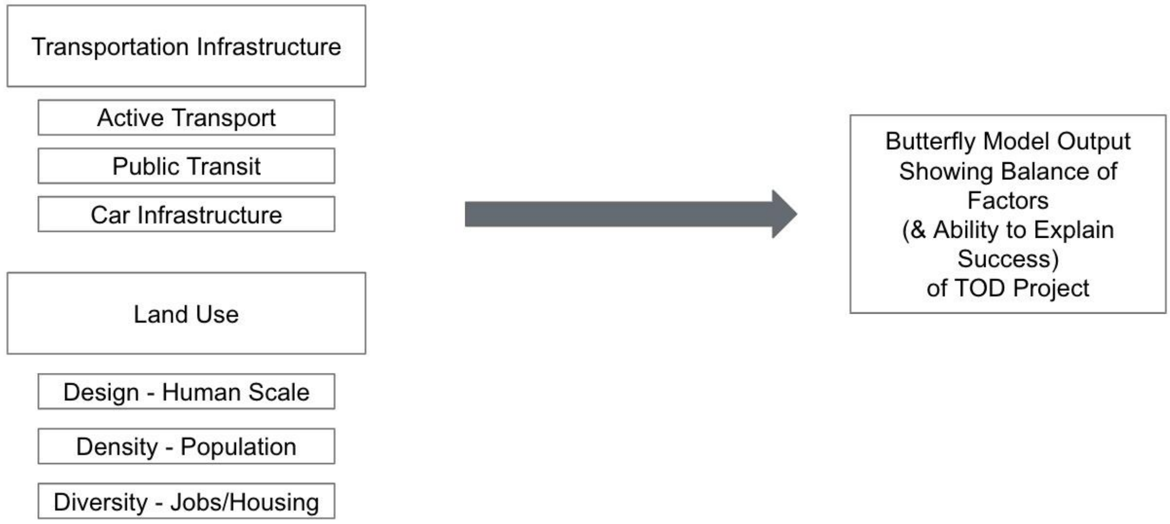

Figure 2: Conceptual framework outlining the factors in the Butterfly model.

3: Research design & methodology

3.1 Introduction

This chapter will explain the type of study and methodology used to evaluate the research question. Data collection methods and evaluation criteria will be explained, and an operationalization table will be provided as an overview of how the collected data informed the test of the model and helped achieve the research objectives.

3.2 Research Type & Strategy Justification

This is an explanatory study examining if the balance between transportation factors and land use factors is a useful way of explaining success or failure of a TOD project. Secondarily, this study also explores the Dutch butterfly model's ability to capture, measure, and explain success in a United States context. This is a mixed methods study, primarily using quantitative data to inform the indicators of the model and evaluate them. Advantages of using and testing a model as a research method include being able to understand which factors have the strongest impact on the outcome, the ability to use the model to predict different scenarios, the opportunity to adjust the parameters and settings of the model to increase flexibility, and the ability to repeat the study using new data to feed into the model. (Bryman & Bell, 2015)

Additionally, two semi-structured interviews were conducted with TOD professionals to gain a more nuanced understanding of the conditions for success of TOD and gain perspective from insiders on the decision-making process for developing and prioritizing different projects. Semi-structured interviews over a video conferencing platform are an invaluable tool for getting expert perspectives from anywhere in the world, while also ensuring the participants are comfortable in their chosen location. Conducting interviews virtually also takes less time and financial resources, making the interview process more flexible and accessible for both researchers and participants. (Lo lacano et al., 2016) Additionally, semi-structured interviews are the best interview type for this information, as it is best to incorporate the perspectives of the interviewees as context-bound and subjective, and while the data from these interviews is not necessarily generalizable, it is useful for adding specific context to the case study. (Nathan et al., 2019) In this case purposive interviewing was used as selecting individuals with special knowledge and experience related to the topic offers more useful information than a wider interview strategy. (Palinkas et al., 2016) The specific mixed methods of a model and case study mean that there is not a wide pool of potential interviewees, so interviewing a couple of key informants is more ideal.

Mixing these methods is advantageous in multiple ways for answering these research questions. Collecting both qualitative and quantitative data allows for a more nuanced understanding of the topics, helps evaluate both the process and outcome of both the use of the model and the real-world decision-making process, and adds greater context to the conclusions reached from each method individually, allowing for integration and a stronger conclusion. (Creswell & Creswell, 2018)

The case study of 9 geographically co-located stations was used for testing the model. Using a case study will help narrow the focus of the paper and is recognized as a powerful tool when attempting to build and test a new theory, due to its flexibility and capturing of nuanced details of a situation. (Ebneyamini & Maghadam, 2018) The case study also provides a real-life framework for testing and investigating a phenomenon with many variables, which is helpful for explaining the complexity of many urban planning problems. (Yin, 2003) Having all 9 stations be a part of the case study is important, as they have many similarities but also enough differences to observe potential pattern matching in the analysis of the model, allowing for a balanced test of the model itself. (Yin, 2003) Case studies allow for better gathering of real-world information on a theoretical idea and help the development of more complex theories based on these realities. (McCutchen & Meredith, 1993)

3.3 Data Collection Methods

Evaluating and interpreting the output of the Butterfly model when applied to each of the 9 case study stations was the primary methodology for this research. To inform each of the 6 points of the wings on the model, multiple indicators were evaluated and aggregated into scores from 1-10, using Excel to aggregate the indicators into scores.

Indicators were primarily based on the RER study done on transit nodes in Brussels, Belgium. This is the most robust and detailed use of the butterfly model yet and provided the most nuanced scores and insight for each of the wings. Initial analysis was done based on the same indicators used in this study, excluding the additional factors added that were specific to the Belgian case data (closeness and betweenness centrality) to test the model in its current state. Consideration was given to whether each indicator was useful in evaluating the nodes in the US context.

Indicator & Source Table

Dimension	Indicators	Source
Active Travel	• Number of bike racks • Presence of bike share/scooter share (Yes or no) • Location of station along network of established walking/biking paths (Yes or no)	• Open Street Maps GIS analysis (OpenStreetMaps Contributors, 2023 (OpenStreetMaps Tiles, 2023) • Bikeshare data (USDOT, 2023) • (Bike Arlington, 2021) • (Bike Fairfax, 2023) • WMATA station data (WMATA, 2023)
Public Transport	• Number of end stations reachable by train • Number of trains serving the station • Number of stations reachable within 20 min of travel • Number of bus lines	• WMATA station data (WMATA, 2023) • Open Street Maps GIS analysis (OpenStreetMaps Contributors, 2023 (OpenStreetMaps Tiles, 2023)
Car/Road	• Number of parking spots • Presence of car sharing service pick up point (Yes or no) • Road network distance to the closest highway access (ft)	• Open Street Maps GIS analysis (OpenStreetMaps Contributors, 2023 (OpenStreetMaps

	● Total length of structural roads within the catchment area (ft)	Tiles, 2023) ● WMATA station data (WMATA, 2023)
Design	● Pedestrian shed ratio of catchment area ● Number of street network intersections within 3 or more links in the catchment area ● Transversable network length (ft)	● Open Street Maps GIS analysis (OpenStreetMaps Contributors, 2023 (OpenStreetMaps Tiles, 2023) ● WMATA station data (WMATA, 2023) ● WMATA Ped Shed Report (WMATA, 2015)
Density	● Number of residents within catchment area ● Number of workers in services and administration within catchment area ● Number of workers in retail, hotel, and catering within catchment area ● Number of workers in industry and distribution within catchment area ● Number of workers within education, health and culture in catchment area	● American Community Survey data by % of census tract in half mile buffer (U.S. Census Bureau, 2021)
Diversity	● Degree of functional mix (jobs/housing balance)	● American Community Survey data by % of census tract in half mile buffer (U.S. Census Bureau, 2021)

Table 1: Indicators based on Belgian case study. (Caset et al., 2018)

The butterfly models generated through this analysis are a representation of the balance between the transportation infrastructure and land use factors. The results produced through building these models are like those seen in other studies using this model. While the factors are adjusted slightly for the US context and different availability of data, the general output is comparable to other instances of this model.

The core component of analysing these models is understanding the meaning of how the different factors balance and relate to each other for each node. The most important factors are the two middle points on the "wings" - public transportation for the left and density on the right. The stronger these factors are and the more in balance they are with one another, the stronger the node, the more successful future development will be and the more likely previous development was successful.

The optimal outcome is developing the stations further while keeping the wings as balanced as possible to ensure new development is adequately used, and an increase in residents and employment opportunities develops in congruence with the mobility network. Additionally, it is interesting and meaningful to analyse each of the 6 points of the model outside of the balance relationship, to understand particularities, strengths and weaknesses of the node in more detail.

To feed the model with appropriate data, data collection included aggregating data from various sources. GIS and Open Street Map data helped inform indicators across the model, including bike share presence, structural road and transversable network length, and number of intersections present. The Quick Open Street Map layers tool made identifying roads and walking paths within a half mile buffer measurable with GIS's built in distance measuring tools. The WMATA website and Open Data Virginia informed each of the public transit indicators, bike parking capacity, and car parking capacity. To get the number of trains serving the station, averages were taken with the publicly available WMATA timetables. For simplicity, the Monday-Thursday train schedules were used to avoid variability with adjusted weekend schedules. For the demographic factors in the density and diversity indicators, totals for each station were compiled using percentages of each census tract that fell within the half mile buffer. Each percentage of each census tract that fell within the buffer zone was the percentage of that census data which was then aggregated into totals for each station. To create the models, each indicator group was normalized with z scores to be comparable, and then given a score from 0-100 which was then reduced to a score out of 10 for simplicity when graphing the models. This is the same normalization and data combination used in the Belgian use of this model (Caset et al., 2018)

Additionally, interviews were conducted with two industry professionals. First, Jamie Carrington is currently a Supervisory Program and Management Analyst at the DC Department of Transportation. In his current position he manages a team of bus planners improving bus lane and transit signal prioritization. Previously, he worked for WMATA to help develop Smart TOD models to inform TOD decisions. Specifically, these models combined strategic planning principles for TOD with land use decisions around stations. The intent was to provide data-driven reasoning for external stakeholders to pursue different types of transit-oriented development with an understanding of how development would affect the existing community. Jamie's insights on the WMATA model building and the overall relationship between transportation infrastructure and land use are incorporated into the following analysis of the butterfly model results.

Steven Segerlin is the current Director of Real Estate Development & Station Area Planning for WMATA. He is an avid transit-oriented development advocate and is a strong proponent of joint development projects between WMATA and the area city governments to expedite the creation of more and better TOD. He has worked on land use projects all over the world and has worked as an urban planner for multiple organizations. He offers valuable insight on the decision making and prioritization process for developing TOD, as well as general commentary as a long-time member of the field on best practices and ways forward.

3.4 Validity and Reliability

In addition to analysing the results of the butterfly model, it is valuable to concurrently analyse the results of the models developed by WMATA for making these planning decisions. WMATA's Smart TOD metrics are one current tool used by the transit agency and industry professionals to evaluate existing and potential TOD. Each transit station is given an overall score on a matrix of existing TOD and future potential, which is informed by a set of indicators. For the existing evaluation, indicators used include a transit connectivity index that measures the number of trips by transit the average household in a census block group can access through walking, which is considered any bus routes and train stations within a half mile radius of the metro entrance. The higher the score on the index, the more favourable the area around the station is for transit-oriented development. This is in line with the principles of land use and transit connectivity being in balance and the need for a high level of transit connectivity. Additional indicators include the total number of accessible jobs in a 30-minute radius, travel time competitiveness between transit options and driving, density of the population, walk score, car ownership, current transit ridership, and a land use balance score assessing the mix of residential, commercial and mixed-use land.

The future TOD scores are evaluated with a stronger emphasis on land use, with factors including development activity (measured through total rentable building square footage under construction or proposed), office market potential, retail market potential, residential market potential, available vacant land, and the projected growth in the population. Each of these is calculated within the half mile buffer zone of the metro stations. This is the generally accepted radius for American TOD projects as it is the distance most people are willing to walk to a transit stop. (Guerra et al., 2012)

An important is that these models were largely developed using 2015 data and reasoning. While some data was updated over the course of the last 8 years, the models are still based on an older understanding of the system and commuting patterns. Changing commute patterns due to an increase in work from home culture resulting from the Covid-19 pandemic will change the functionality and accuracy of these models going forward. Until new models are developed, however, these tools are the best existing visualizations of aggregated data that can help inform TOD decisions.

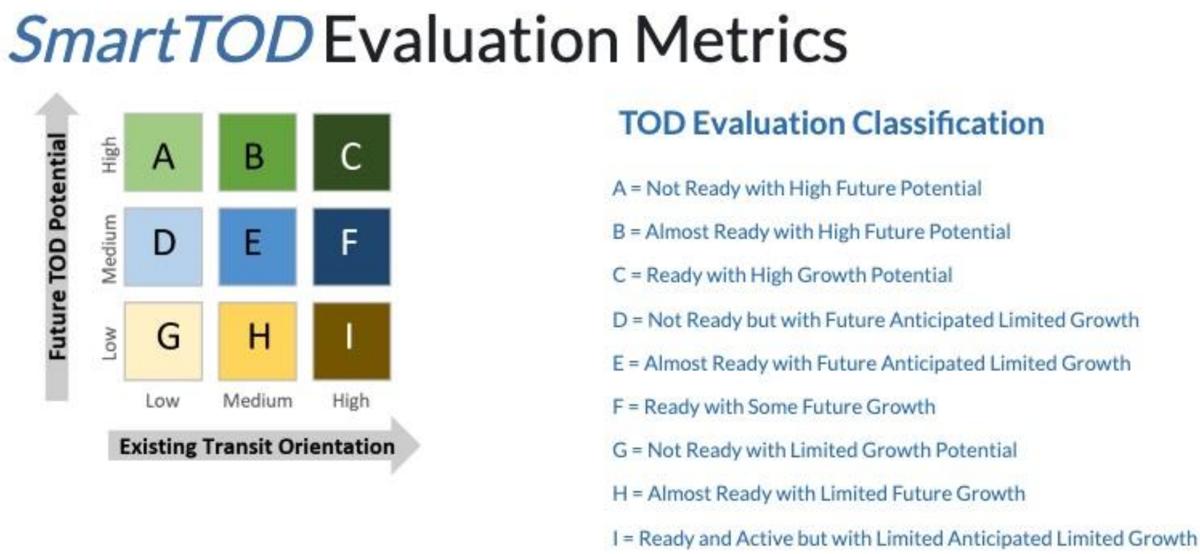

Figure 3: WMATA Smart TOD Model Categorization (Carrington, 2020)

Finally, in the Belgian use case of the butterfly model, stations were grouped into 7 general categories based on the model results. The results are captured here. While the Dutch results are categorized into 12 archetypes dependent on transit system connectivity, the Belgian results are a more generic and widely applicable set of outcomes of the model that can be more easily compared to other places around the world.

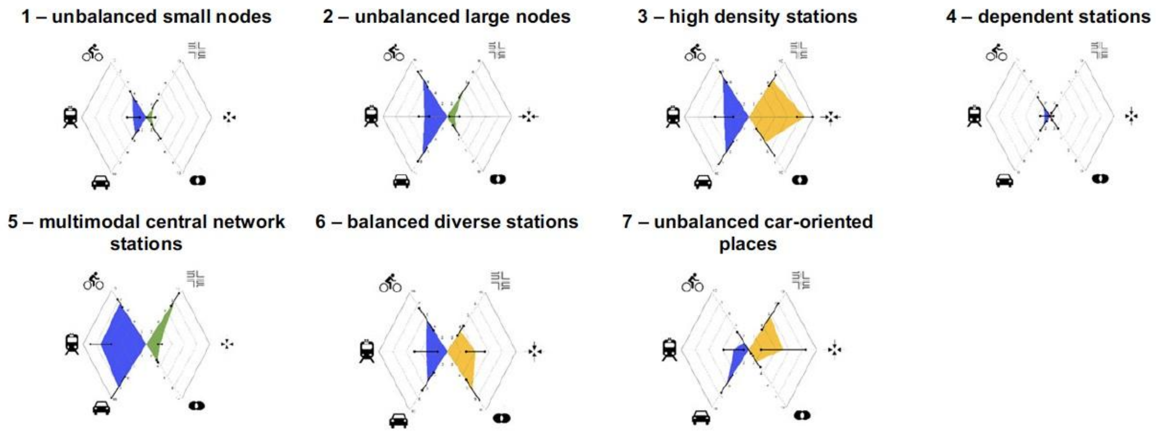

Figure 4: Belgian RER Butterfly model archetypes (Caset et al., 2018)

As another point of comparison, each model result in this study will be compared to the closest compatible interpretation from this Belgian study. Each of the 7 categories identified in the Belgian study show potential variations of balance and imbalance and what each node needs to improve.

Each of the selected case study metro stations will be analysed in chapter 4 through the lens of the history of the development around the station, the WMATA models of the existing and future potential of TOD for the station, and the commentary of the professional interviewees and compared to the results of the butterfly model.

To achieve internal validity, a triangulation of research methods was employed. The model was tested through use of secondary and GIS data, and results are cross referenced with other data sources of success, including a comprehensive literature review of the case study stations' TOD success, and interviews with industry professionals that are familiar with the case study stations and the development projects surrounding them. Together, these methods answer the research question of how accurately the balance between transportation and land use represents TOD success in the American context.

External validity will be achieved through comparing the results of the butterfly model output to other interpretations of success of the case study station areas in literature, seeing how the indicator scores conceptually compare to similar evaluations in the WMATA models, and comparing the outputs to the Belgian use of the butterfly model.

Reliability is achieved through the consistency of the indicators across other uses of this model. By using the same or very similar indicators as other studies, the results of the model will be comparable to other results and the usefulness of the model can be evaluated fairly.

3.5 Limitations

Potential limitations of this research include the lack of inclusion of all potential factors in the model that could explain TOD success and potential. Additionally, while the 9 case study stations were chosen for the type of development that has occurred and their geographical proximity to each other in order to reduce additional factors that may influence results, the study is focused on these stations instead of being a broader analysis of many stations, which might provide further insight into the ability of the model to explain success in other areas of the United States.

3.6 Operationalization Table

Concept/ Variable	Sub-variable	Definition	Indicator	Data Collection Method	Question
Success Factors of US TOD Projects	Balance of factors	The dependency of different factors on each other	Butterfly model results	Inputting secondary and GIS data into model and analyzing results	How can the Dutch butterfly model be applied to the successful TOD project of the Rosslyn-Ballston corridor and other similar projects along the same metro line?
	Transportation Infrastructure	Active Transportation, Public Transit, Car Use	See Indicator Table Above	Secondary and GIS data	
	Land Use	Density, Design, Diversity	See Indicator Table Above	Secondary and GIS data	
Evaluation of TOD	Models	Types of models that are typically used to inform TOD planning (more focus on development strategies, housing market, etc vs. land use and network conditions) and if Butterfly Model is better or a viable alternative	Perception of existing models	Interviews; Inputting secondary and GIS data into model and analyzing results	Are the indicators included in the Dutch model the most appropriate and effective way to employ the model in the US context? How can this tool be useful for decision makers?

Table 2: Operationalization table detailing how each concept will be addressed through this research.

4: Results, analysis and discussion

4.1 Case Study History

The corridor between the Rosslyn and Ballston metro station is considered one of the most successful and prominent examples of transit-oriented development in the United States. (Weaver, 2011) This corridor was and continues to be so successful for a few key reasons. First, the building of the transit line through these areas took political will, so there was already some degree of public and political support for this development. The metro line was originally going to follow the geography of the existing Highway 166, bypassing existing commercial, governmental, and downtown areas. The residents and county board campaigned to get this changed and secured the new plan to run the metro line through these mixed-use areas, simultaneously protecting the single-family zoning around the highway and providing better access to the already busier areas that were more likely to view new transit access in a positive light.

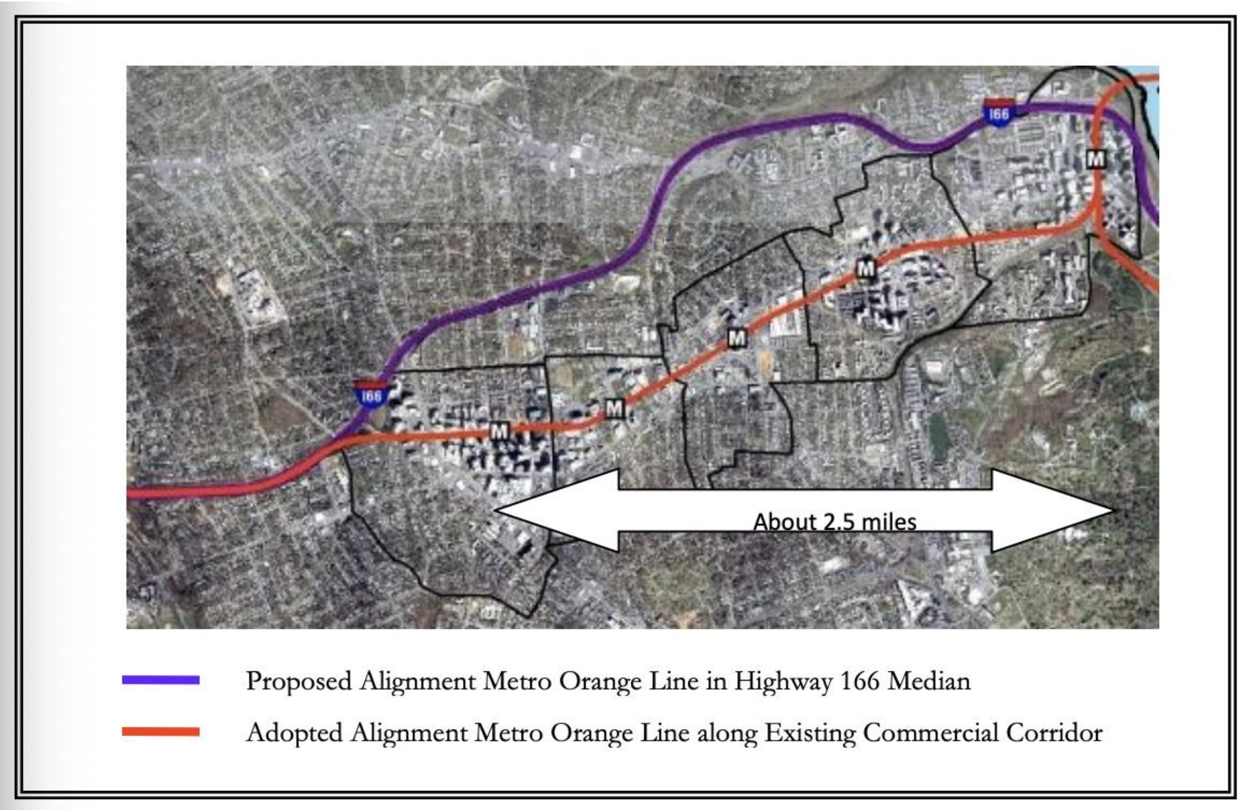

Figure 5: Proposed vs adopted location for Metro orange line (Weaver, 2011)

Once the stations were built, a general land use plan was created for the whole corridor, preserving existing single-family homes while focusing on densifying and creating more mixed use buildings in close proximity to the stations. The development plan for this area was created as a corridor, and followed a general plan known as the bull's eye. Conceptually, the city of Arlington would focus on densifying around the metro stations, and then letting the development taper off into single family homes outside of the walkable buffer zone around the stations. Each station would also have its own special feature or characteristic to justify developing the area as a group as opposed to individual nodes, the more classic way of thinking about transit-oriented development planning. (Calthorpe, 1993)

This was also advantageous as these stations are all within 2.5 miles of each other and developing them all identically could be redundant for residents and employees alike that were able to easily go between each area. This corridor mentality proved to be a vital factor in the success of these developments.

Rosslyn was intended to be a dense commercial center, characterized by high rise office buildings and dense apartments. Courthouse was already home to many county government properties and was thus conceptualized as the governmental and law center. Clarendon was the original downtown area with a higher concentration of commercial and entertainment businesses, and this function was preserved with the prioritization of shops and restaurants in its development plan. Virginia Square was intended to be a center of education and culture. It is home to multiple universities and performing arts centers. There are also multiple parks and recreational spaces to keep residents entertained and able to effectively use the public space. Finally, Ballston was developed to be the "new downtown", following expansion and development west, further from D.C., and providing amenities and density of housing and commercial space to immediate residents around the station, as well as nearby residents in the less densely developed southern and western parts of Arlington that are mostly residing in single family homes. Ballston is also one of the most important technology and research centers in the United States, with multiple national research institutions and the Marymount University campus. (Community Planning, 2023) The idea was to preserve the individual identities of each area while creating a cohesive community. The plan was intentional about land use, ensuring mixed use development was included as well as adequate pedestrian and bicycle infrastructure to provide easy access to the stations to encourage higher ridership. Sector plans for each station were subsequently developed. Success in these development visions has continued because every new development that is proposed must go through a rigorous site plan review process where it is compared to the general land use plan and most recently version of the individual sector plan. Public opinion is also always taken into consideration which has resulted in a high level of community engagement. (Weaver, 2011) This is also a proven method even in today's projects for these stations. Community engagement is employed at all levels of the planning process to ensure development aligns with needs of the community, and any concerns are identified early on. (S. Segerlin, personal communication, June 29, 2023)

Even in the early 1980s as these stations were being built, there was a plan for developing around the stations and taking advantage of the increased density the metro stations would attract. However, planners were cautious of demand management. There was already a recognition that market demand had to match development plans, and demand could not be created out of thin air in sparsely populated areas. (MWCOG, 1983) This is why planners initially focused on Rosslyn to Ballston for development and left East Falls Church to Vienna mostly undeveloped as there was already a higher demand for these first 5 stations as they were closer to D.C. and more attractive for people who lived or spent significant time in the city.

From the 1990s to the present, the development of this corridor has continued to be a success. Populations have grown, office and housing developments have grown and densified, the jobs/housing balance has stayed relatively harmonious, and bike and pedestrian paths have been maintained. An important note is that success in these developments is dynamic. Even in densely developed station areas, improvements are still being made. Maintaining the balance between the land use and mobility networks is crucial for continued success.

The following maps show the zoning changes in the areas between Rosslyn and Ballston from 1990 to 2021.

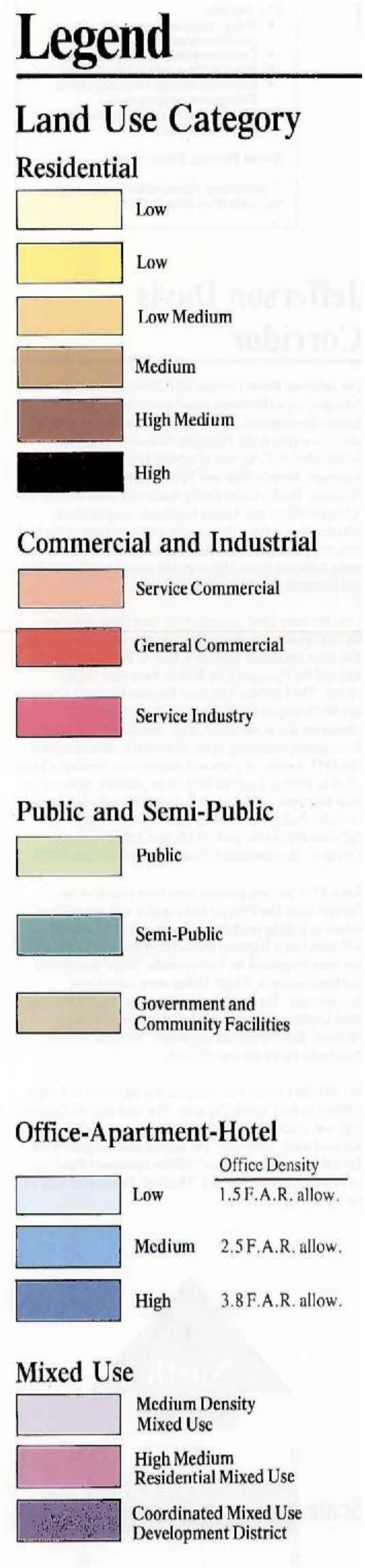

Figure 6: Legend for zoning maps (Community Planning, 2021)

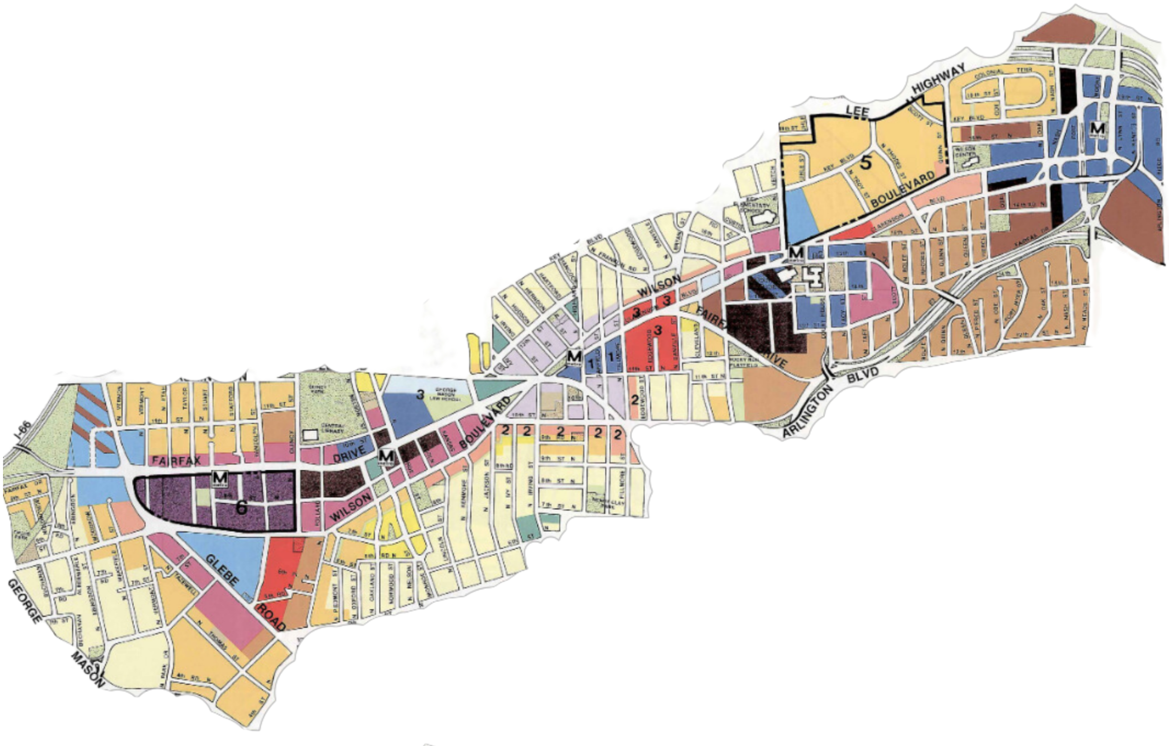

Figure 7: 1990: Primarily low to medium residential zoning, limited high medium residential mixed use development. (Community Planning, 2021)

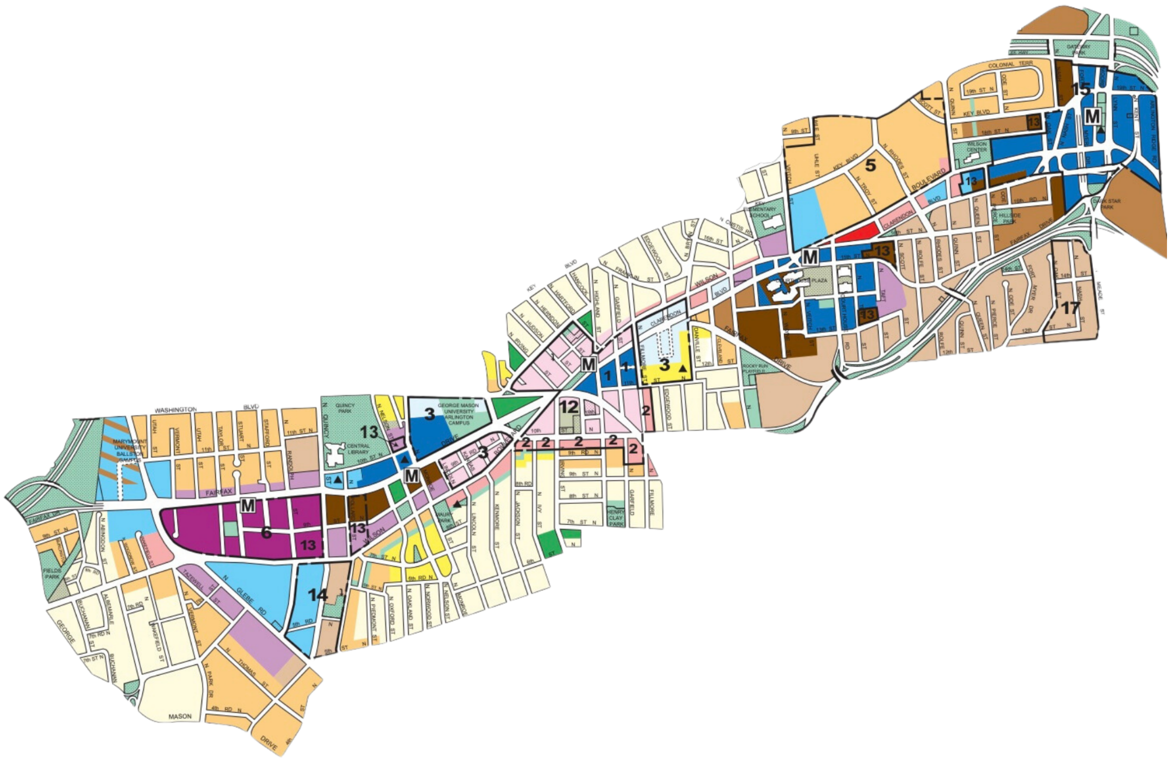

Figure 8: 2004: Some high medium residential mixed use developed into coordinated mixed use. Some commercial zoning converted to residential and office space. (Community Planning, 2021)

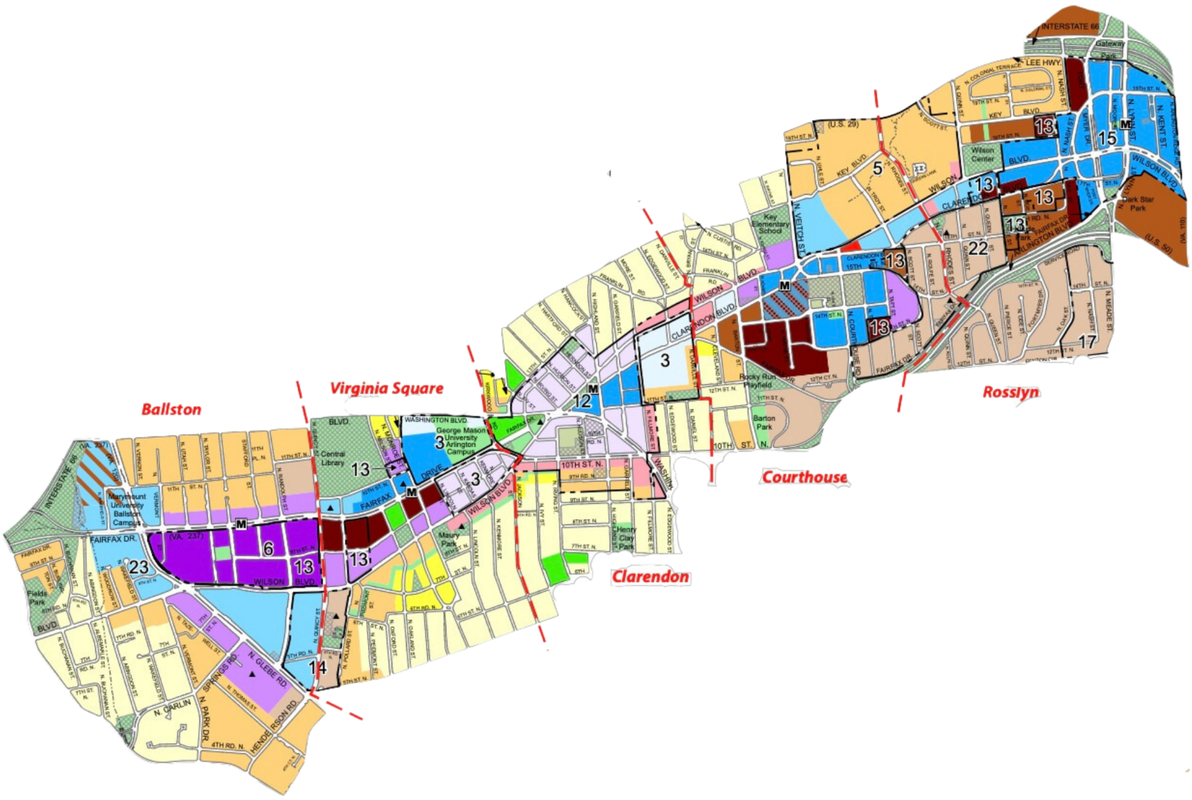

Figure 9: 2013: Introduction of more public space, more office and mixed use zoning. (Community Planning, 2021)

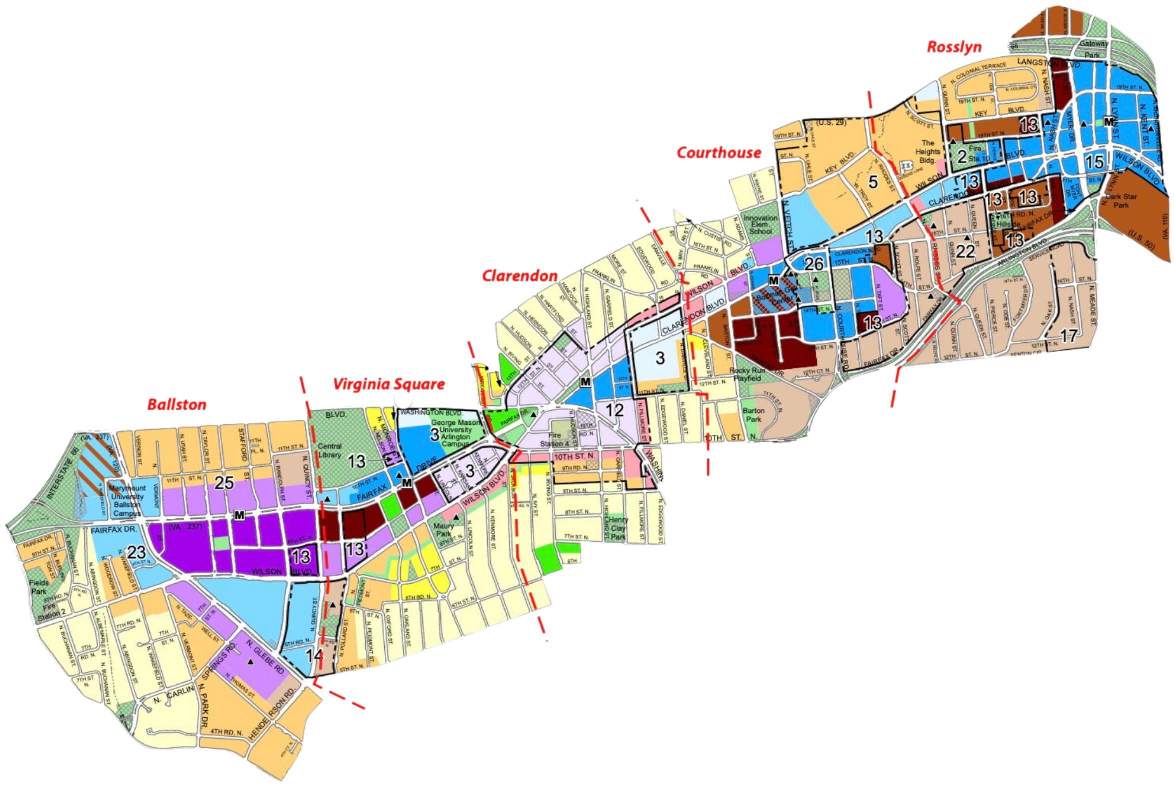

Figure 10: 2021: Some of the lower density residential areas converted to medium or higher density residential and mixed use. (Community Planning, 2021)

Over time, the corridor has seen an increase in mixed use zoning, which has helped develop the areas optimally for transit-oriented development.

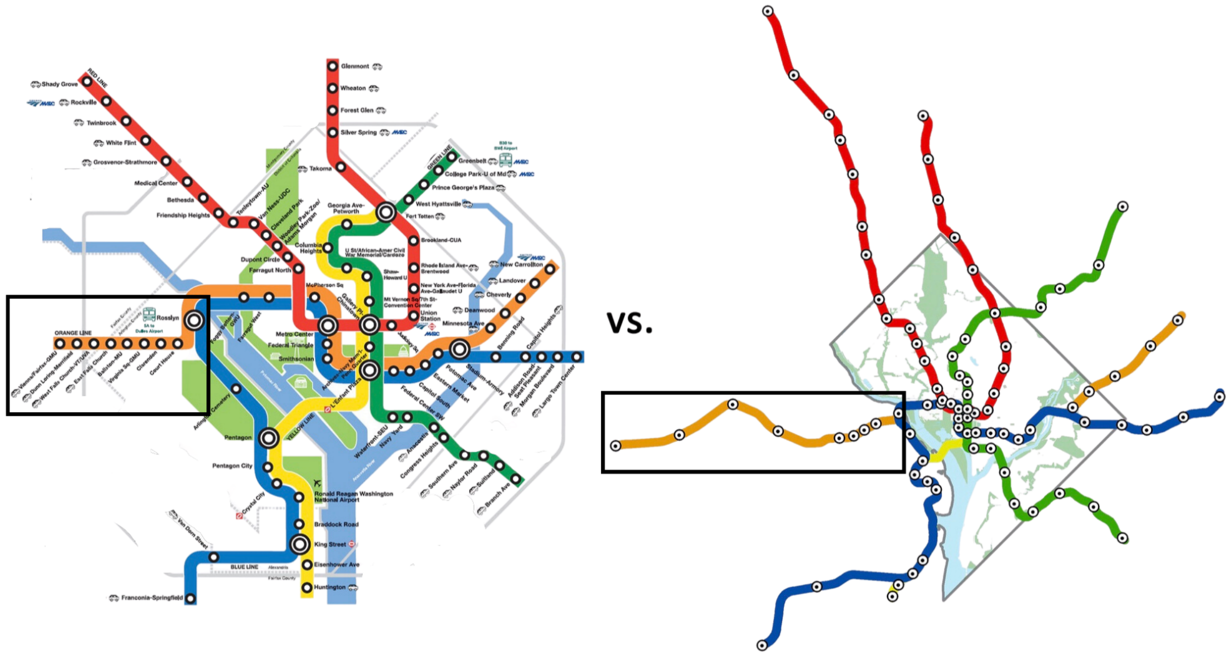

Figure 11: Location of case study stations in relation to entire Washington D.C. metro system (Whiteside, 2009)

In context of the larger system, these 9 metro stations included in this study are the portion of the orange line that extends into Northern Virginia. On the classic metro map, they appear to be all very close to each other, but when they are mapped at a geographically accurate distance, it is easy to see that the first 5 are much closer together and then the remaining 4 are more spread out. The remaining 4 stations from East Falls Church to Vienna have seen some growth and development over time, but have not enjoyed the same level of connectivity, planning, and forethought as Rosslyn to Ballston. They are farther from D.C. and from each other compared to the Rosslyn-Ballston corridor and have far more single-family homes close to the station, making denser development less attractive for developers and current residents. For this reason, they make an interesting comparison when developing TOD models to see if the model can accurately capture different conditions.

4.2 Station Results

Each of the 9 case study stations will be evaluated in the following section. First, the context of the intentions of the local government's plan for developing that station area, and then the detailed results of the butterfly model for that station are presented. Finally, a comparison of the butterfly model results to the WMATA models to evaluate the validity of the butterfly model with the previously evaluated conditions of the station and a comparison to the Belgian study's 7 archetypes to put these results into context with other international uses of the model are included.

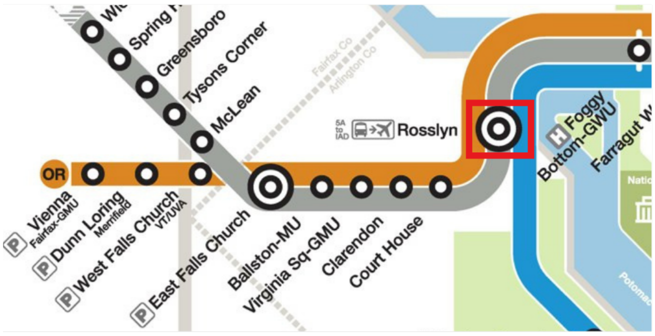

Figure 12: Rosslyn location (WMATA, 2022)

1) Rosslyn

The Rosslyn metro station is part of the Rosslyn-Ballston corridor, considered to be one of the most successful transit-oriented developments in the United States. (Jennings, 2014) The area around the Rosslyn station is centrally located, seeing as it is the first metro station across the Potomac River from Washington D.C., meaning that its residents enjoy easy access to the larger city while still being near the rest of the Virginia corridor.

Rosslyn's role in the corridor was to be the office and business centre, strategically taking on the more job heavy role as the station closest to DC and most centrally located for commuters from both Virginia and D.C. Its 8 million square feet of commercial office space solidified its position in the corridor as a job hub, in addition to being a jumping off point for access to natural areas with its proximity to large parks and landmarks. (Arlington County Board, 2015) Rosslyn has continued to develop in a compact way, with zoning favourable to dense development near the metro station.

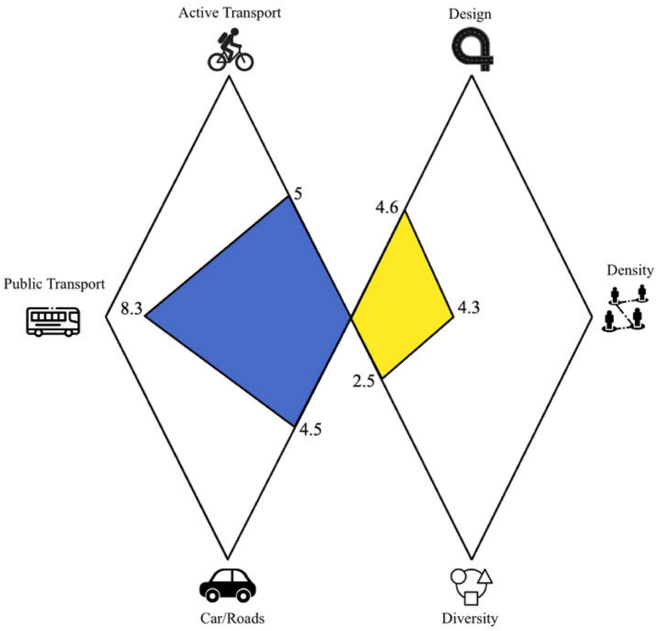

Figure 13: Rosslyn Butterfly model

Within the butterfly model, Rosslyn is a partially balanced station. Each of the scores for the 6 prongs is out of a possible 10 points and compared against the other 8 stations. The model accurately reflects a high transit connectivity score of 8.3, with average active travel presence of a 5, consistent with the general lack of strong bike and pedestrian infrastructure in this region of the United States but the strong transit access at this node being the closest to D.C. and connected to 3 metro lines and the highest number of stations reachable within 20 minutes (40) out of the 9 case study sessions.

It is well connected to the road network but lacks car parking capacity, and is not located directly near a highway, meaning that the transit access part of the transportation wing is much stronger than the other two factors. On the land use side, Rosslyn has one of the more middle scores for design, with part of the half mile buffer around the station extending into the Potomac River, there are fewer walkable areas and intersections. The diversity score is low compared to the other stations, due to a jobs/housing balance that has significantly more housing than jobs, which is interesting given the intention of development around this station was as an office center. It was also advantageous for developers to build large amounts of housing near the station due to its proximity to D.C., as it was seen as an attractive and more affordable option to live right across the river. (Parris, 1989)

The dense urban core around the station is reflected in the moderate density score, but again is not as high as some of the other stations due to a smaller inhabited radius of data.

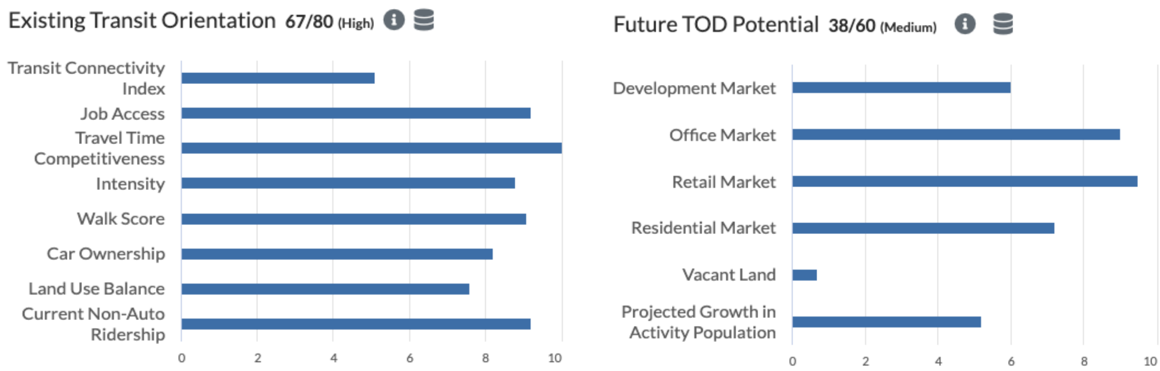

Figure 14: WMATA Smart TOD model results for Rosslyn (Carrington, 2022)

The WMATA model shows a rosier picture of Rosslyn, reflecting both the existing conditions and readiness for growth. Currently Rosslyn is considered ready with existing successful TOD and also has some future growth potential. This model reflects particular factors that make Rosslyn such a shining example of TOD, including high scores for land use balance, job access, and travel time competitiveness. The high intensity, walk score, and job access metrics are similar to the population density, job housing balance, and pedestrian walk shed metrics used to inform the butterfly model. High scores in both models indicate validity of the butterfly model as a way to represent this information, however, the land use balance in the WMATA model and diversity of land use score in the butterfly differ greatly, indicating a potential inability of the butterfly model to capture this element accurately.

The overall balance is relatively preferable and reflects a similar situation to the multimodal central network stations scenario identified in the Belgian case study. It is the most centrally located station of the 9, has access to many modes of mobility, is densely developed and populated, and is well designed to allow for potential further development.

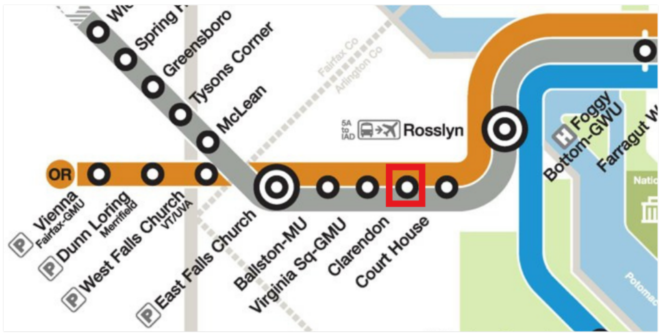

Figure 15: Clarendon location (WMATA, 2022)

2) Clarendon

The Clarendon station is the third station from D.C. in the Rosslyn-Ballston corridor. In the corridor planning it was referred to as the "urban village", or a place where people of all "income levels, ages, and household makeups can walk to home, work, shop, and play. (Clarendon Task Force, 2006) Clarendon was intended as a destination for delight and play in addition to just building out more access to housing and jobs. Clarendon was also historically the downtown area for the whole city of Arlington, has some older buildings that are historically protected, and thus slightly different zoning than other locations along the corridor. The development goals included preserving access to public space while improving housing availability and quality and taking advantage of the high level of accessibility to public transportation options.

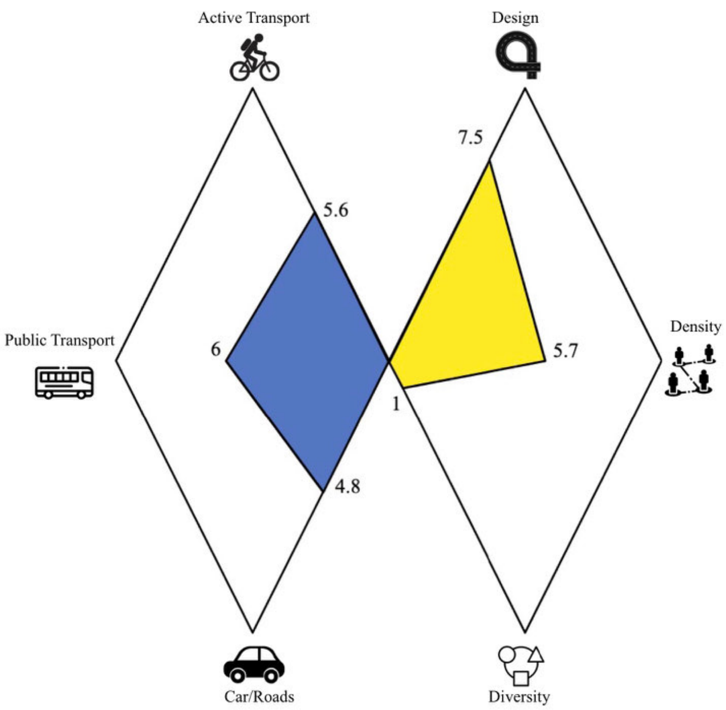

Figure 16: Clarendon Butterfly model

Within the butterfly model, Clarendon's results are similar to Rosslyn's except without as high scores for public transit, and a much higher design score. These differences are explained by Clarendon in comparison being less of a major transit hub for commuters than Rosslyn as it is further into Virginia and only connected to 2 metro lines, and has comparatively fewer job opportunities. The design score is higher as the street network is more complete and denser than in Rosslyn, due to the careful planning and thoughtful creation and preservation of the network surrounding open and community spaces with dense housing. Clarendon has balance between the public transit and density prongs, which are the two most important factors to be in balance according to the creators of the model. The diversity score is the lowest of the 9 stations due to a high amount of housing and comparatively far fewer job opportunities.

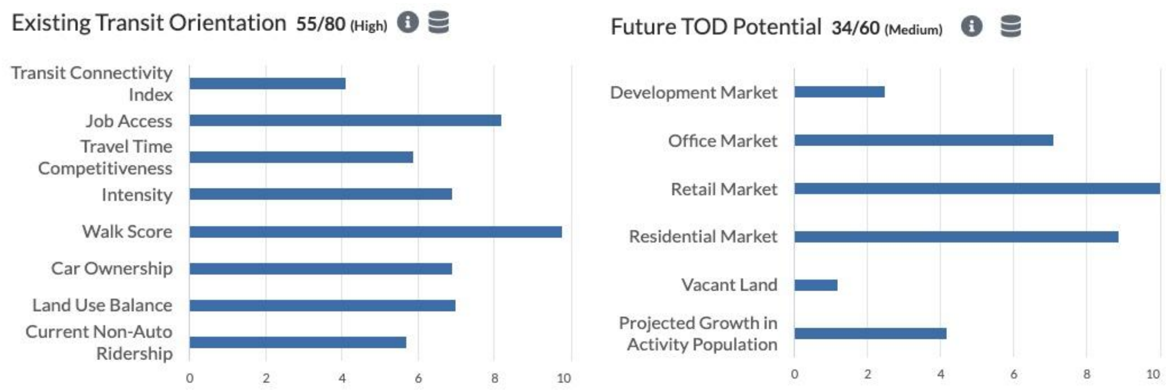

Figure 17: WMATA Smart TOD model results for Clarendon (Carrington, 2022)

This development was largely successful, and this success is captured well and consistently in both the existing and future models created under WMATA as well as the butterfly model. Clarendon is already developed but is ready and still has some potential for growth and improvement. This is particularly reflected in the extremely high walk score and job access scores for the existing evaluation, and the high potential for retail development in the future model. The potential for residential development is also aligned with the historical goals of improving housing access.

The model results are also like the Belgian high density station model, reflecting a slightly lower access to transit with a high population density. This is reflective of its known and heralded success as a transit-oriented development example, as the population has continued to increase as the development and improvements of the station have attracted more residents.

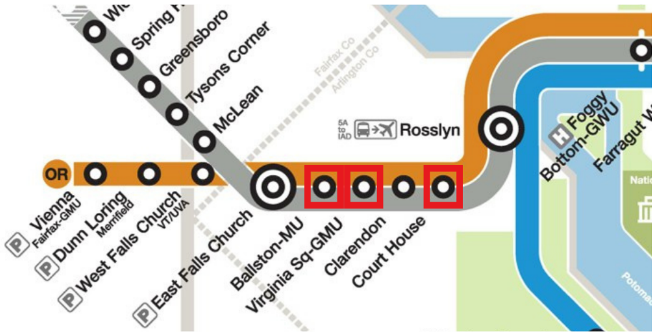

Figure 18: Court House, Virginia Square, Ballston locations (WMATA, 2022)

3) Court House, Virginia Square, Ballston

Court House's intended role was the governmental activity center. With the presence of the actual court house, police department, and public plaza, housing and commercial projects that were built around the area help ensure that the space is functionally mixed, and provides a beautiful gathering place for residents, employees, and visitors alike. Virginia Square is home to multiple college campuses and was intended to be the educational and cultural center of the corridor. Ballston was intended to be the new downtown for further areas around Arlington as well as the science and technology center for the corridor.

Each of these stations is in very close proximity to other stations in the corridor, meaning that they share similar access to transit, cycling, and car infrastructure.

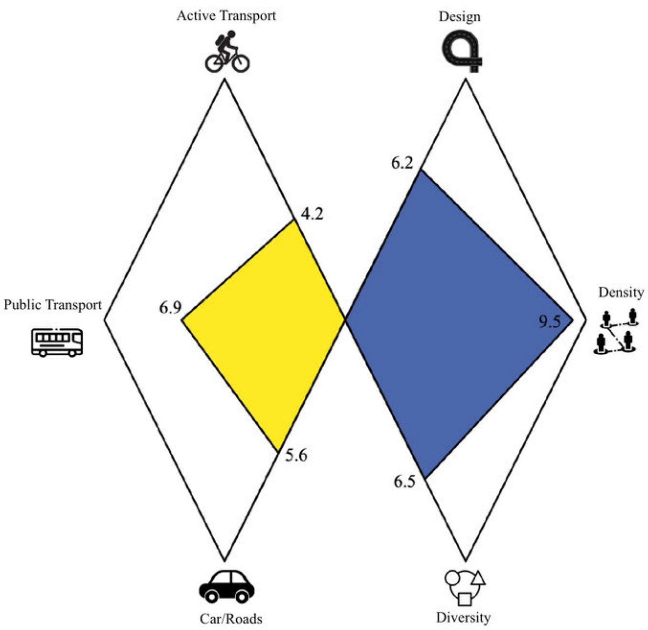

Figure 19: Court House Butterfly model

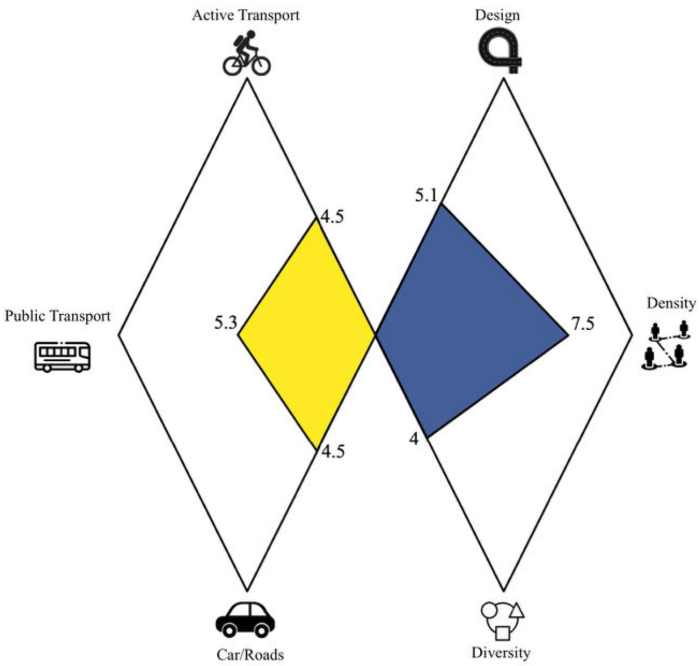

Figure 20: Ballston Butterfly model

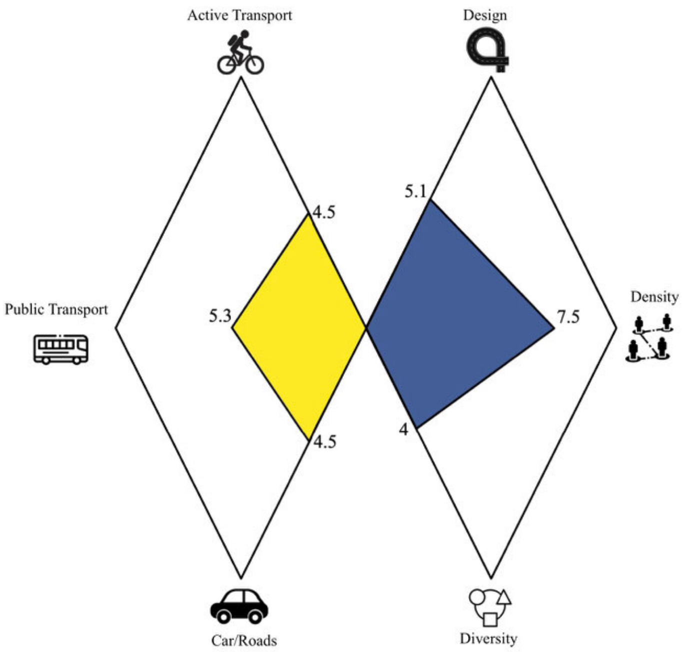

Figure 21: Virginia Square Butterfly model

These three stations ended up with similar butterfly model results and thus can be analysed in tandem. While they each have different purposes, they share similar characteristics in that each node has a main job function that attracts employees and particular residents - Court House's government facilities, Virginia Square's entertainment venues, and Ballston's science and technology centers. None of these stations have direct access to a highway, or any car parking capacity, but they share a high-density road network, frequent and reliable transit services, access to bike share and car share, and some bike parking capacity. For the land use wing, each of these stations scores very highly. While Court House has the highest scores of the three, they share similar characteristics, including access to a dense, well-connected street and walking path network, a variety of jobs, a large population, a favourable jobs and housing balance. Notably, Court House has by far the highest residential population of the 9 stations, which indicates that a large amount of housing was built around the area, due to its intended role as the governmental centre. Many of the governmental buildings already were in place, leaving the rest of the land open for developing into housing. The scores for all three models mean that Court House, Virginia Square and Ballston are relatively well balanced, and this is in line with the success of the development projects that have occurred there and the successful development of the corridor TOD overall. Density is a crucial aspect of making TOD worth the investment as enough people are needed to generate tax value to pay for denser street grids and other amenities. (S. Segerlin, personal communication, June 29, 2023)

Collectively, the high density of these stations combined with their moderate to high transit scores make them the most balanced of the 9 and the best examples of success within the context of the model.

Court House

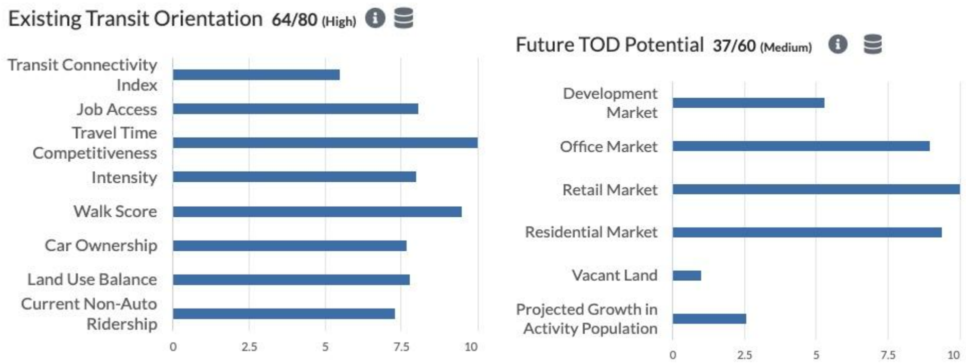

Figure 22: WMATA Smart TOD model results for Court House (Carrington, 2022)

Figure 23: WMATA Smart TOD model results for Ballston (Carrington, 2022)

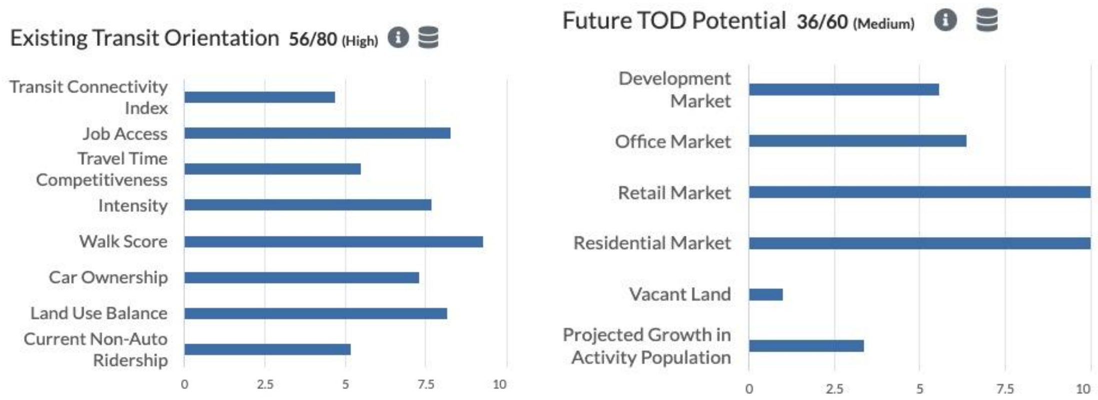

Figure 24: WMATA Smart TOD model results for Virginia Square (Carrington, 2022)

This balance is also reflected in the WMATA models. Each of the stations is considered an already successful development but are still ready for more potential growth. These three stations score particularly high on travel time competitiveness, meaning that walking or taking transit are an ideal transportation method compared to driving for residents of these areas. Dense development was and continues to be effective, eliminating the need for a car to commute or complete day to day tasks. They are already densely populated and developed, however, meaning they score low on vacant land availability which will naturally limit future growth and potential.

When comparing results to the Belgian study, these three stations are the most similar to the high-density station category. Having a more developed right land use wing with some of the transportation factors on the left lacking, yet with an overall balance between the two wings leaves room for improvement while reflecting the observed success of the areas.

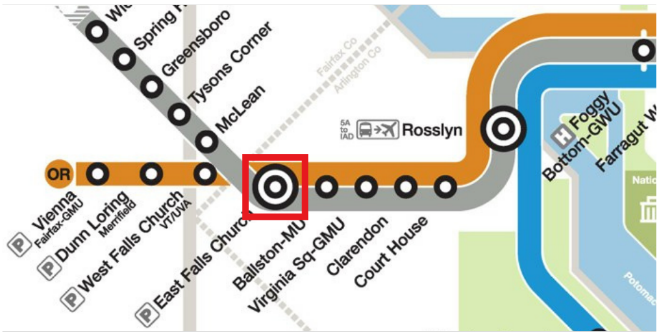

Figure 25: East Falls Church location (WMATA, 2022)

4) East Falls Church

East Falls Church is the next station beyond the developed Rosslyn to Ballston corridor. While it is still geographically located close to Ballston and its residents share similar demographics, this station was not included in the bull's eye development plan and thus has not experienced the same level of investment and growth as the previous five. However, it is located on the same metro lines, shares similar bus access, and scores higher than the core 5 stations above on cycling and parking infrastructure. Compared to the 1990s investment period for Rosslyn-Ballston, East Falls Church's development plan was created in

2011, with a call for more mixed-use development with an emphasis on walkability and livability. (WMATA, 2011)

While East Falls Church also has a significantly higher amount of single-family home zoning than the Rosslyn to Ballston corridor, it also has a couple of large, well-maintained parks, and a high level of bicycle path connectivity. Residents enjoy a high level of physical activity, and there is a high level of desire for increased development that would make walking and cycling to destinations easier and a more preferred means of transportation.

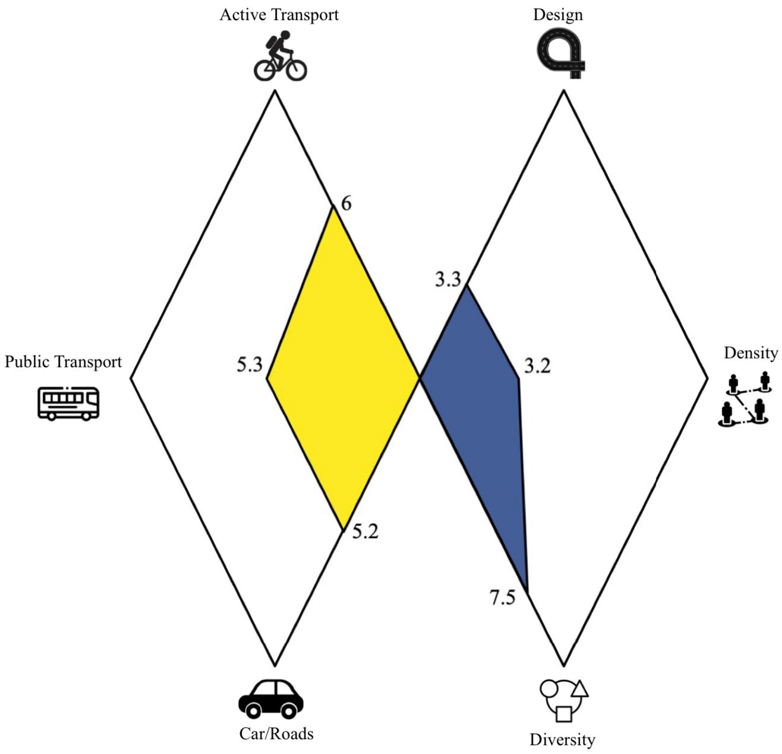

Figure 26: East Falls Church Butterfly model

In the butterfly model, East Falls Church scores moderately on the transportation wing. It shares the same metro train connectivity as the previous 5 stations, serving as the final transfer point between the orange and silver lines. A major difference is a substantially higher amount of bike parking capacity, which evidently was used almost to its entirety every day pre-pandemic. (WMATA, 2011) What sets East Falls Church apart from the previous 5 stations in the butterfly model results is the land use wing, however. There are substantially fewer people living in the area around this station, which aligns with the lack of similar existing transit-oriented development. However, it also means that since the 2011 plan for East Falls Church was created, there has not been substantial progress in building more dense housing around the station. Similarly, there are objectively fewer jobs located in the direct area than Rosslyn to Ballston, but in proportion to the residents there are many employees, leading to a high jobs/housing balance for the third point on the wing. Due to the moderate levels of transportation infrastructure and the partially lacking and imbalanced land use factors, the model for East Falls Church is far less balanced between the two wings than the five previous stations.

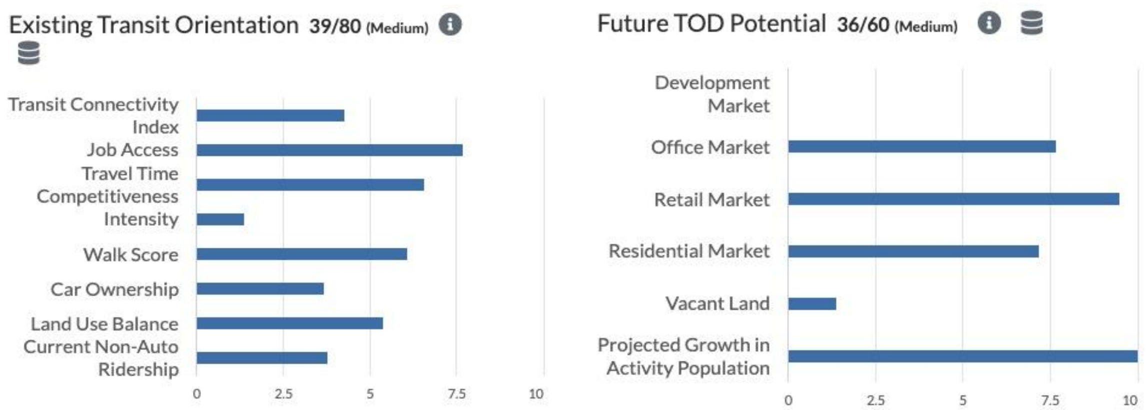

Figure 27: WMATA Smart TOD model results for East Falls Church (Carrington, 2022)

In the WMATA existing and future models, East Falls Church is considered “almost ready but with future anticipated limited growth”. While the job access metric is strong, allowing residents access to over 750,000 jobs within 30 minutes of travel time, the rest of the indicators are moderate at best. The land use balance measuring mixed use, commercial and residential land use within a half mile of the metro station is 0.54, meaning in the context of all the other stations, this station is right in the middle for land use diversity. Notably for the future potential, the development market scored a zero, meaning that there is zero “total rentable building square footage under construction, under renovation, and/or proposed around” the area. Having available area to develop is crucial when considering the scale and type of future construction that can occur in an area. It also scores low on the vacant land metric, meaning that any significant development that would occur would likely involve destruction of existing buildings and rezoning. Limited growth opportunities also mean that stations that are rated in this category are less likely to be candidates for more immediate investment.

When comparing the butterfly model output to the Belgian case study, the closest analogue would be the result for the “unbalanced small node” or “unbalanced large node”. The transportation wing is adequate but the land use wing is lacking, which aligns with the WMATA model’s assessment of the necessary connectivity infrastructure being there with room for improvement of the land use and development potential factors.

Figure 28: West Falls Church & Dunn Loring locations (WMATA, 2022)

5) West Falls Church & Dunn Loring

West Falls Church and Dunn Loring are the third and second to last stations on the orange line. Together they provide access points to the metro system from increasingly more suburban areas the farther the cities are from Washington D.C..

The differentiating factor with these two stations is they have slightly less access to transit options as they only have one metro line running through them. Additionally, these two stations do not share the same access to parks and green space as East Falls Church. Positively, there is a larger commercial development space around Dunn Loring known as the Mosaic District that is slowly becoming a popular gathering place and attracting investment to the area. Negatively, West Falls Church is the site of a WMATA rail yard, meaning that the area surrounding the station is naturally more industrial and there is less available space for development. The already built out commercial development of the Mosaic District puts Dunn Loring in a similar position, as it is already developed to some degree and would not make the most promising candidate for immediate intervention.

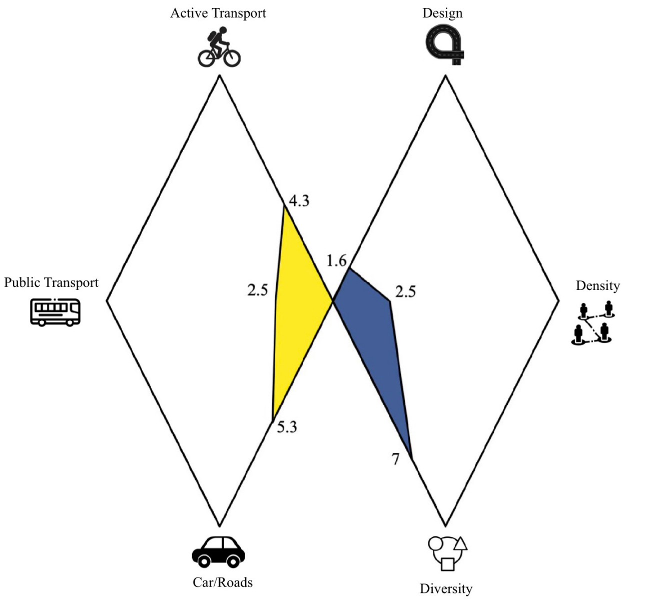

Figure 29: West Falls Church Butterfly model

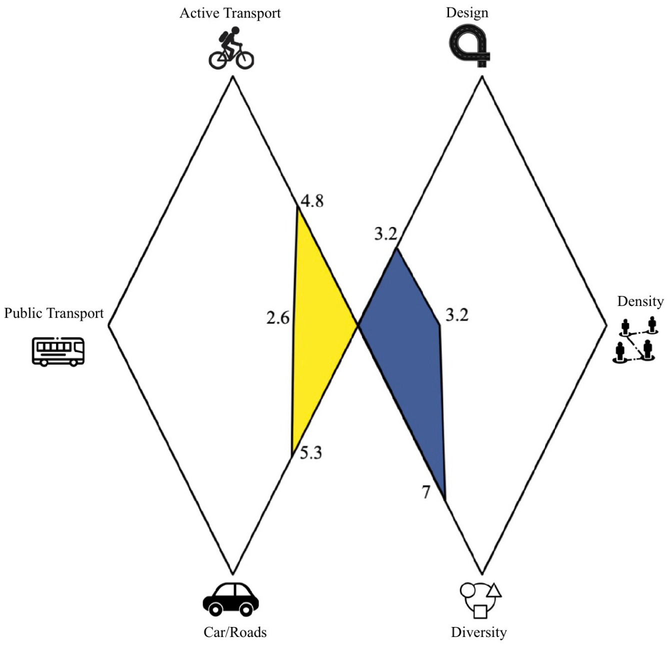

Figure 30: Dunn Loring Butterfly model

On the butterfly model, both stations have higher than average road access, with moderate road network designs surrounding the station in the immediate half mile radius. Both are located directly on a highway access point, and are surrounded primarily by single family home zoning, but are also connected to major bike and walking paths, giving some residents access to the stations without a car. They share similar below average transit access, with the orange line providing the only metro access, while numerous buses serve the station regularly. Both stations also have relatively favourable jobs/housing balances, meaning that the current land use distribution is adequate but could be more balanced and improved with further investment.

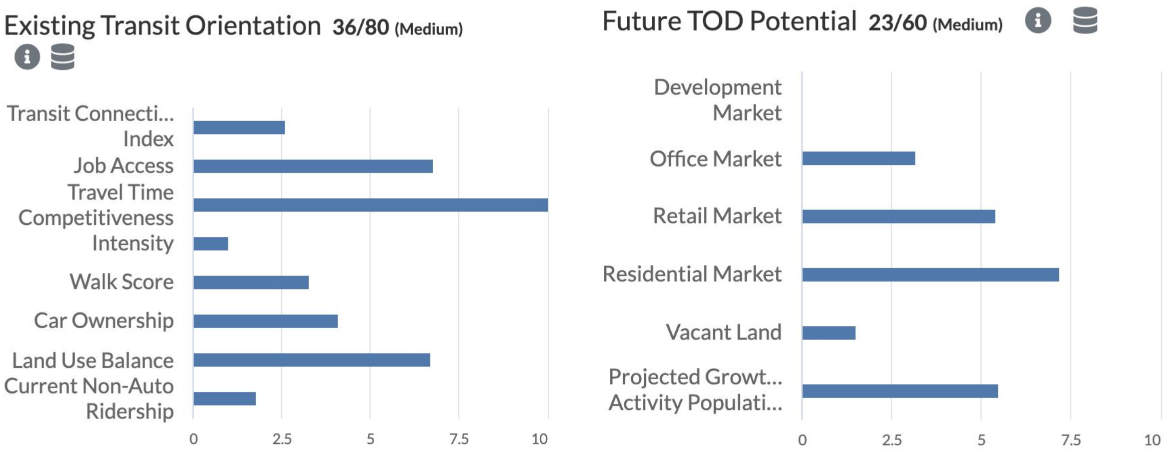

Figure 31: WMATA Smart TOD model results for West Falls Church (Carrington, 2022)

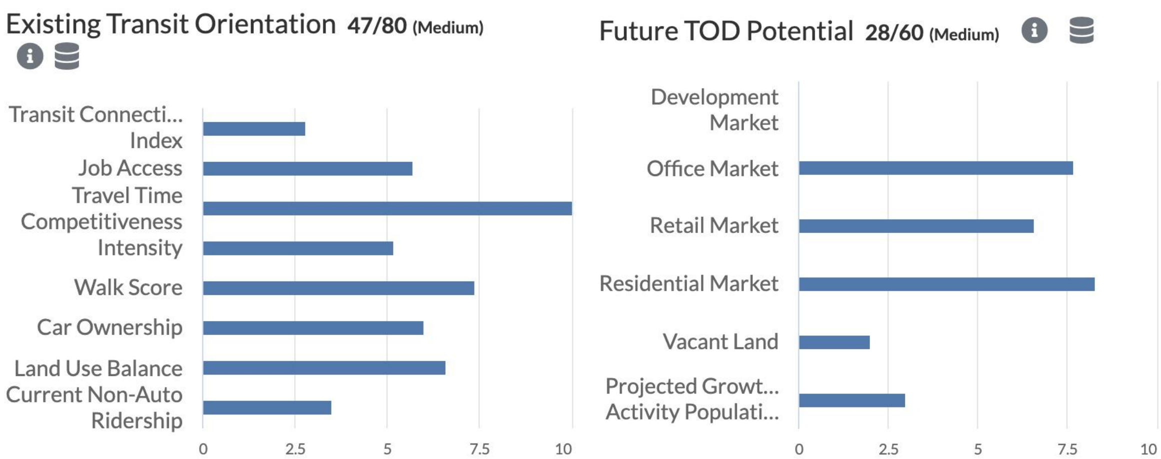

Figure 32: WMATA Smart TOD model results for Dunn Loring (Carrington, 2022)

West Falls Church and Dunn Loring both have moderate levels of jobs accessible within the 30 minute travel time radius, and travel time competitiveness ranks very highly for each station, meaning that it is comparable or better to take transit to destinations instead of driving. For suburban stations, both of these stations have decent walk scores and score above average on land use balance. For the future potential section, both stations share a similar predicament with East Falls Church in that the development market is ranked at a zero and there is limited access to vacant land. Both of these factors do make it harder to invest in these areas as it would require revamping existing buildings instead of building something new in empty or rentable space. There is also not a high amount of projected population growth around either of these stations, indicating that it may not be the first priority for development as it is not currently projected to be an area of high growth and potential.

When comparing these two stations to the Belgian case study, these are similar to East Falls Church in the closest classification being the unbalanced small and large nodes. Significant investment in the area would be needed to bring these nodes into a balance, particularly in improving transit access and providing more housing opportunities to increase the population density.

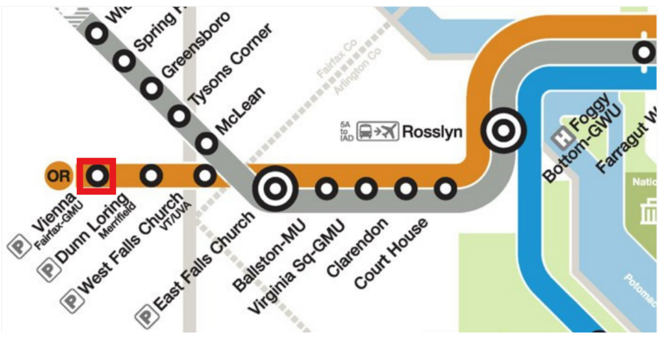

Figure 33: Vienna location (WMATA, 2022)

6) Vienna

The Vienna metro station is the end of the orange line. It was intended to serve the existing residents of the suburban towns surrounding the area, providing an artery of transportation to downtown D.C.. The intent of extending the orange line out to this area was never to stimulate growth, and consequently development decisions around the station were made in congruence with this. High intensity development was considered briefly but concerns about increased traffic congestion from the existing residents prevented any of those ideas from moving forward. There was a high concentration of vacant land around the station when the station was being constructed, but due to the community opposition to densification, the main developments that took place were town home communities and a large park. Years later, further development and densification took place despite some community backlash for having to destroy existing residential communities. A general lack of desire for density from residents for urbanization also created roadblocks to development, as the community was too built out to be able to change easily. (S. Segerlin, personal communication, June 29, 2023)

The lack of development around East Falls Church, West Falls Church, Dunn Loring and Vienna is considered to be a "missed opportunity" compared to the Rosslyn Ballston corridor, one that is ideally not going to be repeated around the development of the new silver line stations from Reston to Ashburn. (Grimes, 2016)

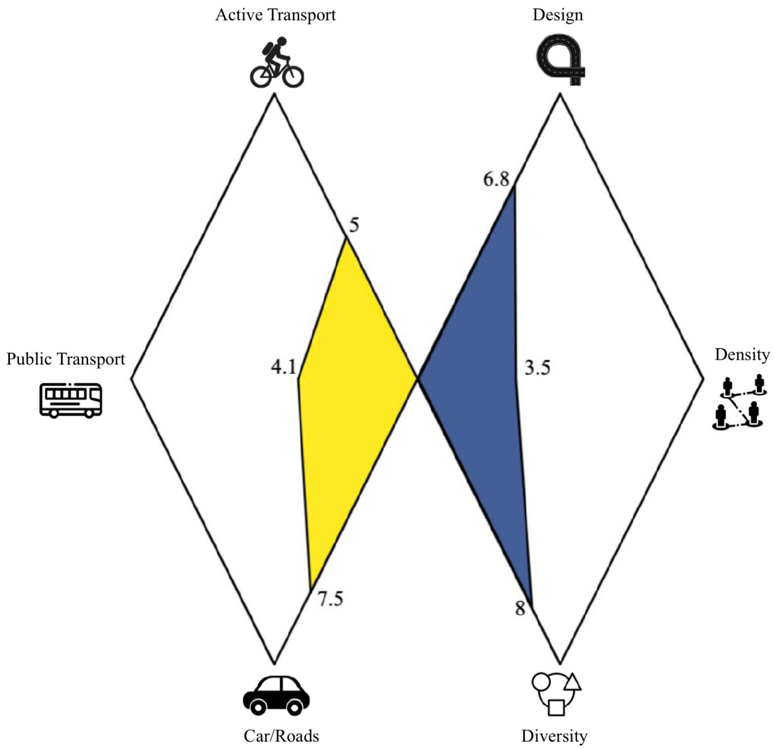

Figure 34: Vienna Butterfly model

The butterfly model does capture this development well. The wing results are flatter than the Rosslyn to Ballston model results, reflecting less access to public transit and a less dense population. It scores the highest of the 9 stations for car infrastructure due to the high levels of car parking capacity and dense road network surrounding the station. More car parking infrastructure is added to end of the line stations to compensate for commuters coming from other stations to park and ride. Interestingly, Vienna is the most balanced of the 4 outside stations, and has a strong design score, which suggests strong potential for future development.

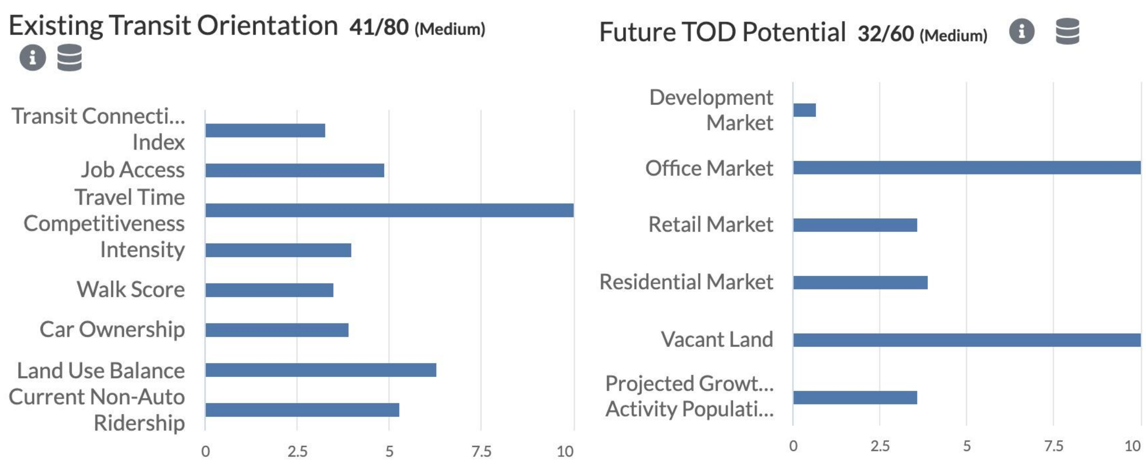

Figure 35: WMATA Smart TOD model results for Vienna (Carrington, 2022)

The WMATA model reflects this as well, with a very high amount of vacant land, and particularly high office space potential. However, the jobs/housing balance is very high already in Vienna, meaning that there are already more employment opportunities than housing in Vienna. This calls into question the level of demand that actually exists for more commercial buildings.

In comparison to the Belgian study, the balanced diverse station is the closest analogue to this result. And while Vienna is objectively balanced, it is not the most prime location for transit-oriented development, which means that just being in balance is not necessarily enough for success, but the balance must complement a large level of development on each side as well.

4.3 Synthesized Analysis of Results

The underlying assumptions of the Butterfly model and the idea of balance between the prongs are that characteristics of successful nodes will develop and continue to develop in harmony with each other. By improving transit and improving housing and job access at similar rates, planners maintain this balance and create the most optimal environment for users of the space. The model is intended to be a snapshot of the current conditions of a node and used both for evaluation of the node itself and comparison to other nodes.

When planning for these projects, developers consider density and connectivity to be the most important factors. (S. Segerlin, personal communication, June 29, 2023) Keeping these factors in balance is crucial to a successful development, as too densely populated areas will be frustrated by a lack of adequate connectivity infrastructure and mobility options, and too sparse of a population will make an expensive, highly connected transportation network a waste of resources.

However, balance does not tell the whole story of why a project is successful, and it may be even more useful to use these models to analyze the individual prongs to understand strengths and weaknesses of a node. Additionally, analyzing stations as regional groups or corridors is crucial if they were intended to have specific functions and development goals that do not necessarily align with the generic idea of a balanced node. Different unbalanced ratios may be more optimal depending on the function of the node as a part of the larger system. In the case of the Rosslyn to Ballston corridor, the intentions of developing the stations to have different yet cohesive purposes are not well reflected in the indicators of the model and yet the model still captures the overall conditions of the stations due to the indicators being relatively generic. None of the 9 stations were fully in balance, but the closer stations to DC did show more balance than the further four.

An important note is that it is naturally easier to build more successful TOD around an existing centrally located railway station than one further out in the suburbs, as the likelihood of citizens to want to live in a denser environment for the sake of convenience is much higher. (J. Carrington, personal communication, June 15, 2023) This is consistent with this set of stations but does not preclude successful TOD from being built further out, just suggests that it needs a different investment strategy to be attractive to area residents. This is another reason why evaluating nodes for balance alone is not using the results of these models to their full potential.

There are many barriers to node and corridor development that make TOD a difficult task despite its idealistic set up. In many places in the US, property owners of vacant land are given subsidies from the government to hold on to this land, which greatly disincentivizes them from selling the land to a developer. This can present a significant challenge to larger scale development ideas if certain crucial pieces of land are not available due to an unwilling seller. (S. Segerlin, personal communication, June 29, 2023) These types of legal challenges often delay and limit projects at a significant and frustrating level.

Additionally, stations being geographically spread out can make it difficult to build cohesive corridors. Part of what makes the corridor so effective is the ability of employees and residents to seamlessly travel between different nodes in the corridor via transit, bike and pedestrian paths. The farther away the stations are from each other, however, the more difficult it is to build effective pedestrian and bike networks that provide adequate connectivity to each node in the corridor. This explains the low to moderate active transportation scores for each of the 9 nodes.

Another obstacle to this type of plan is community opposition. Among city planning professionals, dense and connected development may seem like an obvious improvement to disjointed, semi-vacant and spread out communities, but to residents that are used to neighbourhoods primarily filled with single family homes and car infrastructure, this type of development may be an unwelcome change that is met with significant opposition. Even in the 1980s when the orange line was initially built, community residents "at least initially viewed the high-density development which Metro would bring as an unavoidable evil to be managed by close scrutiny;". (Parris, 1989, p. 7)

Each of these factors are not easy to model, but must be considered when development occurs, and they also can skew model results, such as in the case of the East Falls Church to Vienna stations, which are naturally less densely populated and less connected to transit networks due to their geographical lack of proximity to DC and their community opposition to denser development. Consequently models are only one tool in the toolbox planners and policy makers must draw from when developing new ideas and their results must be interpreted within greater context of the conditions of the site.

While balance in the model might not be achieved, the station could still be considered a success based on both its individual development goals and role within the group.

This suggests that this model in its examination of TOD from different standardized dimensions could be used more as a recipe or benchmarking tool for planners. It has the potential to assess a station at one point in time and identify areas of improvement, help determine a level of readiness for further investment, and provide a source of comparison to its neighbours and itself over time.

5: Conclusions

5.1 Discussion of balance as an explanatory factor in TOD success

Reflected through literature, previous models and this iteration of a newer model, the balance between transportation infrastructure and land use is a crucial relationship in explaining and predicting success of TOD. It is essentially a chicken and the egg problem when developing an area. Developing transit first to encourage densified land use, or densifying and redesigning the land to make transit more attractive for the area, particularly more flexible transit forms like bus and bike share is a trade-off that planners continue to face. (J. Carrington, personal communication, June 15, 2023)

These models do accurately represent the conditions of the sites, however balance of these factors around an individual node may not be the best indicator of success. The density and public transit elements of the model have the highest influence on the overall assessment of balance of the node due to their location on the model in the middle of each wing. Even when the other 4 factors are less balanced, the middle two drive the results of the model. This is consistent with the assumptions behind the model that density of the population and the infrastructure and design of the transportation network are the core pieces of TOD success and that keeping those two factors balanced is crucial.

However, corridor planning was a major factor in the success of the Rosslyn to Ballston stations, and so far no TOD models have been able to reflect corridor planning as a potential tool.

Additionally, corridor development includes higher levels of flexibility offered when there is more land to develop. Expanding to a model for a corridor could be one potential solution to greater successful implementation of TOD in other US contexts. Therefore, balance is still a useful relationship to study and implement for TOD, but it may prove more useful at a larger scale as opposed to an individual node.

In Clarendon's case, the butterfly model does accurately reflect the conditions at the site, however the other important factors that made this station so successful, including the potential for retail development and preservation of public space are not captured in this model. However, they do fall within the overall conception of land use factors, and it could be added to the butterfly model as an indicator to increase the accuracy and predictability of the model given real conditions at the site. They do not necessarily need to be in the classic balance, however. In this case to be consistent with the purpose of the node within the corridor as a space for play and delight, it is perhaps more advantageous to have higher scores for active transportation and design and have less emphasis on a dense population or a well-connected road network.

Reframing the butterfly model as an assessment tool of each of these prongs in addition to looking at the overall balance of the factors may prove more useful for planners than examining it for balance alone. Additionally, there is no universal "best" indicator or most important influencing factor because each of the nodes has a different intended purpose. Recognizing this nuance and adjusting model interpretations based on these intended uses could improve the usefulness of the relationship between each of these factors as a success benchmarking tool for TOD.

5.2 Discussion of the model indicators and assumptions

While no model can perfectly capture a multi-faceted phenomenon and concessions and choices about what to include must be made, there are notable adjustments that could be made in the butterfly model that would make it more useful for the US context. First, the model only uses a few indicators for each piece of each wing. This keeps the model relatively simplistic and does not account for nuance of the situation.

For example, the active transport indicators are very bike-heavy, which is logical for the Netherlands and Belgium due to a more built-up bike network but does not accurately capture the active transport situation in the US context. In this case it might make more sense to add in a safety measure as well, like the one that was implemented in the New Zealand case study. Just the simple presence of bike and walking paths is not necessarily a good indicator in the US of the ease of these modes of travel, due to a general population bias against these modes where safety concerns exist.

Additionally, some of the indicators seem out of proportion, such as the diversity factor only being made up of one indicator (jobs/housing balance), and a high jobs housing balance in this case can significantly alter the final appearance of the model and contribute to imbalance in a way that doesn’t always reflect reality, or at least exacerbates the appearance of imbalance.

While the overall factors used in this model are similar and aligned well with how planners in the US evaluate TOD, with a particular focus on density and connectivity, adjusting indicators to fit the American context would strengthen the case for using this model as a tool.

5.3 Limitations, Gaps, Further Opportunities

This study was limited to only 9 of the 104 Washington D.C. metro stations for the sake of comparing the results of the model to an accepted case study of success with a few additional stations to show variation in the model results. Completing the models for the remaining stations would offer a richer picture of the system as a whole, offering more variations in the model outcomes and potentially improving the viability of the model as a tool for planners.

Adjusting the indicators to better fit the American context and developing a version of the model that could evaluate a whole corridor would be something valuable to further investigate.

An important note in this evaluation is that all existing models that reflect this relationship were developed prior to the Covid 19 pandemic. With such a huge shock to the way we live and work, previously accepted truths of commuting and preferences for proximity to jobs have come into question, leaving models far less accurate than they used to be. There is also far more available information and data now than ever before, meaning that previously developed models may not reflect the nuance and level of detail that could be possible now.

5.4 Final Discussion

Transit oriented development is often seen as a welcome change in the United States after decades of car-centric infrastructure dominating the development landscape. However, these changes can be difficult to implement in the face of geographical challenges, unequal existing infrastructure, often lacking service access, community opposition and density unfriendly design choices. To undertake these expensive and time-consuming projects, planners must be armed with the best information available about how to make their projects succeed.

The balance and interplay between the transportation factors and land use is one way of explaining the conditions of the development around these stations. The mix of built-up bike and pedestrian paths, existing transportation network and car access combined with the advantageous street design and dense populations in the Rosslyn to Ballston corridor is a highly plausible explanation for the success of these developments, and the lacking factors in the East Falls Church to Vienna stations align with the context of how the station development has occurred. Understanding the balance is important for predicting success of new projects, but it is not the only important factor to consider.

Adjustments could be made to the butterfly model to plan for a corridor, and this may prove to be a far more useful and scalable tool for policy makers, as it would allow for understanding where gaps in a corridor might be and seeing which node within the corridor could best be developed to fill that gap, or if the connections between the nodes need to be improved.

For the best chances of success, planners should make use of models, but also rely on historical precedent of other successful projects, work to change the community perception of denser living and working environments, creatively take advantage of funding opportunities, and ideally develop cohesive corridors.

Word Count: 14,946

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6: Appendix 1: Data for Models

6.1 Indicator Tables

Active Travel	Rosslyn	Courthouse	Clarendon	Virginia Square	Ballston	East Falls Church	West Falls Church	Dunn Loring	Vienna
Bike Share Presence within 1000 ft of Station	7	4	9	7	5	3	1	1	0
Bike Parking Capacity at Station	14	25	30	44	22	123	62	83	112
Location of station along network of established walking/bike paths	1	1	1	1	1	1	1	1	1

Public Transit	Rosslyn	Courthouse	Clarendon	Virginia Square	Ballston	East Falls Church	West Falls Church	Dunn Loring	Vienna
Number of end stations reachable by train	6	4	4	4	4	4	2	2	2
Number of trains serving the station on week day based on headways and last train times	444	296	296	296	296	296	148	148	148
Number of stations reachable within 20 minutes of travel	40	35	30	28	26	18	14	11	9
Number of bus lines that stop at station	15	16	12	9	21	16	5	8	26

Car/Road	Rosslyn	Courthouse	Clarendon	Virginia Square	Ballston	East Falls Church	West Falls Church	Dunn Loring	Vienna
Car parking capacity	0	0	0	0	0	455	2122	1993	5429
Presence of car sharing service	1	1	1	1	1	1	1	1	1
Road network distance to the closest highway access (miles)	0.13 miles	0.459 Miles	0.690 miles	0.790 miles	0.275 miles	0 miles	0 miles	0 miles	0 miles

Total length of structural roads within the catchment area (adjusted)	37640.3298	54720.235	64944.298	56177.454	45229.443	46865.398	32649.383	36154.621	56276.17
Car parking capacity	0	0	0	0	0	455	2122	1993	5429
Presence of car sharing service	1	1	1	1	1	1	1	1	1

Design	Rosslyn	Courthouse	Clarendon	Virginia Square	Ballston	East Falls Church	West Falls Church	Dunn Loring	Vienna
Pedestrian shed ratio of catchment area	0.4	0.55	0.61	0.52	0.5	0.44	0.26	0.3	0.45
Number of street network intersections with 3 or more links in the catchment area	73	128	125	134	104	82	68	83	124
Transversable network length (ft, adjusted)	48889.412	53854.748	42234.688	44240.268	33340.891	15560.057	5725.084	24671.874	51782.272

Density	Rosslyn	Courthouse	Clarendon	Virginia Square	Ballston	East Falls Church	West Falls Church	Dunn Loring	Vienna
Number of residents within catchment area (census tract)	10955.11	21548.288	12243.91	16182.94	19036.98	5371.845	2981.43581	5590.17	5928.82
Number of workers in service and administration within catchment area	1363.89	3635.746	2054.06	2382.44	2528.712	770.967	309.09964	601.685	686.36
Number of workers in retail, hotel, and catering within catchment area	250.29	803.494	270.49	361.385	549.846	186.01	52.17572	140.115	353.36
Number of workers in industry and distribution within catchment area	314.72	938.62	596.34	502.93	614.076	141.493	95.13849	235.145	244.98
Number of workers within education, health and culture within catchment area	581.27	1391.592	754.26	909.645	1037.592	277.041	182.28716	446.24	441.22

Diversity	Rosslyn	Courthouse	Clarendon	Virginia Square	Ballston	East Falls Church	West Falls Church	Dunn Loring	Vienna
Degree of functional mix (jobs/housing as a proxy)	0.731156655	1.020039244	0.5574418445	0.9110809847	0.8709138248	1.09121994	1.081226768	1.044033935	1.146386518

6.2 STATA correlation table

	Bik~1000	BikePa~n	Locati~r	Numbe~le	Number~a	Numbe~it	Numbe~at	Carpar~y	Presen~e	Roadne~o	Totall~s	Pedest~e	Numbe~se	Transv~t	Number~h	Number~d	Numbe~ot	Number~n
BikeSha~1000	1.0000																	
BikeParkin~n	-0.7061	1.0000																
Locationof~r	.	.	.															
Numberofen~e	0.7895	-0.5962	.	1.0000														
Numberoftr~a	0.7895	-0.5962	.	1.0000	1.0000													
Numberofst~t	0.8268	-0.8274	.	0.9052	0.9052	1.0000												
Numberofbu~t	-0.1221	0.1677	.	0.1264	0.1264	-0.0050	1.0000											
Carparking~y	-0.7713	0.6538	.	-0.7466	-0.7466	-0.7802	0.3381	1.0000										
Presenceof~e	.	.	.	.	.	.	.	.	.									
Roadnetwor~o	0.7870	-0.5826	.	0.3876	0.3876	0.5900	-0.1734	-0.5623	.	1.0000								
Totallengt~s	0.4549	-0.0679	.	0.1414	0.1414	0.2359	0.3731	-0.0638	.	0.7061	1.0000							
Pedestrian~e	0.6776	-0.3668	.	0.4692	0.4692	0.5539	0.4030	-0.4078	.	0.7797	0.9039	1.0000						
Numberofst~e	0.3297	-0.1733	.	0.0191	0.0191	0.2053	0.3439	-0.0078	.	0.7450	0.9045	0.8203	1.0000					
Transversa~t	0.4087	-0.4066	.	0.4181	0.4181	0.5383	0.5203	-0.0253	.	0.4888	0.6174	0.6597	0.7015	1.0000				
Numberofre~h	0.5722	-0.7188	.	0.5246	0.5246	0.7199	0.2312	-0.6002	.	0.7020	0.4526	0.7257	0.6184	0.6143	1.0000			
Numberofwo~d	0.5748	-0.6816	.	0.4934	0.4934	0.7207	0.1778	-0.6056	.	0.7462	0.5358	0.7739	0.6666	0.6100	0.9805	1.0000		
Numberofwo~t	0.2144	-0.4432	.	0.2986	0.2986	0.4942	0.4979	-0.2687	.	0.4376	0.4752	0.6600	0.6512	0.6632	0.8865	0.8926	1.0000	
Numberofwo~n	0.5116	-0.6660	.	0.3812	0.3812	0.6524	0.2018	-0.5022	.	0.7090	0.5711	0.7699	0.6955	0.6431	0.9402	0.9745	0.8969	1.0000
Numberofwo~i	0.4770	-0.6666	.	0.4074	0.4074	0.6504	0.2311	-0.5028	.	0.6809	0.4912	0.7155	0.6764	0.6583	0.9794	0.9819	0.9250	0.9772
Degreeoffu~h	-0.9086	0.7092	.	-0.6428	-0.6428	-0.6962	0.1240	0.5998	.	-0.6057	-0.3364	-0.5232	-0.1729	-0.3427	-0.3809	-0.3742	-0.0417	-0.3850

	Number~i	Degree~h
Numberofwo~i	1.0000	
Degreeoffu~h	-0.3098	1.0000

Appendix 2: Interview Guide and Transcripts

6.3 Interview Guide

Introductory Questions:

1. What is your title, and how long have you held your current position?
2. To what extent have you worked with developing and evaluating TOD projects along this corridor?

Crucial Questions:

1. What factors are the most important to consider when implementing transit oriented development?
    a. How do you factor in the position of the station in active transport, public transit, and car networks? Do these networks already need to be strong, or do TOD projects in this area typically help add and connect to existing networks?
    b. How do you factor in the density and demographics around the station when evaluating TOD projects?
    c. To what extent does design of the dedicated pedestrian and cycle paths determine where TOD would be the most optimal?
2. What is the optimal land use for transit oriented development to succeed? More specifically, are there certain ideal characteristics, or "golden ratios" of jobs, housing, commercial development, that are considered the gold standard?
    a. How do you adjust when an area has a severe imbalance of land uses? Do you build TOD first with the assumption that by having that development, other development will continue around it? Or is it typically better to mostly build TOD in places that already have a good balance?
3. What models are used to inform WMATA's Smart TOD planning process?

   a. Have you used a version of a node place model before? If so, what type, and how has that informed your planning process?
   b. How has the Smart TOD tool kit changed the way you make decisions?
4. Besides model and scenario building, how else is data used to inform the TOD building and planning processes?
5. How do community demographics play a role in deciding what TOD projects will be built?
   a. To what extent are neighborhood characteristics, gentrification potential, community opposition/support taken into consideration when considering development projects? (ask separately or pivot based on their earlier answers)
6. What are the biggest advantages of building transit oriented development along the Rosslyn-Vienna corridor?
7. Is there anything else you'd like to add that we haven't already discussed?
8. Is there anyone else you could put me in contact with that would be able to add further insight to this discussion?

If Time Permits:

9. Can you explain the process for choosing and approving transit oriented development projects in the Washington D.C. suburbs?
10. How are transit oriented development projects evaluated during the construction phase and after completion?
11. What are the biggest challenges of building transit oriented development along the Rosslyn-Vienna corridor?
12. What does the future of TOD along this corridor look like?

6.4 Jamie Carrington Interview Transcript

[00:33 - 00:49] So I really appreciate you meeting with me, because I really appreciate any kind of perspective you might be able to give me on all these topics.

Yeah, sure.

So first of all, do you mind if I record this interview?

Yeah, go for it.

[00:49 - 00:59] OK. Great. Thanks. And then also just to let you know, this is entirely just for academic purposes. It's not going to be publicized anywhere at all. It's just for my background information.

[01:00 - 01:01] All right, sounds good. No problem.

[01:02 - 01:10] So OK, so the first question would just be, so what is your current title? And then how long have you held your current position at your job now?

[01:11 - 01:28] So I'm currently a supervisory transportation planner. Well, technically, it's something completely absurd that I always have to double check. It's Supervisory Program and Management Analyst, which is kind of a meaningless bureaucratic title.

[01:28 - 01:45] But basically, I manage a team of planners in the bus priority program at DDOT. And so we work on projects like bus lanes and transit signal priority, that sort of thing, all over the district.

[01:46 - 01:48] So I've been in that job for a year now.

[01:48 - 02:21] OK, that's good to know. And then so just so you know, I found your name on the TOD website for Metro, which is why I reached out to you. So do you mind telling me bit about your role with Metro and how you worked with all of that?

[02:20 - 02:35] So I was a senior planner in the Office of Planning and was here from 2015 through last summer. And the Smart TOD project came up.

[02:35 - 02:51] I mean, because one of the things that I worked on was kind of analysis and kind of the kind of strategic planning for for TOD and thinking about land use around stations.

[02:52 - 03:07] In particular, some of the stuff that I was doing was looking at how can we evaluate the ridership potential of new development around stations and how can we track trends in

[03:07 - 03:25] in ridership? How can we correlate that with development and then use that to inform some of the kind of policy priorities and discussions we would be having with the local jurisdictions who control land use?

[03:27 - 03:43] So a lot of it kind of went back to the idea of just reminding local governments who, because of Metro's funding structure, Metro depends on all of those local governments

[03:43 - 03:59] to the local and state governments to fund it. And it takes on slightly different flavor and maybe a little in the weeds. But like in Virginia, the way that it's set up is that cities and counties

[03:59 - 04:17] actually contribute out of their own budget to to Metro. But then in Maryland, it all comes out of the state budget. So it's a little wrinkle that informs the way we talk about it, because we can then be going to jurisdictions and saying, [04:18 - 04:35] hey, you were very conscious of the money that you were putting towards Metro out of out of your budgets. So keep this in mind when you're planning for development, because the more the more riders you have at a particular station,

[04:36 - 04:53] you know, that's that's something that starts to bring in more revenue for for Metro and helps to limit the growth of the subsidy that then you'll be expected to provide. So that was a narrative that was kind of in the background of a lot of work that I did on

[04:53 - 05:08] on TOD. So, yeah, the smart TOD thing was something that we'd had some internal conversation with saying, hey, wouldn't it be nice if we had like a fun little web tool, basically, so that people who are

[05:08 - 05:25] either just kind of all purpose planning nerds or people who are thinking about development, either as developers or planners with with local jurisdictions, that they can start to get a sense of, OK, what is this relationship here with ridership

[05:25 - 05:45] and development and what kinds of it also is a way to take some kind of internal tools that we've developed, but only existed in Excel files full of macros and taking that and turning that into

[05:45 - 06:04] something that a normal person would potentially be able to use. So, yeah, that was kind of the the origin of smart TOD. But it was something that did kind of evolve over the process. And in some cases, the evolution was more due to

[06:04 - 06:22] certain technical constraints of kind of trying to develop this tool within the existing framework that that WMATA.com had. But I think in the end, I think it came out

[06:22 - 06:30] pretty well and I certainly learned a thing or two about the way that websites work that I didn't know before.

[06:30 - 06:49] Yeah, definitely. That makes sense. So as you were working with all this different data and trying to kind of help figure out these models, do you kind of have a sense now more for like, what are the major factors that kind of helped build these models? Like what are the major factors that are going into planning

[06:49 - 06:53] for transit oriented development, especially when you have to communicate it to all these external people as well?

[06:54 - 07:11] Yeah, I mean, we were fortunate that we had some of the main like Excel file models that we had was this swarm thing. And it was it was something that it was just doing

[07:11 - 07:30] kind of a statistical regression. And we had first developed it back. I think it was even before I joined. This was around 2015. And what it had done was it took a number of different data sources

[07:30 - 07:45] looking at ridership and land use types. And, you know, in some cases, the link was looking at square footage of a particular land use.

[07:45 - 08:01] In other cases, it was looking at the number of jobs. And then within that, certain types of jobs having more or less impact on on rail ridership.

[08:02 - 08:19] And then also looking at the distance to this station in terms of the walkshed, of whether it's within 10 minute or approximately half mile walkshed or not.

[08:19 - 08:37] And even within that, having some gradations of, you know, once you're within an eighth of a mile, it's significantly more sensitive. And then the farther you go, the less impact it might have.

[08:37 - 08:55] So all of these different factors, the basic the building blocks of that model had been developed in like 2014, 2015. And kind of updated a little bit over the years a few times with updated ridership data

[08:55 - 09:10] or updated land use data. But the basic idea was that there was this tool that you could plug in some numbers in a scenario and you have something spanned out that say, if you were a developer,

[09:10 - 09:27] you could take to a, you know, public hearing or something and say, oh, well, we were really trying to reduce our parking requirements for said development. And the justification is, look, that because we're this close,

[09:28 - 09:43] we can really expect that a lot of these trips that are generated by our development will go to transit rather than driving. So we don't need to accommodate that as much. So that was one little use of it. OK.

[09:43 - 09:58] That makes a lot of sense. Yeah, just kind of being able to explain all the different factors that go into it and see like how how that can be used in in more specific context, like the parking thing or something. OK, I can see that. That makes sense. Sorry if these feel a little rigid, but I just kind of want to get a little bit of a -

[09:59 - 10:16] Oh, yeah. Yeah, yeah, yeah.

Specific answers. So when you're building these models again, right. So are you factoring in you mentioned ridership data, but are you also factoring in kind of like the existence of the place within the transit network? So like access to how many buses are coming,

[10:16 - 10:18] bike share stations, that kind of thing.

[10:19 - 10:37] The way that this model was in this one model, it was only focused on metro rail ridership. That's something that I know that we talked about. Oh, wouldn't it be great if we had more data that could integrate bus service into the whole thing?

[10:37 - 10:47] But that was just tougher because we didn't have like the models really just looked like, OK, land use and and metro.

[10:47 - 11:02] OK, that makes sense. So do you feel like adding in those kind of extra pieces would have made the model stronger like and maybe more convincing potentially? And like when you're talking about transit oriented development projects?

[11:03 - 11:21] Yeah, it's it's tough. I mean, buses, it's it's a big. I I think it would introduce a lot more complexity. It would definitely make the model better. But the level of complexity, once you introduce bus service,

[11:21 - 11:37] at least in our region, there's a lot more variation depending on where you are of a kind of what are people using the bus for and whether people are.

[11:38 - 11:54] You know, would prefer to take the bus over the train or whether people are even comfortable with the bus that you've got areas of the region where the bus is just kind of, oh, yeah,

[11:54 - 12:13] this is how you get around. And then you have other areas that are more post-war suburbs that kind of see the bus as kind of like, oh, that's not what I take. That's what. You know, like that's what my maid takes.

[12:13 - 12:29] Yeah. The stereotype of that. But it's just that it's when when your land use context is is already in that you have very post-war suburban area.

[12:29 - 12:46] People are just going to be less oriented to it. And they whereas taking the train would be more certainly for commuting. They'd be more willing to have that a part of their lives, whereas the

[12:46 - 13:02] more that you're in D.C. and in particular inner suburbs, the more you have people who really are oriented to transit in general. So you'd have to factor in those nuances and also the kind of level of bus

[13:02 - 13:20] service and dependability, because I think that with the metro rail brand, if you will, it's not only the actual level of service and how fast it can get you somewhere and reliability and whatnot, but it's kind of the the presumption of it,

[13:20 - 13:37] which is. More consistent across the region if you don't have as many situations where one person is like, my line is super unreliable, and so I will never consider using it

[13:37 - 13:52] in another person's metro line as a breeze and convenient for everything, whereas when it comes to buses, there are just many more factors that go into whether or not

[13:52 - 13:57] people are using the buses rather than just the fact that they're there.

[13:58 - 14:16] OK, that completely makes sense to me as well. Yeah, because there's a whole big equity component, of course, to all of this. Yeah. So that's interesting, because it's also similar to one of my other questions, which is kind of how like community demographics play a role in TOD development and also like modeling in different scenarios.

[14:17 - 14:32] And I'm kind of curious what your thoughts are on that. Like, how much is that considered when kind of coming up with these plans or building these models? Like, do you do a lot of like research into like who actually lives in the neighborhood? Are you working with much more like high level general data?

[14:33 - 14:52] For for smart TOD and the work that I was doing, it was much more high level of trying to just look universally because so much of what. Kind of the the end goal of a lot of the work was stimulating

[14:52 - 15:08] transit oriented development in general. And I there was we did start to have some internal conversations about how can we start to account for equity and things like affordable housing

[15:08 - 15:24] just because there has been evidence elsewhere that when you have an affordable housing anchored transit oriented development, that that's going to generate a lot more transit ridership than something that is

[15:24 - 15:40] TOD in kind of its built environment. But where it's built in a way that appeals to people who are like, well, I live in the suburbs, but I'm looking to downsize.

[15:40 - 15:57] And maybe I'll have the the train right here and I'll take it from nowadays like three days a week to the office. That's the only time that I'll use transit. So there's so and that's something that because this was all done

[15:57 - 16:13] before the pandemic, I think it's fair to say that I the model, it's not completely broken at this point, but I would I certainly expect WMATA planners to do.

[16:13 - 16:29] I try to figure out a new approach for things. I mean, I think that it's still an important element in just looking at that that relationship of when you build stuff near the station, what;s kind of a rule of thumb for how much rail ridership it could potentially generate. But i do think it is going to need to be reevaluated in terms of current working arrangements because so many of those factors are presuming that someone is doing a 9-5 commute and they are just going to be

[16:56 - 16:59] commuting into major job centers 5 days a week. Right. Right.

[17:00 - 17:16] Yeah, I've noticed that, too, and doing kind of a lot of background research is just everything is so set in like the classic nine to five commuting everything, which makes sense, of course, that everything changed so quickly and so recently that there is not a lot of research coming out of like the last few years

[17:16 - 17:30] that reflect all of those changes, of course. So it will be interesting to see kind of how that develops and how different things change over time. Just out of curiosity, like, are you working on some more stuff for DDOT with that, like in kind of revamping?

[17:31 - 17:49] Not to the same degree, because we're focusing on mostly on bus priority corridors where we've selected the corridors based on their existing. You know, on existing data in terms of

[17:49 - 18:08] demographics, existing ridership, existing bus operational needs of where there's congestion that the buses are getting stuck in, so there's not quite as much imagining different development futures,

[18:09 - 18:24] but it does come into play when we are thinking about a project that that does go go near a major kind of future development area. Yeah, we might think about, OK, how does that

[18:24 - 18:43] impact what what our approach is? And in many cases, it is it certainly informs our thinking and our discussions of saying, well, if you do have this major development coming online, we really want to make sure that the buses is reliable and

[18:43 - 18:59] desirable as possible. The moment that that big development opens, because that's the time when people are making their decisions and getting set in their habits. And if the presumption at that point is like,

[18:59 - 19:16] oh, I don't understand the buses and they seem slow and it won't take me where I need to go. So then I will just kind of float out of people's minds. So we want to try to be there to kind of absorb the demand as much as possible.

[19:16 - 19:32] That totally makes sense. So, OK, so another question on that, then. So when these new developments happen and there's all of a sudden like all these new housing complexes or new commercial centers, and then as a transit agency, people are trying to kind of make sure that the transit

[19:32 - 19:49] is ready to go for that as well. Like, do you feel like it it makes more sense or is more successful generally to like have the transit component strong first and then build more like housing and stuff in areas where transit is already strong? Or do you think it makes that kind of more sense to do the other way around

[19:49 - 19:54] and build all the housing and then connect the transit or like from your experience?

[19:54 - 20:10] It's I yeah, it is kind of a chicken and egg sort of challenge. I mean, I would say that if if there's going to be major transit oriented development or at least major

[20:10 - 20:25] kind of urban or transit oriented in in form and density that you want that to be. You want that transit to be there when

[20:25 - 20:41] when it opens, it does get more difficult. So with with Metro Rail, so much the argument of of TOD is like, well, we already have this infrastructure here that's built and that it's going to

[20:41 - 20:57] be providing a certain basic level of transportation of of access so that we need to take take advantage of the infrastructure that's already there, whereas on the the bus side,

[20:58 - 21:15] it can sometimes be easier for people kind of on a bean counting level to say, oh, well, why should we have scarce money that we have to put towards bus service? To what extent do we really want to be committing to

[21:17 - 21:33] frequency of bus service that we can't really you know, use past ridership to inform and justify? Yeah, especially when you get equity concerns coming in.

[21:33 - 21:50] And there is like, OK, do we in in the theoretical finite high of of of DC's funding for transit is like, do we focus on the places that are already demonstrating that they're used transit a lot for everything?

[21:51 - 22:08] Or do we put money as well if there's going to be some major new development in an area that is far from Metro Rail, but where it's it is kind of already been identified as a growth area.

[22:09 - 22:25] So in some cases, I would say traditionally. WMATA working with the district, because when it comes to service planning, there's probably a lot more back and forth because the.

[22:25 - 22:42] DC's funding contributions end up becoming much more. Tied up in those little decisions about where the buses are going and how much service there is, whereas the rail discussion

[22:42 - 23:00] are more regional and everyone just kind of if everyone can get to a general consensus on how much service is everywhere, then everybody chips in. So, yeah, that's a long way of saying that there have been a few areas recently in DC

[23:00 - 23:16] where there has been major development, but where the bus service was really it was not beefed up or even. And it marketed in a way, which I think is something that

[23:16 - 23:34] it is necessary when you have a real new development in an area where maybe people weren't we're thinking as much about transit that you do need to kind of connect new people to

[23:34 - 23:47] to the transit service that's that's there. And if the transit service is not there, then you're just missing the opportunity. But it sure is a chicken and egg.

[23:48 - 24:04] It really it really is. But that was really helpful. That was an interesting answer. So thank you. OK, let's see what else. So. Let's see. Can you talk a little bit more just about how data is used to inform

[24:04 - 24:14] kind of any decisions with TOD planning, not necessarily just model building, but like just kind of any other uses or things that you did in your experience?

[24:15 - 24:17] Sorry, you're breaking up a little bit.

[24:17 - 24:33] Oh, sorry, sorry. So basically, do you have any kind of other uses for data besides building these models when you're kind of helping make these decisions? Like, are we are you generally kind of building like dashboards or presentations or that kind of thing?

[24:33 - 24:37] How else would you be using this data essentially to inform these decisions?

[24:40 - 24:57] I mean, I would say so at this point in my career, I did. Yeah, that's not a major. Part of what I'm focused more on. Yeah, just getting that the transit projects built out on,

[24:57 - 25:11] you know, the places where things have already been identified, but it definitely informs some of our decisions about how we're facing things and where we might be prioritizing.

[25:12 - 25:31] Gotcha. OK, that makes sense. A couple of last questions before we are done. So from from your experience, from working in the space a lot, what would you say just in general are kind of the biggest advantages of building transit oriented development around existing metro stations?

[25:31 - 25:46] Yeah, I mean, the biggest advantage is that the infrastructure is there, that particularly if it's a station where there is lots of capacity that's left.

[25:46 - 26:05] I mean, you do have to think about these things that if and it's probably not as and maybe this is actually a wrinkle of to go back to the smart TOD. Another wrinkle of it that and the swarm model, that's a wrinkle of it that is maybe more complex now,

[26:05 - 26:23] possibly a pandemic, because a lot of the ideas behind it were not only trying to identify what the ridership impacts could be with different development, but also determining if based on old based on anticipated ridership patterns,

[26:23 - 26:43] whether that would cause station crowding at peak hours. So if you have a residential TOD that might be out in the suburbs, but it is but under 10 year ago, ridership patterns,

[26:44 - 27:02] you can presume that a large number of those people would be traveling to jobs in downtown D.C. And so you try to get a sense of, all right, will this actually cause crowding on particular parts of the system at peak hours? That may be a little less of a concern now.

[27:02 - 27:12] So that's a yeah, kind of a a side note about some of the thinking when the thing was created.

[27:13 - 27:24] OK, yeah, that definitely makes sense as well. OK, I don't want to take up too much of your time, but do you do you have any other kind of general comments or anything that you wanted to add that I didn't ask about?

[27:26 - 27:41] Oh, no, I mean, I think that just the main thing is that it's it's an area where. Metro and other places were doing a fair amount of research about

[27:41 - 27:58] how do you look at the the impacts of TOD, how do you use that to inform the types of TOD that you're you're planning? But so much of this stuff has just been flipped upside down with the pandemic.

[27:58 - 28:17] So I think that there's definitely room for taking a more holistic look at things, not to mention the amount of like location based service data that was not available back when these models were first put together.

[28:18 - 28:28] So it would be great to see somebody take that on in a way that is more big picture and takes advantage of some of the new data sources out there.

[28:29 - 28:45] Yeah, that makes sense. I'm assuming there's quite a bit that is now available that was not back in 2014. Yeah. Yeah. Yeah. OK, good to know, too. And then I know you already mentioned Steven, who I'm going to speak with. But do you happen to know anyone else that might kind of have insight on this

[28:45 - 28:47] or anybody that you think I should talk to?

[28:49 - 29:05] I think, yes, Steven I think it's probably the best one, because, you know, he's kind of in the in the lead on a lot of Metro's joint development planning.

[29:06 - 29:18] And yeah, and I know that they've been really aggressively moving, moving forward on a lot of things. So, yeah, he probably has the most to give you.

[29:18 - 29:34] OK, cool. Yeah. All right. Awesome. Well, I really, really appreciate your time. Thanks for speaking with me. And no problem. Some insight. But yeah, I will let you know how the rest of the writing thesis goes.

[29:34 - 29:35] Thank you for your time.

[29:35 - 29:40] Great. Well, best of luck on the rest of your work. Thank you so much.

[29:41 - 29:42] All right. Have a good rest of your day. Take care. Bye.

6.5 Steven Segerlin Interview Transcript

[02:51 - 02:52] OK, great. So first of all, do I have your permission

to record this interview?

[02:52 - 02:53] Yeah.

[02:53 - 03:02] Perfect. OK, thank you. OK, so just for the sake of the interview, so what is your title and how long have you held your current position?

[03:03 - 03:16] My title is Director for Real Estate Development and Station Area Planning in the Office of Real Estate and Development. And I've had my current position for two years.

[03:17 - 03:17] Cool.

[03:17 - 03:29] Thank you. And then next question. So I'm specifically studying the stations from Rosslyn to Vienna. Have you worked on any projects on any of those stations?

[03:31 - 03:35] Yeah. Every station. Oh, perfect.

[03:36 - 03:46] Yeah. OK, great. OK, so that's good to know as well. So in any of these other questions, feel free to bring in examples or anything that you want to chat about.

[03:46 - 03:57] OK, so first big question would be, what factors would you consider to be the most important when implementing transit-oriented development, like a new development project?

[03:59 - 04:03] **Density.**

[04:03 - 04:03] OK.

[04:04 - 04:13] **Connectivity. And pedestrianization.**

[04:15 - 04:18] It's like safety pedestrianization,

[04:18 - 04:23] that kind of confluence of, yeah, I need to slow people down to do good TOD.

[04:23 - 04:39] Yeah. OK. Right. That makes sense. So then specifically, so how would you factor in the active transport network when you're talking about transit-oriented development? Like, do you look for places that already have

[04:39 - 04:45] a lot of connectivity to bike paths and walking paths? Or is that something that comes later once the development project is taking place?

[04:47 - 05:04] Kind of depends on the project. So some of our sites are mostly vacant, large parking lots, et cetera. And they really are like master planned communities.

[05:05 - 05:25] You're creating a street grid out of nothing. And you're going to have multiple buildings. So that has a lot of design discussion. The other example is infill projects,

[05:26 - 05:43] where it's like there's only a one building, maybe two building opportunity. Or maybe there is, the buildings already exist. And you're needing to improve that safe pedestrian,

[05:44 - 05:57] bicyclist environment or the interaction between these modes and bus and pickup drop-off activity, et cetera. So it's really project-driven, site-driven.

[05:58 - 06:06] OK. That makes sense. So typically, are most of the projects that Metro works on more infill projects or more starting from scratch?

[06:08 - 06:23] No, both. Both are like Rosslyn to Ballston is more infill. And improvement of the public realm

[06:23 - 06:42] and true multimodal nature of the road design as the buildings exist. And there's the East Falls Church to Vienna, which are more of these large vacant sites.

[06:42 - 06:44] That is, you're creating a street grid.

[06:47 - 07:00] OK. I see. So would you say that the approach to the Rosslyn to Ballston section versus East Falls Church to Vienna is very different? Or do you think you have the same general ideas of what you do?

[07:00 - 07:09] Well, it's the same general ideas fom a principal's perspective. It's just the execution of them is very different.

[07:10 - 07:12] That makes sense. Just give them a scale.

[07:13 - 07:30] You're doing a master plan community. You're starting from scratch. And you're having one developer that's really putting it all together. And you're designing with that developer. Whereas, I'm sorry.

[07:30 - 07:32] I heard a call, but it's in the room next to me.

[07:32 - 07:33] Oh. OK.

[07:33 - 07:50] On the infill type projects or improvement projects, those have a bunch of different strategies for them.

[07:50 - 08:07] You might have the developer. There's a new building coming in. Do portions of the project around their frontage. Or it might be a project that is driven by the jurisdiction. And they are making a modernization effort

[08:07 - 08:16] for the roads and sidewalk public realm as a scandal on public effort. So lots of different ways these things come together.

[08:17 - 08:36] OK. OK. That makes sense. And then a similar question is, I know you mentioned bus connectivity as well. And then I think also with the four outer stations, car network connectivity is probably also very important. So another similar question of, is that

[08:36 - 08:45] something that gets built up a lot throughout the project? Or is it something, again, that you are strategically picking spots that are already well connected to these things?

[08:47 - 08:51] Yes. I guess that's where my role is different.

[08:52 - 08:53] OK.

[08:53 - 09:10] Like, I'm focused on metro rail stations. So we're not picking projects because we want to fix them all. Right, yeah. So it's more of a process of evaluation.

[09:11 - 09:25] And we're trying to systematically move through our portfolio inventory stations that have deficiencies, and then evaluating what improvements are necessary.

[09:26 - 09:26] OK.

[09:27 - 09:36] So it sounds like very different than if you're talking to a developer, what developers like having a lot of different criteria driving what's picking their attention.

[09:37 - 09:53] Sure, yeah. That makes sense. So in terms of the people that are already living around the station, in terms of density and demographics, how do you factor that in when you're choosing which projects to prioritize or which ones to choose

[09:53 - 09:53] over others?

[09:55 - 10:11] So again, we're not really choosing. Right, yeah. Because we're acting at the mall. Yeah. But **that feedback from the community does drive a lot of the design decisions**.

[10:12 - 10:12] OK.

[10:12 - 10:31] So yeah, it's definitely a partnership. It's usually the community that is identifying some of the safety concerns and conflicts. And through that consultation with our own operational staff

[10:31 - 10:49] and the locality staff of the county, in this case, that's the body or brain trust that helps to identify the problem statement, and then sort of drives the problem statement,

[10:50 - 11:00] drives the solution set or the creation of a solution set. And then that same body brain trust is who is involved with evaluating the proposed solutions.

[11:01 - 11:12] I see, OK. Can you walk me through a little bit more just like how the public is involved at different stages? Like, is it typically more of like community meetings, or how does that work?

[11:15 - 11:29] Yeah, so it's different things depending on the scale of the project. So our large projects where, like, when I mentioned we have these big parking lots and bus

[11:29 - 11:31] loops, we're not going to change everything.

[11:31 - 11:37] And on property that we own, we have to do something that's called a compact public hearing.

[11:38 - 11:38] OK.

[11:39 - 11:58] And that's like an official procedure mandated by our founding documents, like a bylaws, I guess you could consider them. And that says that we will do this like formal public comment

[11:58 - 12:15] period, almost like a local government does or a rezoning application or something, or a comprehensive plan amendment. So that's like one thing. There's usually a lot of informal community meetings

[12:15 - 12:34] that happen prior to that. They may be meetings that we've organized and trying to form a problem statement or form a committee to evaluate site needs. They may come through an old process, [12:35 - 12:51] like if they're doing a comprehensive plan amendment or a sector plan update for a corridor or station area. And so we would get that type of feedback possibly through that process.

[12:51 - 12:52] OK.

[12:53 - 13:01] That makes sense. So it seems like they're fairly involved throughout the process and kind of does seem to be a pretty big factor, public opinion.

[13:01 - 13:02] America loves democracy.

[13:04 - 13:20] Well, it makes sense, honestly. But OK, great. So talking a little bit more generally, maybe, in your experience, would you say

[13:20 - 13:35] that there is kind of an optimal set of land use in terms of successful transit-oriented development projects? Like is there kind of an optimal jobs housing balance? Is there a need to have specific features built

[13:35 - 13:44] into a transit-oriented development project? Thinking maybe on the larger scale ones where you're kind of starting from a larger point of view versus the infill.

[13:46 - 14:07] Yeah. I don't know if there's a rule. I think there is a paradox in America that belief that greater density is going to solve transit

[14:07 - 14:22] like financial obstacles. OK. And I think like outside of New York City where you can get Asian levels of density, that is a possibility.

[14:23 - 14:27] **But like in most of America, you can't build out corridors**

[14:27 - 14:30] with 20 to 50 story buildings.

[14:31 - 14:45] So like density, I think, is a reasonable goal because it does drive ridership, but it is not like a silver bullet.

[14:45 - 14:46] Right.

[14:46 - 15:05] I think density is actually more important to make the financial equation of TOD work. TOD is really expensive. Creating street grids, designing them with all the multimodal amenities, creating the open space, the other parts

[15:05 - 15:21] and other kind of like attractions cost money, money for either the developer or the public sector. So you need a level of density to generate enough tax value to pay for these things. And that's where I think is actually the most important part

[15:21 - 15:39] of density. And you also need those tax values to pay interest subsidy. You know, you're not going to be able to do 50 story buildings everywhere and like be positive on ridership operations. So that's kind of my views on density.

[15:40 - 15:51] But it's really hard to get density in most of America. **And then the irony is like outside of that corridor you're talking about in Virginia, which is the communities are very opposed to density.**

[15:52 - 15:55] Especially when you get to East Falls Church and onward.

[15:55 - 16:10] Much of the rest of the region has actually, I think, given too much density and they've like flooded them all. And so like Maryland, I think, is drowning in density allowances. Nobody's building anything because they're building a little bit everywhere.

[16:12 - 16:18] So like density can also stall a real estate market kind of like flooding an engine.

[16:19 - 16:25] That's interesting. Can you explain that a little bit more? Just like when you say density can flood it,

[16:25 - 16:37] what do you mean? Imagine if you only have demand for 3 million square feet in a year for housing. [16:37 - 16:37] Yeah.

[16:38 - 16:57] And you have on the market 30 million square feet of development potential in your county, Arizona, that's unused. How valuable do you think is the land in your county?

[16:58 - 17:17] Like zero. Yeah. And then if you're trying to do like dense transit-oriented development and a developer can say, well, I can build, you know, Metro's asking me to build a high rise out of concrete

[17:17 - 17:38] at the Metro station, 15 stories. But I can go half a mile away, just half a mile. And I can do the same amount of square footage,

[17:39 - 17:57] 250,000 or 400,000 square feet. But I can do it in a four-story building. It takes up more land. I'm going to do it with surface parking or maybe a standalone parking garage rather than a sub-serene parking garage. And I'm probably going to get the same rents.

[17:57 - 18:06] Fairly different rents, because it's not that far. And that Metro station currently today has no amenities because it's a suburban Metro station.

[18:07 - 18:26] So, you know, why would I build there? So it's like, well, jurisdictions shouldn't have allowed multifamily development of that sort. You know, in the one mile of the Metro station,

[18:27 - 18:43] if the Metro station was already a vacant lot, they're not prioritizing where you want people to build. You're just saying, build anywhere, I don't really care. And then you complain, like, we're not getting

[18:43 - 18:59] the type of development that we want. It's like, well, you're getting actually the exact type of development that you allowed. That you created. Yeah. And that's why you're not getting development where the amenities, because the developer is saying

[18:59 - 19:04] it's cheaper for me to build a development that is for car lovers.

[19:05 - 19:06] Yeah, okay.

[19:06 - 19:22] With surface parking. And they'll drive to the places where they want amenities. Right, right. So, like, there's a zoning issue, there's an investment issue in creating that quality environment that's not just connected,

[19:22 - 19:38] but amenitized. Like, zoning rules, like, the Federal Transit Administration has some general guidelines. It's called the Land Use and Economic Development Assessment.

[19:38 - 19:55] If you look at that report, it has some, like, suggestions of what FAR levels should be. Okay. In transit station areas. And, like, a CPD versus, like, kind of a suburban station. So, at some useful points.

[19:56 - 20:04] Yeah. We have trouble achieving those levels of density. So, they're good rules.

[20:04 - 20:19] So, how does your team kind of handle these situations when you know that the kind of political or zoning situation has been set up in a way that is not going to allow you to build or help build what you want to build? What is your process?

[20:19 - 20:37] This is where I think it's about communication and transparency. Okay. So, we've been trying to do this work of coordinating with the jurisdictions and saying, you know, your vision and our vision to some degree is a dense area.

[20:37 - 20:58] And we came up with a site plan with you and your staff. It is for 15-story buildings, walkable, all monetized, et cetera. That cost is, you know, $500 million for all of these things.

[20:59 - 21:04] But let's make it a smaller scale. Let's say $100 million. The land value is only $40 million.

[21:05 - 21:05] Yeah.

[21:05 - 21:20] So, we're $60 million shy of paying for what we want. We could do a tax abatement. That could cover another $40 million. So, now we're $20 million shy.

[21:23 - 21:40] You could, if we get a federal grant or we take advantage of a federal or state loan facility that provides, like, concessional or below-market-rate loans,

[21:40 - 21:58] and we provide that to the developer, not only for the public realm, but for their buildings, that's going to save them another $20 million in financing costs. So, now you've covered your $100 million gap. But this is pretty complicated stuff.

[21:58 - 21:58] Yeah.

[22:01 - 22:17] And so, it's just having those discussions. Okay. Seeing, you know, what would you be willing to do. So, like, at New Carrollton is probably our best example. We got that. They've done tax abatements. They've done, we did federal grants.

[22:17 - 22:34] We got some federal grants. We are pursuing additional, like, state allocations, just straight-up budget allocations, or I guess earmarks. Yeah. And then we're using Amazon's low-rate financing

[22:34 - 22:50] to increase the affordability. So, we've been throwing everything in the kitchen at it. Right. Okay, interesting. But it's taken a decade to kind of get all these things together,

[22:50 - 23:00] I see. Okay. So, do these projects all typically take years to be realized just because of all these different obstacles?

[23:01 - 23:19] Yeah, and, like, the extra challenge of just real estate development sector in general is even if you didn't have any of these challenges, it takes five years if you have no challenges. Wow, okay. It's definitely a slow process.

[23:20 - 23:35] Getting a developer, negotiating with a developer, and then the developer beginning their, like, permitting process with the jurisdiction if it requires rezoning or not. Like, it usually still takes two-ish years.

[23:36 - 23:55] Buildings take two-ish years. Depending on where interest rates are and the, you know, inflation, you might have to delay the project a year or two to wait for, you know, the economics, the balance. And then, you know, that's like in a no-problem scenario

[23:55 - 24:07] if the land value can pay for all of these things. And that's with an agency that's willing to discount their land value. Like, if private properties, they're like,

[24:08 - 24:09] I'm not giving my land away for free.

[24:10 - 24:30] Like, why would I do that to make a project faster and pay for, you know, moving utilities, like a gravity sewer that goes diagonally through the site? Like, I'm not paying for that. So that's why you see so much vacant property around transit stations

[24:30 - 24:43] and privately owned. Because that landowner's like, I'm going to wait for a sunnier day, then someone's going to pay me my full land value and accept these problems at the site.

[24:44 - 24:48] That makes sense, unfortunately. Just because, of course, people want to...

[24:48 - 24:57] And then in America, there's like, we have the terrible system of allowing to carry forward losses.

[24:57 - 24:58] What do you mean?

[24:59 - 25:18] So if you own property, whether or not it's being used or not used, if it's running at a loss, you can take those losses and you can apply them on your taxes.

[25:19 - 25:39] And let's say you're making zero money after your losses, the federal government gives you a credit for those losses. So you could have vacant, unused property, and the federal government pays you to keep that property.

[25:40 - 25:47] So that just causes another obstacle, of course, because no one's going to want to sell it if they're getting paid to hold onto it.

[25:47 - 26:03] Exactly. And this is why America looks the way it does. This is like, for me, my... maybe I'm fully research theory, is like the failure of the American real estate market.

[26:04 - 26:08] And that's why you see so many properties that are vacant for very long times.

[26:10 - 26:17] That's actually really interesting. I had no idea that that was a thing. So somehow they have to be incentivized to let go of that.

[26:19 - 26:32] Because yeah, you can carry forward those losses, and then depending on certain types of losses, like depreciation loss, you can end up getting credits for it, and then actually get a check from the federal government.

[26:34 - 26:42] Interesting. Okay. So typically, is the way that Metro deals with that, like, somehow incentivizing?

[26:42 - 26:47] So we discount your land value. Okay. Because we have an interest in getting projects to move.

[26:47 - 26:48] Right.

[26:48 - 26:51] Because we're not getting ridership with vacant property.

[26:51 - 26:54] Yeah, so it's not worth it to hold onto the land. Yeah.

[26:54 - 27:08] And like our jurisdictions who fund us, they need tax revenues. So if we have vacant property, like, we're shooting ourselves in the foot, and we're shooting them in the foot. Right. Yeah, of course. And we rely on them to pay our subsidy.

[27:08 - 27:22] Yeah. That makes sense. So other kind of logistical question with that. So are all the projects that Metro has a hand in Metro land, or is it not necessarily?

[27:23 - 27:39] Not necessarily. So, like, you know, we've got Roslyn, and, like, there are projects in Roslyn and in Ballston areas that we've already developed our land.

[27:40 - 27:57] But we're still working with the jurisdiction to coordinate these, like, roadside improvements or public realm improvements. Like Courthouse is a good example, where it's like we have people doing pick-up and drop-off in the bus stop

[27:57 - 28:00] because there's, like, no clear area to pick up and drop-off.

[28:00 - 28:19] And then the bicyclists are also trying to navigate that area, and there's no bike lane. And so everybody's, like, converging on the Metro station entrance. And then there's, like, bad crosswalks, and so pedestrians are getting hit. Or you're having bus and bike or bus and, you know,

[28:20 - 28:31] pick-up drop-off customer vehicle, Uber incidents. So that's where we're trying to do a lot more coordination on, like, design and location and signage and wayfinding.

[28:32 - 28:36] Okay. So at that point it's more, like, minor improvements, like, right around the station?

[28:38 - 28:41] And maybe leading to, like, a whole overhaul of the entire section of the road.

[28:41 - 28:42] Okay.

[28:43 - 28:54] And then, like, with BRT and stuff, like, these are leading to huge overhauls of the road. But, yeah, minor in the sense of no buildings.

[28:54 - 28:58] I see. Okay. But still extremely important, of course. Yeah.

[28:59 - 29:03] Makes sense. Or there's, like, a new building that's being proposed,

[29:03 - 29:12] and we're like, well, this building, your access and loading location is going to create conflicts. And so we're coordinating with that new development.

[29:13 - 29:19] Just to make sure that there's all cohesiveness around the station. Yeah. Okay. Okay. That makes sense.

[29:20 - 29:36] And that, in part, at courthouse, led to, like, our proposal marking the developer in the county to actually close, like, a little side street. Oh, really? Okay. Because we were like, this is too chaotic.

[29:36 - 30:00] It was like too much activity of vehicles and pedestrians. We need to dedicate more space to pedestrians. And we also needed more, like, pick up and drop off frontage for private vehicles. And so by closing this mid-block streets,

[30:01 - 30:07] we were able to use that frontage that was actually the entrance to that mid-block to be now the pick up and drop off zone.

[30:08 - 30:09] Oh, smart. Okay. That makes sense.

[30:10 - 30:29] Because, like, we had the discussion of, well, there's parking just beyond this mid-block intersection. Why don't we just do better signage there? And for, like, the driver, they're like, well, that's the next block.

[30:30 - 30:45] Your metro station's on this side of the block. I'm going to stop right there. But that's the bus stop. We don't want you to stop there. We want you to go through the mid-block intersection and use that parking. But for drivers, they don't care.

[30:45 - 30:48] Right. Everybody's just convenience, convenience, convenience, right? Yeah.

[30:49 - 30:51] So we were like, we need to make a convenient space for them.

[30:51 - 30:52] Right.

[30:52 - 30:52] Okay.

[30:53 - 30:58] And then we're doing things like putting cameras on our buses now and we're going to start getting tickets for people parking in lanes.

[30:59 - 31:01] That's good, too. A negative reinforcement.

[31:01 - 31:02] I think that's really innovative.

[31:03 - 31:06] Yeah, that would be really good to make sure people are using it effectively.

[31:07 - 31:07] Yeah.

[31:08 - 31:16] Okay. Cool. So, kind of going back to more of the beginning of our discussion, but.

[31:17 - 31:22] I might jump out of my phone, so I'm going to go walk and pick up a sandwich. Is that okay? Oh, yeah, of course.

[31:22 - 31:23] No worries. Yeah.

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