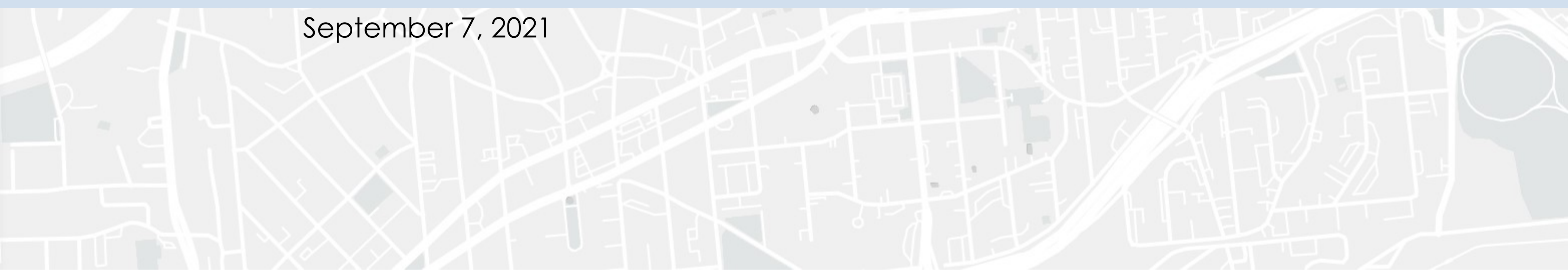
# ARLINGTON COUNTY CURB SPACE ALLOCATION TOOL



September 7, 2021

Page Intentionally blank

# Arlington County Curb Space Allocation Tool

Arlington County, Virginia

*Prepared for:*
**Arlington County Department of Environmental Services**
**Transportation Engineering & Operations**
2100 Clarendon Boulevard, Suite 900
Arlington, Virginia 22201

*Prepared by:*


**Kittelson & Associates, Inc.**
100 M Street SE, Suite 910
Washington, DC 20003
202.450.3710

**W-ZHA, LLC**
1031 Skidmore Drive
Annapolis, Maryland 21409
410.757.0732

**Foursquare Integrated Transportation Planning**
51 Monroe Street, Suite 1103
Rockville, Maryland 20850
301.774.4566


*Project Staff:*

**Alek Pochowski, Like Liu, Lake Trask, Jamie Henson** (Kittelson & Associates, Inc.);
**Sarah Woodworth** (W-ZHA, LLC); **Andy Zalewski, Jessica Klion, Laura Duke** (Foursquare ITP);
**Stephen Crim, Christine Baker, Kevin Casadei** (Arlington County); **Jon Schermann** (MWCOG)



*Kittelson Project Number 25450*

**September 7, 2021**

***This project was funded by the Metropolitan Washington Council of Governments (MWCOG) as part of the FY 2021 Transportation Land-Use Connections (TLC) Program***

Page Intentionally blank.

# CONTENTS

# LIST OF FIGURES

# LIST OF TABLES



# LIST OF EQUATIONS

Page Intentionally blank.

# Section 1
# Introduction

# INTRODUCTION

The curb is where transportation systems and land uses intersect. It is where flows of people and goods meet destinations and origins. Historically, the curb has been primarily used for parking, but through proactive curb management that optimizes the balance of multiple modes, a jurisdiction like Arlington County can better support land-use and transportation goals and more efficiently use limited public space. Since 2009, new modes and technologies have fundamentally changed the transportation landscape at the curbside. These include ride-hail apps, e-commerce deliveries, and the revolution in micromobility services. This has created the need to proactively allocate curb space for multiple modes of transportation, economic activity, and other uses, such as green infrastructure. As demonstrated in Figure 1, there are many demands for curb space on County roads, including deliveries, micromobility services (e-scooters), people walking, and parked cars.

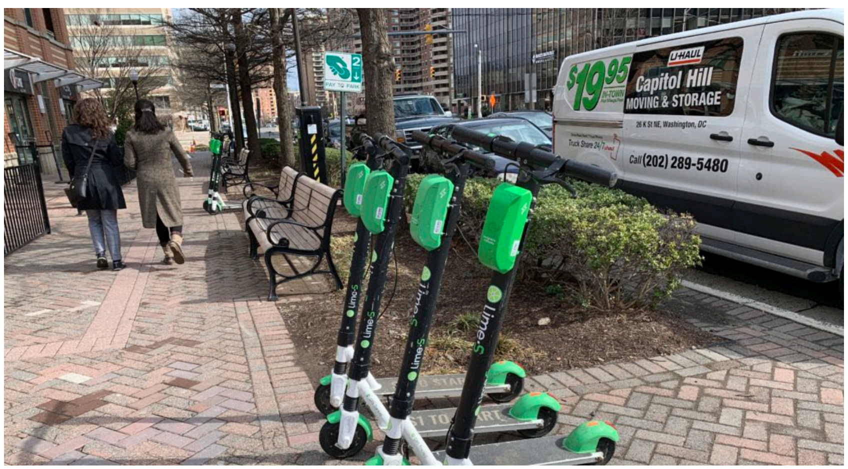



**Figure 1. Electric Scooters and Deliveries in Arlington County**
(Electric Scooters to Stay on Arlington Streets for Another Six Months | ARLnow.com)

## LOCAL CONTEXT

Arlington County, Virginia (the County, Arlington or Arlington, Virginia) is an urban county of approximately 26 square miles across the Potomac River from the District of Columbia (the District or DC). With a population of over 236,000, the County is the second largest "principal city" of the Washington metropolitan region behind the District. Arlington is the smallest self-governing county in the United States by geographic area, the fifth highest-income county by median family income, and the 11th most densely populated county. The Department of Defense is the largest employer in the County, with 28,000 employees, 23,000 of which work at the Pentagon. The Amazon HQ2 co-headquarters under construction in the Crystal City and Pentagon City neighborhoods (recently renamed "National Landing") of the County is expected to accommodate 25,000 Amazon employees by 2030. The County is a national leader in "Smart Growth," as evidenced by the National Academy of Sciences hailing Arlington as one of the nation's best transit-oriented development examples citing the County's "adherence to textbook planning principles," and focus on creating attractive, walkable spaces, and proactive community involvement.[1]

[1] http://onlinepubs.trb.org/onlinepubs/sr/sr298.pdf

The 2009 Parking and Curb Space Management Element of the Arlington County Master Transportation Plan[2] identifies principles for prioritizing different curb uses depending on rough categories of surrounding land uses. As shown in Table 1, for all densities and land-use types, the highest priority is safety followed by public multi-user vehicles (transit) service, periodic and temporary uses (pick-up/drop-off, deliveries), and dedicated short-term and specialized uses (ADA drop-off, motorcycles, scooters, and bicycles, short-term customer parking) for high-density and commercial district, and medium-density districts. This is followed by individual intermittent or long-term uses for all densities and land-use types. The prioritization of safety functions remains consistent with the County's adoption of a Vision Zero resolution in July 2019, committing to a Vision Zero strategy to eliminate traffic fatalities and severe injuries.

As noted in Table 1, periodic and temporary uses and dedicated short-term and specialized uses comprise many potential users and user groups. In the years since the development of the Parking and Curb Space Management Element of the Arlington County, Virginia Master Transportation Plan, new modes and technologies have fundamentally changed the transportation landscape at the curbside. These include ride-hail apps, e-commerce deliveries, and the revolution in micromobility services. This has created the need for jurisdictions like Arlington County to proactively allocate curb space for multiple modes of transportation, economic activity, and other uses, such as green infrastructure.

While the County's Master Transportation Plan provides input on curb space prioritization, the document does not translate the priorities into specific allocations at the building site, neighborhood block, or corridor level. This is a similar problem facing jurisdictions across the United States. In recent years, the Institute of Transportation Engineers (ITE) published the *Curbside Management Practitioners Guide*[3], which provides a treatment selection process, and builds off information developed by the National Association of City Transportation Officials (NACTO) in *Curb Appeal: Curbside Management Strategies for Improving Transit Reliability*.[4] Both documents reference the City of Seattle's Flex Zone/Curb Use Prioritization, which, as part of the City's Comprehensive Plan, establishes policies that set the priority for the use of the flex zone (the flexible space between streets and sidewalks "where people find their bus, park a car, hail a cab, drop off a passenger or make a delivery").[5]

---

2 https://arlingtonva.s3.dualstack.us-east-1.amazonaws.com/wp-content/uploads/sites/31/2014/02/DES-MTP-Parking-and-Curb-Space-Management-Element.pdf

3 Curbside Management Practitioners Guide (ite.org)

4 NACTO-Curb-Appeal-Curbside-Management.pdf

5 Flex Zone/Curb Use Priorities in Seattle - Transportation | seattle.gov

**Table 1. Arlington County Curb Space Management Priorities**

| | High-Density and Commercial Districts | Medium-Density Districts | Low-Density Districts |
|---|---|---|---|
| **Highest Priority** | **Safety** | | |
| | ▪ No parking areas due to visibility and operational safety<br>▪ Fire hydrants<br>▪ Emergency access<br>▪ Curb extensions | ▪ No parking areas due to visibility and operational safety<br>▪ Fire hydrants<br>▪ Emergency access<br>▪ Curb extensions | ▪ No parking areas due to visibility and operational safety<br>▪ Fire hydrants<br>▪ Emergency access<br>▪ Curb extensions |
| | **Public Multi-User Vehicles** | | |
| | ▪ WMATA and ART Bus Stops<br>▪ Other public bus services | ▪ WMATA and ART Bus Stops | ▪ WMATA and ART Bus Stops |
| | **Periodic and Temporary Uses** | | |
| | ▪ Taxi Stands<br>▪ Metro Station drop-off areas<br>▪ Carshare parking<br>▪ Loading and deliveries<br>▪ Semi-public and private bus service<br>▪ Slug lines<br>▪ Vending | ▪ Taxi Stands<br>▪ Carshare parking<br>▪ Loading and deliveries<br>▪ Vending | |
| | **Dedicated short-term and specialized uses** | | |
| | ▪ Paratransit and ADA drop-off<br>▪ Motorcycles, scooters, and bicycles<br>▪ Accessible parking spaces<br>▪ Short-term customer and visitor parking | ▪ Motorcycles, scooters, and bicycles<br>▪ Accessible parking spaces<br>▪ Short-term customer and visitor parking | |
| | **Intermittent or long-term users** | | |
| **Lowest Priority** | ▪ Tour and commuter bus parking<br>▪ Valet parking<br>▪ Commercial vehicles<br>▪ All-day parking<br>▪ Long-term vehicle storage<br>▪ Non-vehicle storage | | ▪ Reserved accessible parking spaces<br>▪ Resident parking<br>▪ Commercial vehicles<br>▪ Trailers, campers, and boats<br>▪ Non-vehicle storage<br>▪ Long-term vehicle storage |

# TOOL CAPABILITIES AND USAGE

The increased demand for curb space coupled with the changing landscape at the curbside made the need to practice active curb space management clear to Arlington County planners. For these reasons, the County requested assistance through the Metropolitan Washington Council of Governments (MWCOG) Transportation Land-Use Connections (TLC) Program to develop a sketch-planning tool that will compute the monetized societal benefits of various curb allocation scenarios. Through discussions with the project team at the onset of the tool development, the capabilities shown in Figure 2 formed the framework for the tool development.

**1.** Provides a mechanism to help determine the optimal allocation of curb space given a block's existing or proposed land uses and transportation services.

**2.** Helps County planners better manage their curb space by understanding the demand for various curb uses and the relative value of various curb allocations at the block level.

**3.** Delivers information for decision-makers and the public when presenting curb-allocation alternatives

**4.** Offers an additional input for making decisions on curbside regulations.

**Figure 2. Arlington County Curb Space Allocation Tool Capabilities**

The identification of the proposed use of the Tool, seen in Figure 3, ensured the tool accounted for Arlington County's multifaceted curb space demands to address the needs of County planners in managing the curb space while ensuring the allocation maximizes the potential economic and societal value of the curbside.

- Be utilized as a curb management tool to understand the value of curbside uses
- Be used for single-site, corridor and small-area planning efforts that help define the best use of the curb space
- Be functional for the entire County
- Be able to accommodate various geographies and functions
- Serve as the foundation for future region-wide efforts
- Provide results for various times of day

**Figure 3. Tool Usage Scenarios**

Page Intentionally blank.

# Section 2
# Background

# BACKGROUND

After establishing the tool capabilities and usage scenarios, an initial review of previous research was undertaken to help develop a proposed framework. A more detailed literature review, documented in the "Literature Review" section of this document, followed the development of the model framework and focused on the dependent variables, influencing factors, and relationships for each of the six proposed modules presented in this section. The development of the proposed framework helped guide the initial tool development stages. This was followed by identifying a modular approach, incorporating future updates, a supporting mathematical approach, and the economic methodology discussed in this section.

The use of the curbside began to change dramatically, starting with the introduction of ride-hailing services (transportation network companies) in 2011, followed by carshare companies like Car2Go, which used public right-of-way to store their shared vehicles in March 2012. Other companies requested curbside access, including Lyft in 2013, Split, UberPool, and Lyftline in 2015, and Via in 2016. In addition, on-demand delivery services, including Postmates, DoorDash, UberEats, and Grubhub, arrived between 2014 and 2015, placing additional demands on the curb space. At the same time, parcel deliveries and a corresponding number of delivery vehicles have increased dramatically. For instance, internet sales increased from $290.4 billion in 2008 to $1.6 trillion in 2018.[6]

As part of the initial review of previous research, seminal curbside management documents from the past several years, including the aforementioned *Curbside Management Practitioners Guide*[7] and NACTO's *Curb Appeal: Curbside Management Strategies for Improving Transit Reliability.*[8] The *Cincinnati Curb Study*[9] developed in a partnership between the City of Cincinnati and Uber, along with two documents from San Francisco, including the *On-Street Parking Management and Pricing Study*[10] developed by the San Francisco County Transportation Authority, along with the *SFpark: Pilot Project Evaluation*[11] developed the San Francisco Municipal Transportation Authority, were also reviewed. Additionally, nearby efforts from the District were reviewed, including the *parkDC: Penn Quarter/Chinatown Performance Parking Pilot Final Report* (parkDC)[12] and an accompanying freight management study[13] conducted as part of the parkDC evaluation.

While the transportation industry has speculated that ride-hailing services and deliveries are a more productive use of curb space than on-street parking, the research backing up such speculation is limited. A 2018 study[14] from Los Angeles reviewed various curb uses (parking, no parking, loading), the types of vehicles that accessed the curb space, and the number of

[6] https://www.dpdhl.com/content/dam/dpdhl/en/media-center/media-relations/documents/2018/dhl-whitepaper-shortening-the-last-mile.pdf

[7] Curbside Management Practitioners Guide (ite.org)

[8] NACTO-Curb-Appeal-Curbside-Management.pdf

[9] Cincinnati's Curb of the Future

[10] parking_study_final.pdf (sfcta.org)

[11] sfpark_pilot_project_evaluation.pdf (sfmta.com)

[12] https://trid.trb.org/view/1741681

[13] https://trid.trb.org/View/1637870

[14] https://www.its.ucla.edu/project/pushed-from-the-curb-optimizing-the-use-of-curb-space-by-ride-sourcing-vehicles/

people picked up or dropped off. The study found ride-hailing to be a more productive use of curb space, with about four times the number of people accessing the curb than traditional on-street parking. Similarly, the Curbside Productivity Index (CPI) referenced in the *Cincinnati Curb Study* identified similar theoretical productivity benefits associated with transit and pick-up/drop-off zones compared to on-street parking. The CPI provides a simplified metric for calculating the number of people using the curb, per hour, per 20 feet of curb space (the length of a typical on-street parking space), which takes the form shown in Equation 1.

$$\frac{Activity}{Time \times Space} = \frac{P}{\frac{T}{60} \times L} \times 20$$

**Equation 1. Curbside Productivity Index (CPI)**

Where:

$P$ is the number of people served over a time period for a particular curb space use

$T$ is the amount of time in minutes the curb space is occupied over the same period for a particular curb space use

$L$ is the length of curb space in feet required for a particular curb space use

As part of this review, curbside management strategies like enforcement, time restrictions, pricing, transportation demand management (TDM) strategies (off-peak deliveries and congestion pricing), and the physical design and use of the sidewalk or roadway space adjacent to the curbside (the Flex Zone in Seattle) were identified but noted to be too complex for inclusion in the curb space allocation model at this time.

Using the results of the review of previous research, the project team developed a proposed framework and modular approach discussed in the subsequent sections.

# PROPOSED FRAMEWORK

The proposed model framework, seen in Figure 4, provided a starting point for discussion and a more focused Literature Review, presented in the next section. The premise of the framework was that a series of inputs, which were developed based on typical data used for travel demand modeling applications and were later adjusted based on the literature review, would be used to determine the unconstrained demand (the total demand without accounting for spatial, political, or monetary constraints) estimation using regression models for each mode. This estimation would provide an output for the number of feet of curb space demand for each mode, including ridesharing services, commercial loading, on-street parking, transit stops, micro-mobility uses, and non-transportation uses, including parklets (defined as an extension of the sidewalk into the street that provides curbside road space for additional public gathering space), or "streateries" (an extension of the sidewalk into the street where private eating and drinking establishments offer curbside table service).

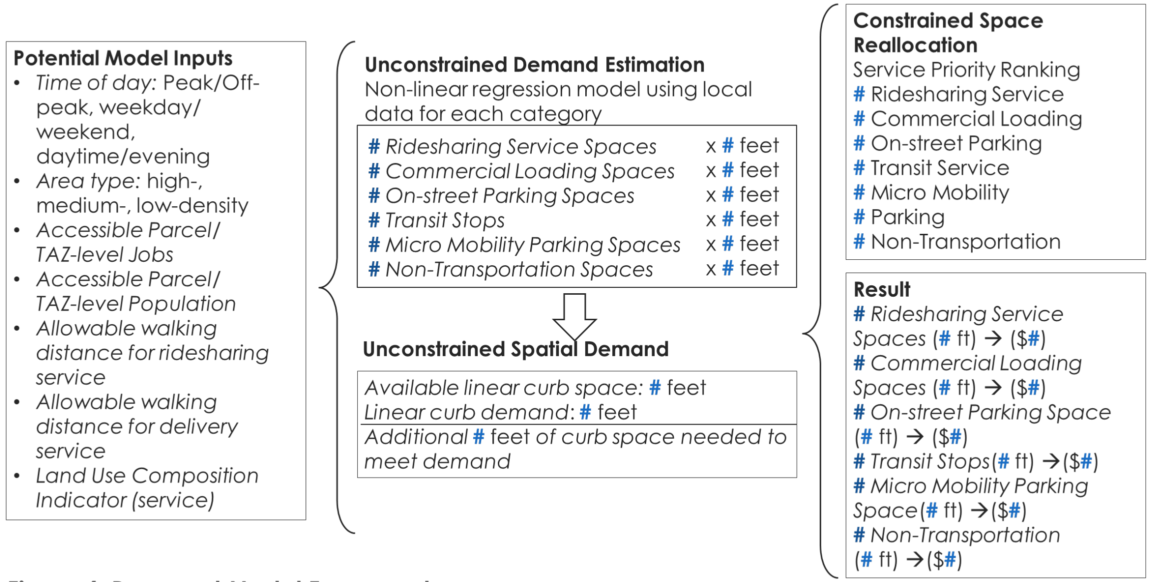



**Figure 4. Proposed Model Framework**

Inputting the available linear curb space applies a constraint to the unconstrained demand. The model then allocates the demand for each type of space to maximize the economic or societal benefits of the curb space. This allocation provides the constrained space reallocation and resultant curb space allocation. While it was initially assumed that the tool would accommodate all the demand for the highest value usage, followed by all of the demand for the second-highest value usage and so on until no additional space was available, the realization that a full space that only serves a partial amount of demand would provide less value than a space that serves the full demand of the next highest priority usage later necessitated more advanced mathematical modeling than was initially anticipated and is discussed in the Mathematical Approach section.

# MODULAR APPROACH

A proposed modular approach, shown in Table 2, was developed to accommodate expected data availability limitations due to the COVID-19 pandemic, which limited the collection of new data in late 2020 and early 2021 when the bulk of the work for this model took place. The modular approach allows the project team to use the best available literature or data to calculate the demand and economic or societal benefit. In this approach, each mode's demand and economic or societal benefits are computed in individual modules. As previously discussed, as new data or literature become available in the future, each module can be updated to incorporate the updated information. Further, as new modes become available, additional modules can be added to the allocation tool in the future, allowing the tool to evolve rather than become obsolete. The modular approach also includes "non-transportation uses," which, by definition, are not a transportation mode but provide an additional option for the use of curb space. As discussed previously, in the context of the allocation tool, non-transportation uses include parklets and "streateries."

**Table 2. Proposed Modules by Mode**

| Task \| Module | Curb Use<br>*A* | Activity<br>*B* | Potential Land Use/ Transportation Impacts<br>*C* | Potential Activity Volume<br>*D* | Potential Unit of Measurement<br>*E* | Potential Economic and Societal Value<br>*F* | Potential relationship of Impact/ Value<br>*G* |
|---|---|---|---|---|---|---|---|
| **1** | Ride-hailing Service | Passenger Pick-up/ Drop-off | Input 1<br>Input 2<br>…<br>Input i | # Pick-up/Drop-off Requests / period | Passenger Loading Zone Curb Demand | Value per trip and number of people accessing the curb | $Y = aX^b + k$ |
| **2** | Commercial Loading | Commercial Vehicle Parking (Short-term) | –" – | # Commercial Delivery Parking/period | Commercial Loading Zone Curb Demand | –" – | –" – |
| **3** | On-street Parking | Private Vehicle Parking | –" – | # Private Parking/period | On-street Parking Demand | –" – | –" – |
| **4** | Transit Service | Existing Station Locations and Passenger Boarding/ Alighting | –" – | Station Ridership / period | Transit Station Curb Demand | –" – | –" – |
| **5** | Micromobility | Micro Mobility Vehicle Parking | –" – | # Micro Mobility Vehicle Parking/period | Micro Mobility Curb Parking Demand | –" – | –" – |
| **6** | Non-Transportation Uses (Parklets, Streateries, etc.) | Number of people served/ Daily sales | –" – | # Customers served | Non-Transportation Space Needs | Daily sales/ number of people served | –" – |

Each module in Table 2 was proposed to be developed concurrently through a series of work tasks. Initially, the six curb uses were identified (work task "A," which was followed by the determination of the activities that directly and indirectly support each curb use (work task "B"). The range of land-use and transportation variables that alter the value of the activities (work task "C") was left undefined during the initial stages of the model framework development but were later filled in as part of the detailed Literature Review discussed in the next section. The volume of activities (work task "D") and units of measurement (work task "E") was proposed and later updated as part of the Literature Review. The relative economic (monetary) and societal value (task "F") associated with the activity volume and unit of measurement, along with the relationship between the variables (task "G"), were both completed during the latter Literature Review. At the onset of the tool development, it was understood that the monetary values would likely be derived from other geographic locations and that the values would have to be adjusted for the Washington, D.C. region.

Curbside space for uses related to safety, as identified in Table 1, including no parking areas due to visibility and operational safety, fire hydrants, emergency access, and curb extensions are not included in the model but remain the highest priority curbside uses. It is assumed that these uses would be allocated prior to using the Curb Space Allocation Tool, and the available curbside space provided in the Tool inputs would be the net space after the safety uses have been determined.

# FUTURE UPDATES

A key focus of the curb space allocation tool was the ability to "future-proof" the tool to allow for future updates, including incorporating new data, new methodologies, and new modes. Because of the combination of limited resources available for tool development and the inability to collect representative data during the COVID-19 pandemic, no new data collection was undertaken as part of the curb space allocation tool development. Rather, the focus was developing a methodology and framework, including the proposed framework and modular approach previously discussed, allowing new data and mathematical models to be incorporated over time. The project team conducted a thorough Literature Review, which is described in the next section, that identified the most up-to-date data sources or proxy data available. Understandably, these data sources do not provide the micro-level fine-grained analysis that would be preferable and, like all data sources, are not perfect representations of the local context. With this understanding, the tool is capable of incorporating new data sources or proxies.

# MATHEMATICAL APPROACH

As work began to verify the feasibility of the proposed model framework, it became clear that a more focused mathematical approach would be necessary. The identification of the optimal curbside allocation was consistent with "the knapsack problem"[15] developed by the mathematician Tobias Dantzig. "The deterministic knapsack problem is a classical problem with a wide range of transportation applications and a substantial body of literature. In this problem, there are a collection of objects, each with a given weight and value. The objective is to choose the set of objects with a maximum collective value without exceeding an upper bound on their combined weight.[16]

Within the transportation profession, the most common application of the "knapsack problem" approach is likely the development of a constrained long-range transportation plan, typically referred to as a Transportation Improvement Plan (TIP). In long-range transportation planning, a comprehensive transportation plan (CTP) with a 20+ year time horizon is typically developed first and includes the entire universe of potential projects without consideration for fiscal constraints. As fiscal constraints are determined, and the potential projects are scored and prioritized, the "knapsack" problem becomes relevant as key stakeholders determine the constrained project list by identifying the collective set of projects that provide the highest economic or societal value as determined by local fiscal and political determinations, along with consideration of the fiscal and political reality of the local community.

The knapsack problem approach parallels the goals of the Curb Space Allocation Tool. The proposed modeling approach behind the Curb Space Allocation Tool will seek to maximize a defined "value" of the curb space usage, subject to the curb space limit, calculated demand, and other key factors.

A mathematical programming approach was identified as an appropriate methodology for identifying optimal solutions for constrained "knapsack" problems like curb space allocation. Mathematical programming sometimes referred to as mathematical optimization, "is the selection of the best element, with regard to some criterion, from some set of available alternatives." Linear programming, integer programming, and nonlinear programming are all broadly used optimization techniques that can be used to help identify these optimal solutions.

Mathematic programming is an optimization approach for maximizing or minimizing an objective function (for instance, economic or societal benefit) and is subject to a set of constraints on the decision variables. These decision variables are the unknown values that the mathematical programming seeks to determine. Constraints, such as ensuring minimum demands of a specific mode are met, or ensuring that a maximum demand is not exceeded, are used to limit the "solution space" of the decision variables. The Curb Space Allocation Tool is the amount of curb space for each mode optimized for each location.

The optimization methodology involves an Integer Linear Programming methodology to determine the usage of the curb space. The integer refers to the fact that the decision variables will be whole numbers. For instance, a curb usage type will have a predefined required curb length, and outputs like 1.5 bus stops will not be allowed. The linear nature of the methodology relates to the objective function and the constraint. Multiple linear

[15] https://en.wikipedia.org/wiki/Knapsack_problem

[16] The stochastic knapsack problem with random weights: A heuristic approach to robust transportation planning (psu.edu)

functions proposed for the Curb Space Allocation Tool are proposed to be used to achieve acceptably approximate nonlinear constraints.

The objective functions maximize the economic or societal value of curb space usage. Matching demand using a weighting function makes the objective function similar to a cost or economic value function. Objective functions can be combined using linear weights, or a Pareto-optimal curve can balance multiple objectives. The functions take the following form:

Minimize:

$$w_1x_1 + w_2x_2 + w_3x_3 + \cdots + w_nx_n$$

**Equation 2. Objective function maximizing the value of curb space usage**

Where:

$x_i$ is the number of spaces of curb usage type $i$

$w_i$ is the weight (cost, economic value, etc.) associated with curb usage type $i$

Using summation shorthand:

Minimize:

$$\sum_{i \in S} w_i x_i$$

**Equation 3. Shorthand objective function maximizing the value of curb space usage**

Initial constraints were developed for the "knapsack" optimization problem, including the available length of curb space and the demands for curb usage types. The constraint for the available length of curb space looks like this:

$$l_1x_1 + l_2x_2 + l_3x_3 + \cdots + l_nx_n \leq L$$

**Equation 4. Constraint on available length of curb space**

Where:

$x_i$ is the number of spaces of curb usage type $i$

$l_i$ is the length associated with curb usage type $i$

$L$ is the total available length of curb space

$S$ is the set of all types of curb space usage

Using summation shorthand:

$$\sum_{i \in S} l_i x_i \leq L$$

**Equation 5. Shorthand constraint on available length of curb space**

The constraint on demands for curb usage types looks like this:

$$D_{min,i} \leq x_i \leq D_{max,i}, \text{ for all } i \in S$$

**Equation 6. Constraint on demand for curb usage**

Where:

$x_i$ is the number of spaces of curb usage type $i$

$D_{min,i}$ is the minimum allowable demand for curb usage type $i$

$D_{max,i}$ is the maximum target demand for curb usage type $i$

The Integer Linear Programming approach can solve different objective functions while maintaining the same fundamental set of constraints, such as physical, geometric, or demand. As desired, different objective functions result in different answers. During the development of the model framework, the project team and County decided to move forward with two objective functions for maximizing the value of curb space. The first objective is the direct economic value, discussed in the next sub-section, associated with the six curb use modules. For the five transportation modes, this value is the economic output per person trip. For the non-transportation uses, including Parklets or Streateries, this value is the sales per square foot of available non-transportation use space. The second objective function is the societal value, which for the purposes of the allocation tool is the number of person trips associated with the five transportation modes and the number of people served for the non-transportation use. The use of more than one objective function helps users find a balance between multiple objectives.

# ECONOMIC METHODOLOGY

The review of previous research revealed little prior work related to the economic value associated with curb space uses other than on-street parking, and even the work identified that was related to on-street parking was typically focused on how jurisdictions typically undervalue on-street parking. Dr. Donald Shoup's work in this area is well-documented in his book "The High Cost of Free Parking" and has led to performance parking initiatives across the country, including in San Francisco (SFpark[17]) and locally in the District of Columbia as part of the parkDC: Penn Quarter/Chinatown performance parking pilot.[18]

However, for the curb space allocation tool's purposes, rather than assessing the potential revenue associated with various curb space allocations, the economic methodology needed to determine the potential direct economic benefit associated with various curb space allocations while also providing economic outputs rooted in sound economic theory using the limited available curbside economic data. Due to data limitations, the economic methodology is further required allowing for future updates as new data becomes available while also fitting within the established model framework and previously discussed mathematical approach. Consequently, the literature search shifted towards identifying direct economic benefit data, such as spending or direct sales, which could be tied to the five transportation modes and parklets or streateries.

17 Demand-Responsive Parking Pricing | SFMTA

18 ParkDC - Resources

As a starting point, the document "Curb Appeal: Curbside Management Strategies for Improving Transit Reliability,[19]" published in 2017 by the National Association of City Transportation Officials (NACTO), demonstrates how various curbside uses can provide additional value compared to on-street parking. As shown in Figure 5, pick-up/drop-off zones average about 100 passengers per day, while metered parking spots average about 15 vehicles per day. Loading zones average about 20 deliveries per day and support $10,000 in daily sales per block. Except for the economic output associated with loading zones, this information could not provide the direct linkage necessary to link curbside activity to economic output.

A more promising source was found in Seattle, Washington, when the project team discovered that since 2011, the Seattle Department of Transportation (SDOT) has been conducting regular intercept (in-person) surveys[20] in Seattle's business districts to help local business organizations and city departments understand:

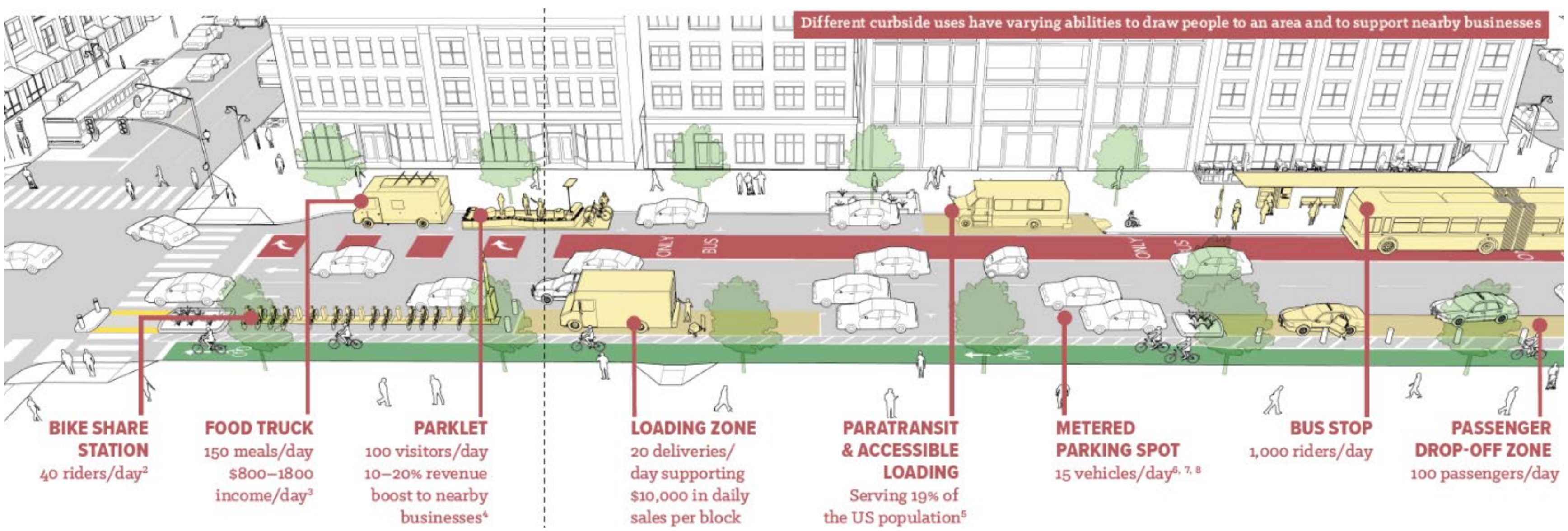



**Figure 5. Economic and societal benefits of different curbside uses**
*NACTO-Curb-Appeal-Curbside-Management.pdf*

19 NACTO-Curb-Appeal-Curbside-Management.pdf

20 *Neighborhood Business District Intercept Surveys - Transportation | seattle.gov*

- How often people visit neighborhood business districts
- The purpose of their visit
- How they got there (walking, driving, transit, biking, etc.)
- If they drive, where they park
- How travel patterns change over time


**Figure 6. Lower Fremont Neighborhood Intercept Survey – Spending by Residency/Work/Visitor Status**
*(seattle.gov)*

These surveys also collected spending information by both market segment (visitor type) and travel mode. The market segment data identified people who:

- Live in the neighborhood
- Work in the neighborhood
- Both live and work in the neighborhood
- Visitors

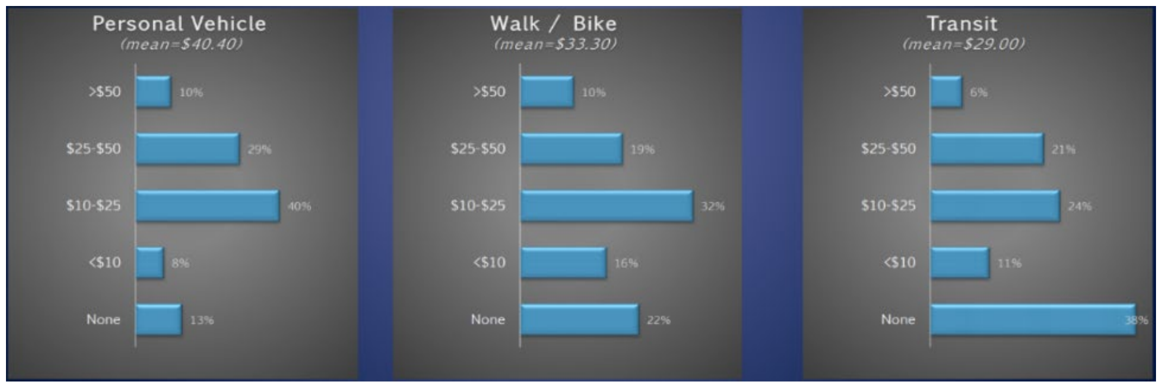



**Figure 7. Lower Fremont Neighborhood Intercept Survey – Spending by Travel Mode**
*(seattle.gov)*

This spending data proved to be the key linkage necessary to develop an economic methodology rooted in sound economic theory for various curb space allocations. While data from Seattle will never provide a perfect match for Arlington County, a review of various Seattle neighborhoods with available economic data identified the Lower Fremont neighborhood as a potential corollary for Arlington County. Data for the Lower Fremont neighborhood was collected in 2019, and because of the neighborhood's proximity to downtown Seattle, built environment, and similar Walk Score[21] and Transit Score[22] as Arlington County, the neighborhood was identified as an appropriate site for testing the economic medthodology. Figure 6 displays the spending by residency and work status, and Figure 7 shows the spending by travel mode from data collected from the 2019 intercept survey for the Lower Fremont neighborhood.

21 https://www.walkscore.com/

22 Transit Score Methodology (walkscore.com)

Using the methodology shown in Figure 8, a test was developed to assess the initial feasibility of using the Seattle data.

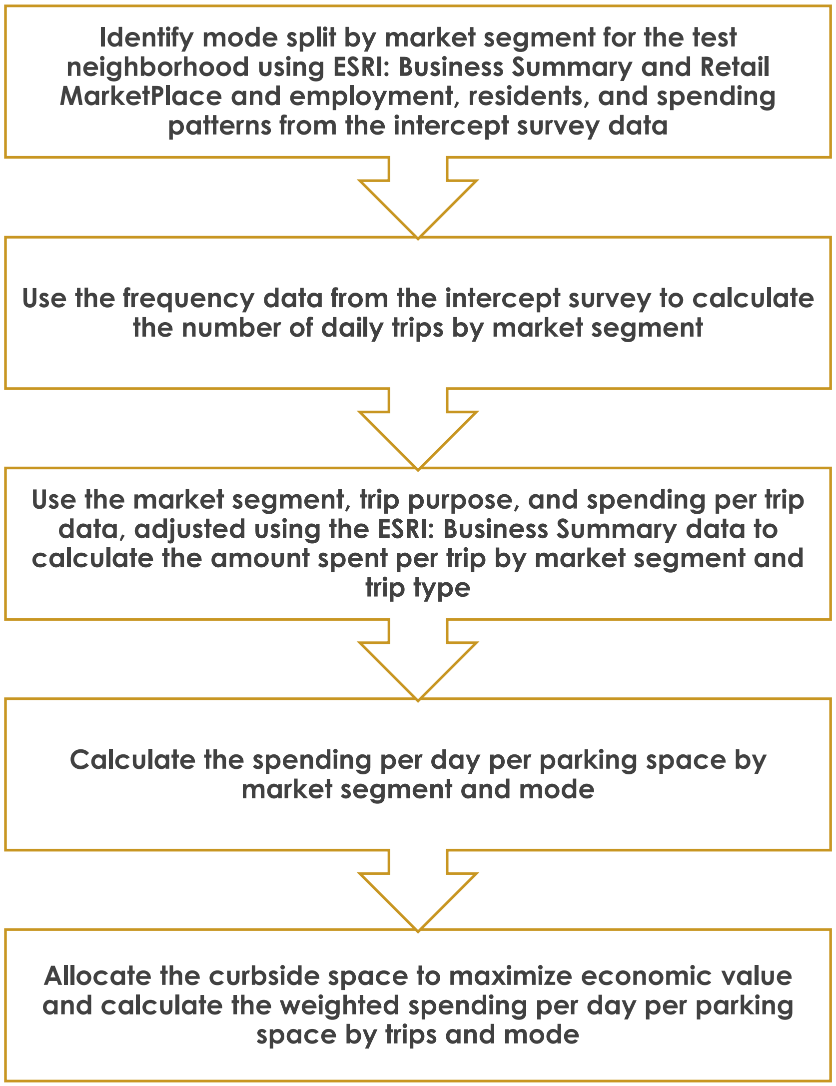



**Figure 8. Test to determine the feasibility of the proposed economic methodology using the Seattle data**

Because the economic value of delivery data was not available from the intercept surveys, the $10,000 in daily sales number from NACTO's Curb Appeal document was used as a placeholder. The project team reached out to the authors of NACTO's Curb Appeal for additional information about the source of the $10,000 in daily sales estimate, but the authors were unable to provide further clarity. While the results of the test demonstrated the high-level feasibility of the proposed economic methodology, as discussed in the Developing the Curb Space Allocation Tool section, the identification of the mode split by market segment data for Arlington County had to be adjusted based on data sources that would be available to users of the tool. While the test demonstrated the feasibility of using the Seattle data, the process had to be adjusted because ESRI: Business Summary and Retail MarketPlace would not be available to all potential tool users. The Economic Value subsection describes these adjustments.

# Section 3
# Literature Review

# LITERATURE REVIEW

While other jurisdictions and researchers have developed a theoretical approach to allocating curb space under the premise that on-street parking is unlikely to provide the greatest economic or societal benefit, Arlington County sought to create a tool that allocates curb space with demand constraints and data relevant to the context of Arlington County. A more comprehensive literature review was undertaken to identify relationships for estimated unconstrained demand, including dependent variables, influencing factors, and relationships for each of the five proposed transportation modules. Approximately ten articles per module were scanned, and relevant articles were reviewed in more detail. In particular, the literature review sought to understand what influences the demand for curb space, which the project team attempted to couple with the available data to allow the model to estimate the unconstrained demand.

## REVIEW SUMMARY

Table 3 through Table 7 summarizes the literature review findings for ridesharing services, commercial loading, transit service, on-street parking, and micromobility services, respectively. It was determined prior to the literature review that because of the potential "limitless" demand for parklets or streateries, constraints on the demand for this non-transportation use would be determined by user input in the model. Consequently, the literature review did not focus on relationships related to these non-transportation uses. The first column of each table provides potential factors influencing the demand of the identified transportation mode, and the second column provides the source, including the reference, the geographic location of the study, and the year of publication. The third column provides additional details and clarifying information, while the last column provides potential input data for the curb space allocation tool.

**Table 3. Literature Review Summary - Ridesharing Services**

| Potential Factors Influencing Demand | Source (Author, Year, Geographic Location of Study) | Details | Potential Input Data |
|---|---|---|---|
| **Age** | Yu and Peng, 2019 & 2020, Austin;<br>Lavieri et al., 2018, Austin;<br>Yan et al., 2020, Chicago. | Depending on the geographic granularity, the age could be described by the median age of the surrounding area. (Most of the study used median age at Census block/tract level). The data could usually be extracted from U.S. Census. | U.S. Census (American Community Survey) |
| **Income Level** | Yu and Peng, 2019 & 2020, Austin;<br>Lavieri et al., 2018, Austin;<br>Yan et al., 2020, Chicago. | Depending on the geographic granularity, the income could be described by the median income of the surrounding area. (Most of the study used median income at Census block/tract level). The data could usually be extracted from U.S. Census. | U.S. Census (American Community Survey) |
| **Education Level** | Yu and Peng, 2019 & 2020, Austin;<br>Lavieri et al., 2018, Austin;<br>Yan et al., 2020, Chicago. | This variable could be calculated in various forms, e.g., can use the % of the population with Bachelor or above degree at the geographic unit. This is similar to other socio-economic factors. This data could be extracted from U.S. Census or City database. | U.S. Census (American Community Survey) |
| **Population to Employment Ratio** | Yu and Peng, 2019 & 2020, Austin. | This variable usually indicates the population and employment balance within the area. For example, a better-balanced area means more short-distance activities and less long-distance car driving. This could be calculated with the formula. Typically, the value ranges between 0-1, with 1 as perfectly balanced from a trip generation's standpoint and 0 as no balance. | Population to employment balance:<br>$$1 - \frac{Employment - 0.5 \times Population}{Employment + 0.5 \times Population}$$<br>*(Population and employment data available from ESRI: Business Summary and Retail MarketPlace with a paid subscription)* |
| **Land Use Mix** | Yu and Peng, 2019 & 2020, Austin. | This variable indicates the extent of land use mix. A greater mixed land use means people do not have to drive a long distance to access parks, shops, eating, etc. Millennials like mixed-used neighborhoods while the elderly like suburban. This could be calculated with the formula, where P could be % of land use type, n is the number of land-use types. 1 means perfectly mixed, while 0 means single-use land use. | $$land\ use\ mix = \sum_i \frac{P_i \times \ln(P_i)}{\ln(i)}$$<br>*(Localized land use data is typically available from open data portals as a shapefile)* |
| **Precipitation** | Gerte et al., 2018, New York City. | Did not use. | ▪ Data could be obtained from National Oceanic and Atmospheric Administration (NOAA) - average daily precipitation.<br>▪ https://www.wunderground.com/ |
| **Population Density** | Yu and Peng, 2019 & 2020, Austin;<br>Lavieri et al., 2018, Austin;<br>Yan et al., 2020, Chicago. | This could be measured by the total population divided by area size (the most used census tract, but it could be calculated by proportion approach, block group, or block-level). Data could be obtained from U.S. Census. | U.S. Census (American Community Survey) |

**Table 4. Literature Review Summary - Commercial Loading**

| Potential Factors Influencing Demand | Source (Author, Year, Geographic Location of Study) | Details | Potential Input Data |
|---|---|---|---|
| **Freight Trip** | Campbell et al., 2018, New York City. | The daily freight trips can be used to estimate commercial loading demand. It will be based on the freight trip attraction (FTA) models from the National Cooperative Freight Research Program (NCFRP) Report 37, "Estimating Freight Generation Using Commodity Flow Survey Microdata." | NCFRP Report 37: $FTA_i = \alpha + \beta E_i$<br>▪ Where E represents the employment sector, alpha and beta are sector-specific coefficients (Refer to Table 9 – FTA Linear Model for recommended values of alpha and beta)<br>(Population and employment data available from ESRI: Business Summary and Retail MarketPlace with a paid subscription) |
| **Service Trip** | Campbell et al., 2018, New York City. | The daily service trips can be used to estimate commercial loading demand. It will be based on the service trip attraction (STA) models from the National Cooperative Freight Research Program (NCFRP) Report 37, "Estimating Freight Generation Using Commodity Flow Survey Microdata." | NCFRP Report 37: $STA_i = \alpha + \beta E_i$<br>▪ Where E represents the employment sector, alpha and beta are sector-specific coefficients (Refer to Table 14 – STA Linear Model for recommended values of alpha and beta)<br>(Population and employment data available from ESRI: Business Summary and Retail MarketPlace with a paid subscription) |
| **Residential Population** | Chen et al., 2017, New York City. | This could be measured by the total population divided by area size (the most used census tract, but it could be calculated by proportion approach, block group, or block-level). Data could be obtained from U.S. Census | U.S. Census (American Community Survey) |
| **Commercial Employees** | Campbell et al., 2018, New York City:<br><br>Jaller et al., 2013, New York City. | Many researchers used commercial employment at the establishment level to estimate commercial loading needs. However, establishment-level data usually requires additional cost to purchase. Therefore, the number of commercial employees at the TAZ level is recommended to use as the proxy. | TAZ data from Arlington County Travel Demand Model (aggregated total within 0.25 miles of the corridor) |
| **Industrial Employees** | Campbell et al., 2018, New York City:<br><br>Jaller et al., 2013, New York City. | Many researchers used industry employment at the establishment level to estimate commercial loading needs. However, establishment-level data usually requires additional cost to purchase. Therefore, the number of industrial employees at the TAZ level is recommended to use as the proxy. | TAZ data from Arlington County Travel Demand Model (aggregated total within 0.25 miles of the corridor) |

**Table 5. Literature Review Summary - Transit Service**

| Potential Factors Influencing Demand | Source (Author, Year, Geographic Location of Study) | Details | Potential Input Data |
|---|---|---|---|
| **Age** | Dill et al., 2013, Portland. | The research used a proportional average of age. Depending on the geographic granularity, the age could be described by the median age of the surrounding area. The data could usually be extracted from U.S. Census. | U.S. Census (American Community Survey) |
| **Income Level** | Dill et al., 2013, Portland;<br><br>Pulugurtha and Agurla, 2012, Charlotte, NC. | The researchers used a proportional average of income level within the buffer area. Depending on the geographic granularity, the income could be described by the median income of the surrounding area. The data could usually be extracted from U.S. Census. | U.S. Census (American Community Survey) |
| **Household Car Ownership** | Dill et al., 2013, Portland;<br><br>Pulugurtha and Agurla, 2012, Charlotte, NC. | This factor could be calculated as the % of HH without cars based on a balanced approach depending on the geographic granularity. The data could usually be extracted from U.S. Census. | U.S. Census (American Community Survey) |
| **Commercial Land Use** | Dill et al., 2013, Portland;<br><br>Lee et al., 2013, Minneapolis;<br><br>Pulugurtha and Agurla, 2012, Charlotte, NC. | The research used 0.25- and 0.5-mile walking distance buffer to get the % of the commercial land-use area. Since this might not be obtained easily, the commercial employment to total employment will be used instead to understand the impact. | U.S. Census (American Community Survey) |
| **Population Density** | Dill et al., 2013, Portland. | This could be measured by the total population divided by area size (the most used census tract, but it could be calculated by proportion approach, block group, or block-level). Data could be obtained from U.S. Census. | U.S. Census (American Community Survey) |
| **Speed Limit** | Pulugurtha and Agurla, 2012, Charlotte, NC. | The approach to the estimated speed limit is not specified in the research. This can be calculated as the average speed limit of roadways within a 0.25-mile buffer of the corridor, weighted by street length. | Roadway Basemap |

**Table 6. Literature Review Summary - On-Street Parking**

| Potential Factors Influencing Demand | Source (Author, Year, Geographic Location of Study) | Details | Potential Input Data |
|---|---|---|---|
| Parking Cost | Lim et al., 2016, Knoxville. | The parking cost of the study site - the study used the parking fees for the parking facility. | Default |
| Walking Cost | Lim et al., 2016, Knoxville. | Each of the walk trips attracted to the parcel from the parking facility has a different cost. This could be calculated as (D/V)*VOT, where D is the walking cost from the facility to an adjacent parcel, V is the walking speed, and VOT is the value of time for walking ($23.9 per hour as recommended). Because V and VOT are fixed, the weighted walking distance by users is used. | TAZ data from Arlington County Travel Demand Model (aggregated total within 0.25 miles of the corridor) |
| Presence of Mixed-use Developments | McGuiness and McNeil, 1991, Pittsburgh:<br><br>Marshall and Garrick, 2006, multiple cities in the U.S. | Marshall and Garrick 2006 find that it is surprising to note that the towns with mixed-use centers demanded almost as much parking for new construction as did the towns where the conventional sites are located. There is no empirical model from the research, but it provided groundwork on why land use mix affects parking demand. | Did not use |

**Table 7. Literature Review Summary - Micromobility Services**

| Potential Factors Influencing Demand | Source (Author, Year, Geographic Location of Study) | Details | Potential Input Data |
|---|---|---|---|
| Age | Hosseinzadeh et al., 2020, Louisville. | Depending on the geographic granularity, the age could be described by the median age of the surrounding area. (Most of the study used median age at Census block/tract level). The data could usually be extracted from U.S. Census. | U.S. Census (American Community Survey) |
| Income Level | Sohrabi and Ermagun, 2021, Washington, DC. | Depending on the geographic granularity, the income could be described by the median income of the surrounding area. (Most of the study used median income at Census block/tract level). The data could usually be extracted from U.S. Census. | U.S. Census (American Community Survey) |
| Commercial Coverage | Caspi et al., 2021, Austin. | The research created a grid cell within its study area and calculated the percentage of commercial land use within the station buffer (200m). As an alternative, commercial employment to total employment will be used to understand the impact. | U.S. Census (American Community Survey) |
| Residential Coverage | Hosseinzadeh et al., 2020, Louisville;<br><br>Caspi et al., 2021, Austin;<br><br>Sohrabi and Ermagun, Washington, D.C., 2021; | Sohrabi and Ermagun's research used population density as a proxy of the residential coverage. Caspi et al.'s research created a grid cell within its study area and calculated the percentage of residents within the station buffer (200m). Therefore, the total population divided by area size will be used. | U.S. Census (American Community Survey) |
| Points of Interest (POI) Density | Hosseinzadeh et al., 2020, Louisville;<br><br>Sohrabi and Ermagun, 2021, Washington, DC. | The research used a 300-meter buffer to calculate the number of POI around the study facility. Depending on data availability, POI could be hotels, museums, shopping centers, parks, schools, etc. | POI Data |
| Infrastructure Density | Sohrabi and Ermagun, 2021, Washington, DC. | The research used a 300-meter buffer to calculate the number of transportation infrastructure, including bike stations, carsharing stations, bus stops, metro stations, etc. These types of variables could be calculated by a different type of infrastructure depending on the data availability. | District of Columbia Open Data Portal |

# DATA

The literature review also revealed data that would be needed for both the demand and allocation aspects of the model. Within the subsequent section, "Developing the Curb Space Allocation Tool," the data inputs used to calculate the demand are discussed in more detail in the "Calculating the Demand" subsection, and the data used to allocate the curb space are discussed in more detail in the "Allocating the Curb Space" subsection.

The project team anticipated challenges due to the understood lack of fine-grained local data for each of the six modules. Where possible, data proxies or alternate data were utilized to fill the data gaps and enable the model to provide reasonable outputs. Local data (first from Arlington County and then from regional jurisdictions, most notably the District of Columbia) was prioritized when possible. When local data wasn't available, the most recent data available was utilized.

As discussed in the Future Research and Identified Gaps section, more data is necessary for future tool refinements. Demand estimation procedures for ridesharing and micromobility are in their infancy within the transportation industry. While the curb space allocation model provides reasonable outputs for ridesharing and micromobility demand, new data and demand procedures would allow more robust demand calculations for these two modules. While it is understood that the private operators of both ridesharing and micromobility services have internal data that would allow for these more robust demand calculations, this data is not currently available to practitioners. In a similar vein, the published research and available data regarding commercial loading are relatively thin. A clear identified gap in research concerning commercial loading was identified as part of this research. As commercial loading providers strive to convert curb space to delivery zones, delivery zones' usage and economic outputs would provide greater justification for the conversion.

# Section 4
# Developing the Curb Space Allocation Tool

# DEVELOPING THE CURB SPACE ALLOCATION TOOL

## CALCULATING THE DEMAND

For each of the six modes, the potential factors influencing demand identified in the literature review were cross-checked with available data, and regression models were attempted. As described in this section, regression models were developed for the ride-hailing service and transit service modules and attempted for the commercial loading module. Micromobility demand is estimated based on different typological zones, as described in the subsequent section. For simplicity, on-street parking demand was essentially considered "limitless," although a limit of 100 on-street spaces per hectare was applied based on the typical density of parking supply in major cities.[23]

## RIDE-HAILING SERVICES

As identified within the literature review, several socio-economic indexes and land-use factors could impact ride-hailing service demand. Therefore, regression models were proposed to estimate the ride-hailing service demand for Arlington County based on the local data.

### Data Inputs

The following data inputs were obtained for the model development:

#### *Arlington County 2019 Census Data*

- At the block level.
- Attributes include median age, median income, percent of the population with a bachelor's degree or higher, population density.

#### *Arlington County 2019 TAZ Socio-Economic Data*

- Obtained from the Arlington County, travel demand model.
- Attributes include population, industrial employment, retail employment, office employment, and other employment.

#### *Arlington County 2019 Ride-hailing (TNC) Pick-up & Drop-off (PUDO) Data*

- Provided by SharedStreets through a license to Arlington County.
- The data is intended for use in an aggregate form for planning and policy analysis.
- Weekend bin data includes records from February 28, 2019, through March 25, 2019, and weekday bin data contains records from April 29, 2019, through June 10, 2019.
- The bin data was downloaded by predefined periods (AM, Midday, PM, Night) instead of hourly or daily.

23 http://escholarship.org/uc/item/485983zw?view=search

## *Data Clean-up*

A preliminary review of the pick-up/drop-off (PUDO) data from SharedStreets for both the weekday and weekend datasets identified two locations warranting a closer look. The first was an extremely heavy weekday PUDO activity in Rosslyn on the eastern side of Lynn Street between 19th Street and the I-66 eastbound on-ramp, shown in Figure 9, and the second was heavy weekend PUDO activity along Wilson Boulevard near the Clarendon Metro Station shown in Figure 10.

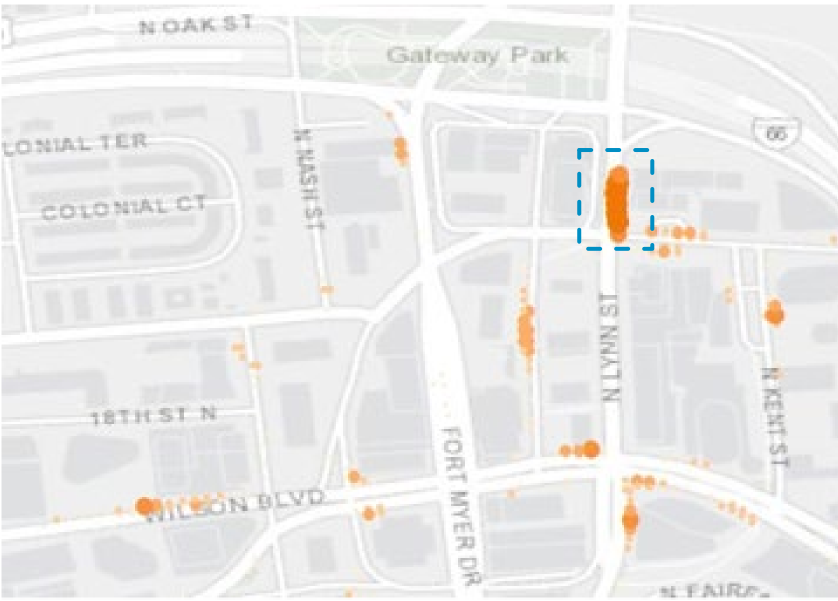



**Figure 9. Weekday PUDO Activity in Rosslyn with significant activity on the east side of Lynn Street north of 19th Street highlighted**

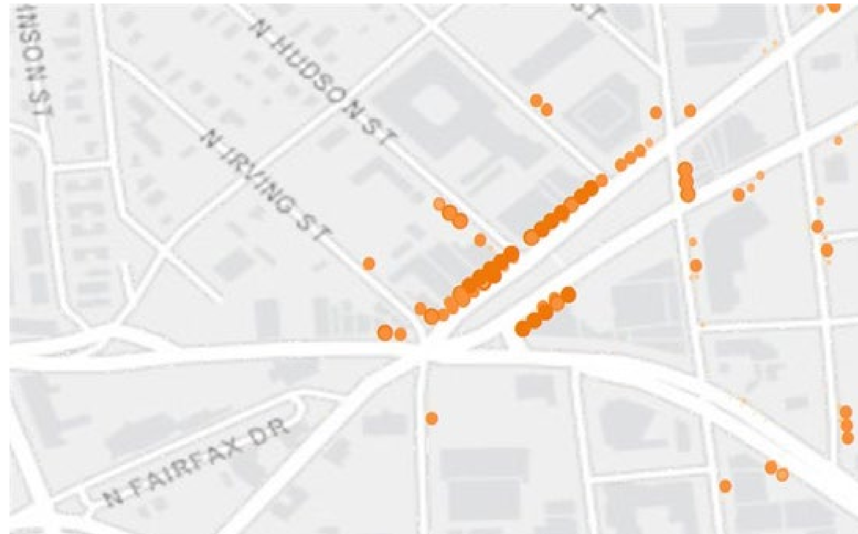



**Figure 10. Weekend PUDO Activity near the Clarendon Metro Station**

A root cause analysis was performed to identify potential explanations for the activity – particularly for the Rosslyn location, which by the magnitude of usage was significantly higher than any other location in the County. A review of Google Street View imagery from the last seven years and conversations with County staff identified a semi-official pick-up/drop-off location in front of the office building on Lynn Street. Per discussions with County staff, specific bin data records were removed from the weekday dataset as outliers, including:

- RefId: 6d066831e08131e4abd2c4cd6700475c.
- Removed daily, AM, Midday, and PM data points for bins 3, 4, and 5.
- Removed daily and AM data points for bin 6.

The same preliminary review process was conducted for the weekend data near the Clarendon Metro Station. Many bars, clubs, and restaurants are located in this area, where heavy PUDO activity would be expected. Therefore, no additional data clean-up was conducted for the weekend PUDO dataset.

## Regression Model Development

### Regression Model Inputs

Based on the literature review, six different attributes were used as influencing factors, with the PUDO demand data considered the dependent variable for the demand estimation regression models:

- **Influencing Factors:** Median age, median income, percent of the population with a bachelor's degree or higher, population density, population to employment ratio, land use mix
- **Dependent Variable:** TNC PUDO Demand

Rather than assuming all blocks or zones are accessible within one-quarter mile of the designated study corridor, a distance decay curve was implemented to reflect better how far people will walk to a destination. The distance decay curves were based on Iacano et al.'s 2008 research shown in Figure 11. [24]

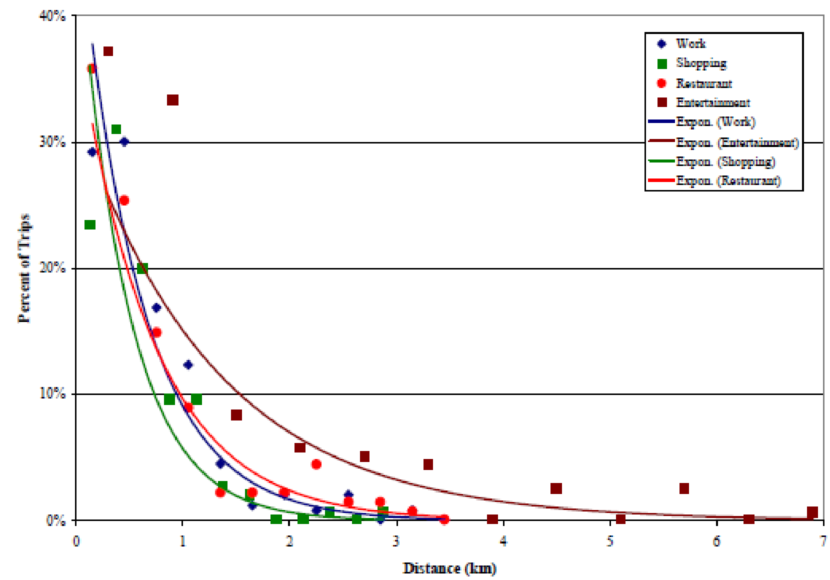



**Figure 11. Distance Decay Curves for Walking Trips** [25]

### Regression Analysis

The final regression formulas for the ride-hail service demand are summarized in Table 8.

$$D_{weekday} = A_0 + A_1 x_{median\ age} + A_2 x_{median\ income} + A_3 x_{percent\ with\ bachelor's} + A_4 x_{population\ density} + A_5 x_{population\ to\ employment\ ratio} + A_6 x_{land\ use\ mix}$$

**Equation 7. Ride-hailing service regression equation**

[24] Iacono, Michael, Kevin Krizek, and Ahmed M. El-Geneidy. "*Access to destinations: How close is close enough? Estimating decay functions for multiple modes and different purposes.*" (2008).

[25] ibid

**Table 8. Ride-hailing Service Regression Model**

| Coefficients: | Estimate | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| (Intercept) ($A_0$) | 7.036e+01 | 9.100e+00 | 7.732 | 1.12e-14 *** |
| $median\ age$ ($A_1$) | 2.481e-01 | 2.279e-01 | 1.089 | 0.276307 |
| $median\ income$ ($A_2$) | -1.448e-04 | 2.759e-05 | -5.25 | 1.54e-07 *** |
| $percent\ with\ bachelor's$ ($A_3$) | 1.312e-02 | 7.252e-02 | 0.181 | 0.856466 |
| $population\ density$ ($A_4$) | -3.886e-04 | 1.139e-04 | -3.414 | 0.000643 *** |
| $population\ to\ employment\ ratio$ ($A_5$) | 4.908e+01 | 1.545e+01 | 3.177 | 0.001492 ** |
| $land\ use\ mix$ ($A_6$) | -3.944e+01 | 5.785e+00 | -6.818 | 9.60e-12 *** |
| Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1<br>Residual standard error: 35.59 on 14869 degrees of freedom<br>Multiple R-squared: 0.01138, Adjusted R-squared: 0.01098<br>F-statistic: 28.52 on 6 and 14869 DF, p-value: < 2.2e-16 | | | | |

## COMMERCIAL LOADING

Regression models for the commercial loading module were attempted, but as described, the failure to identify a model with reasonable outputs prompted the team to use a rate of commercial loading spaces per curb space length adjusted to an average value based on an approximate service area.

Because commercial loading zone data was unavailable for Arlington, data from parkDC was utilized.[26] For the parkDC project, the collected data was used to evaluate double-parking in loading zones before (May 2015) and after (January 2018) loading zones pricing and expanded hours of operation were implemented in 2017. The data includes loading zone location, loading zone hours of operation, data collection date, and the arrival and departure time of all passenger cars and commercial vehicles using the loading zone. Duration of stay for all commercial vehicles using the loading zones was calculated from the dataset and categorized by predefined periods (AM, Mid-day, PM, Night) instead of hourly or daily. The attempted regression models were built using influencing characteristics surrounding the District's Penn Quarter/Chinatown neighborhoods where the loading zones are located.

[26] https://wiki.ddot.dc.gov/display/RL/ParkDC+DataBook

## Data Inputs

The following data inputs were obtained for the model development:

### *Arlington County 2019 TAZ Socio-Economic Data*

- Obtained from the Arlington County, travel demand model.
- Attributes include population, industrial employment, and retail employment

### *parkDC Commercial Loading Data*

- This data was borrowed from parkDC

## Regression Model Development

### *Regression Model Inputs*

Based on the literature review, five different attributes were used as the influencing factors, while the parkDC commercial loading data was considered as the dependent variable for the demand estimation regression models:

- **Influencing Factors:** Freight trips at zone level, service trips at zone level, population, industrial employees, commercial employees.
- **Dependent Variable:** Commercial loading demand.

Considering the commercial loading trip characteristics, a limited walking distance was assumed. Therefore, rather than use the distance decay curves as discussed in the Ride-hailing Services section, the variables of the adjacent zones to the study corridor were the only values considered in the regression model.

**Figure 12. Commercial loading activity on 12th Street in the Clarendon neighborhood**

### *Regression Analysis*

The final regression formula attempted for the commercial loading demand is summarized in Table 9.

$$D_{weekday} = A_0 + A_1 x_{freight\ trips} + A_2 x_{service\ trips} + A_3 x_{total\ population} + A_4 x_{industrial\ employeess} + A_5 x_{commercial\ employees}$$

**Equation 8. Commercial loading regression equation**

Although the developed regression model shown in Table 9 produced the most reasonable demand estimates compared to previous model attempts, testing the curb space tool identified issues with the reasonableness of model results. As a result, the commercial loading regression model was replaced with a value that provides a simple average commercial loading zone demand value based on the parkDC commercial loading data. This value is applied using a rate of commercial loading spaces per curb space length defined by user inputs. The Future Research and Identified Gaps section noted that collecting Arlington County-specific loading zone data would substantially upgrade the curb space allocation tool and is likely the highest priority research gap in the current tool.

**Table 9. Commercial Loading Regression Model**

| Coefficients: | Estimate | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| (Intercept) ($A_0$) | 7.484e+02 | 3.560e+02 | 2.102 | 0.0649 |
| ***freight trips*** ($A_1$) | 1.730e+01 | 9.260e+00 | 1.868 | 0.0946 |
| ***service trips*** ($A_2$) | -8.554e+03 | 4.450e+03 | -1.922 | 0.0868 |
| ***total population*** ($A_3$) | -1.155e-01 | 5.764e-02 | -2.004 | 0.0761 |
| ***industrial employees*** ($A_4$) | 1.548e+00 | 7.906e-01 | 1.958 | 0.0819 |
| ***commerical employees*** ($A_5$) | 2.308e+03 | 1.201e+03 | 1.922 | 0.0868 |

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 9.19 on 9 degrees of freedom

Multiple R-squared: 0.5734

F-statistic: 28.52 on 6 and 14869 DF, p-value: < 2.2e-16

# TRANSIT SERVICE

A wide variety of tools are used within the transportation industry to estimate transit ridership and demand, including travel demand models and the Federal Transit Administration's (FTA) Simplified Trips-on-Project Software (STOPS).[27] Because these tools require significant inputs and calibration, they were not considered feasible options for the curb space allocation tool. As a result, simplified regression models were developed based on the literature review summary to estimate the transit service ridership demand.


**Figure 13. Arlington Transit (ART) bus servicing a transit stop in the Ashton Heights/Ballston neighborhood**

## Data Inputs

The following data inputs were obtained for the model development:

### *Arlington County 2019 Census Data*

- At the block level.
- Attributes include median age, median income, household car ownership, and population density.

### *Arlington County 2019 TAZ Socio-Economic Data*

- Obtained from the Arlington County, travel demand model.
- Attributes include retail employment and total employment.

### *Arlington County Roadway Speed Limit Data*

- Provided by Arlington County.
- Reflects the posted speed limit in early 2020 (pre-pandemic)

### *Washington Metropolitan Area Transit Authority (WMATA) and Arlington Transit (ART)*

- Arlington County provided the year 2019 Arlington Transit (ART) ridership data, and the project team had access to October 2019 Washington Metropolitan Area Transit Authority (WMATA) Metrobus ridership data. The data were summarized by predefined periods (AM, Mid-day, PM, Night) at the station level.

27 STOPS – FTA's Simplified Trips-on-Project Software | FTA (dot.gov)

## Regression Model Development

### Regression Model Inputs

Based on the literature review, six different attributes were used as the influencing factors while the processed ridership data was considered as the dependent variable for the demand estimation regression models:

- **Influencing Factors**: Median age, median income, household car ownership, population density, commercial land use percentage, speed limit
- **Dependent Variable**: Overall ridership demand (total of WMATA and ART ridership)

Rather than assuming all the blocks or zones are accessible within one-quarter mile of the designated study corridor, a distance decay curve was implemented to reflect how far a person would be likely to walk to or from their destination. The same distance decay curve used for the ridesharing service was applied for the transit service.

### Regression Analysis

The final regression formula attempted for the commercial loading demand is summarized in Table 10.

$$D_{weekday} = A_0 + A_1 x_{median\ age} + A_2 x_{median\ income} + A_3 x_{car\ ownership} + A_4 x_{population\ density} + A_5 x_{commercial\ land\ use} + A_6 x_{speed\ limit}$$

**Equation 9. Transit service regression equation**

**Table 10. Transit Service Regression Model**

| Coefficients: | Estimate | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| (Intercept) ($A_0$) | 1.44e+03 | 1.80e+02 | 7.964 | 4.61e-15 *** |
| $\boldsymbol{median\ age}$ ($A_1$) | -3.12e+01 | 4.10E+00 | -7.605 | 6.66e-14 *** |
| $\boldsymbol{median\ income}$ ($A_2$) | 4.68e-04 | 3.19e-04 | 1.467 | 0.14277 |
| $\boldsymbol{car\ ownership}$ ($A_3$) | 1.19e+03 | 3.69e+02 | 3.214 | 0.00135 ** |
| $\boldsymbol{population\ density}$ ($A_4$) | -1.30e-02 | 2.34e-03 | -5.565 | 3.38e-08 *** |
| $\boldsymbol{commercial\ land\ use}$ ($A_5$) | -3.24e+02 | 1.36e+02 | -2.38 | 0.01752 * |
| $\boldsymbol{speed\ limit}$ ($A_6$) | -4.11e+00 | 2.15e+00 | -1.915 | 0.05582 |
| Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1<br>Residual standard error: 199.2 on 977 degrees of freedom<br>Multiple R-squared: 0.09004, Adjusted R-squared: 0.08446<br>F-statistic: 16.11 on 6 and 977 DF, p-value: < 2.2e-16 | | | | |

## ON-STREET PARKING

While on-street parking likely has more literature and research than all the other modes combined, this prior research made clear that the demand for parking is directly tied to the amount of parking provided, up to the point at which demand is saturated. Therefore, a key data input for calculating the demand for on-street parking would be the total supply of on-street parking in the area, which was not available. Because of the lack of available parking inventory data, coupled with the understanding that no location in Arlington County being considered for a reallocation of the curb space likely has sufficient on-street space to fulfill the saturated demand, the on-street parking demand was essentially considered "limitless" for the purposes of the allocation tool model. Even so, an upper limit of 100 on-street spaces per hectare was applied based on the typical density of parking supply in major cities.[28]


**Figure 14. On-street parking adjacent to commercial uses on 23rd Street in the Aurora Highlands neighborhood**

28 http://escholarship.org/uc/item/485983zw?view=search

## MICROMOBILITY

Micromobility ridership results from a range of factors like vehicle availability, land-use, and existing mode share characteristics. While academic papers propose statistical models for estimating bike-share demand, none are easily replicable for this study. Instead, the study team adopted a sketch-level modeling approach to estimate micro-mobility demand. This approach relies on dividing Arlington County into different typological zones based on the presence of specific features. This process is loosely built on the bikeshare demand methodology previously developed for Arlington County.[29] Typologies are categorized as follows:

- **High Ridership Demand**

  Typically, central business districts and major transportation hubs. In Arlington, we would expect places like Crystal City and Rosslyn would fall into this category.

- **Moderate Ridership Demand**

  Typically, densely developed neighborhoods are in proximity to key activity centers. In Arlington, these would include areas adjacent to high-ridership demand areas.

- **Low Ridership Demand**

Areas with suburban land uses and more auto-oriented land uses. Examples in Arlington would include Aurora Highlands and North Arlington.

**Figure 15. Micromobility Zone in Arlington County near the East Falls Church Metro Station**

[29] http://www.bikearlington.com/wp-content/uploads/2017/07/CaBi_TDP_ESummary_LowRes.pdf

## Data Inputs

The following data inputs were obtained for the model development:

### Shared Micro-mobility Device Trips

- 453,690 shared mobility device trips during the pilot period (October 2018-December 2019) in Arlington.[30]

### Capital Bikeshare Trips

- Calendar year 2019 Capital Bikeshare Trip data obtained from the Capital Bikeshare System Data website[31]
- Data Source: Calendar Year 2019 Capital Bikeshare Trips
- Filter to trips that start or end in Arlington.
- 258,681 Capital Bikeshare trips started in Arlington in 2019.
- Stations with a high number of trip starts also had a high number of trip ends.

### Other Data

- Capital Bikeshare Stations: Provides information on station location and station dock capacity.
- U.S. Census American Community Survey and Longitudinal Employer-Household Dynamics: Inputs to calculate job and population density in the study area.

## Demand Estimation Methodology

### Defining Typologies

Typologies were defined based on existing station-level Capital Bikeshare ridership. Existing land use patterns were used as a secondary input. Figure 16 shows the results of the typology identification through the following steps:

1. Calculate annual ridership by capital bikeshare stations for the year 2019.
2. Determine stations with high, moderate, and low ridership.
    a. High Ridership Stations: ~5,000 or more trips annually
    b. Moderate Ridership Stations: ~1,500-4,999 trips annually
    c. Low Ridership Stations: ~1,499 or fewer trips annually
3. Draw ¼-mile buffers around high ridership stations. This buffered area will become the area designated as the High Ridership Demand typology.
4. Draw ¼-mile buffers around moderate ridership stations. Eliminate the buffered areas around the moderate ridership stations that overlap with the high ridership demand station buffers. The remaining buffered area will become the area designated as the Moderate Ridership Demand typology.
5. The area remaining in Arlington County that is not part of the High or Moderate Ridership Demand typologies is designated as the Low Ridership Demand typology.

30 https://arlingtonva.s3.amazonaws.com/wp-content/uploads/sites/19/2019/11/ARL_SMD_Evaluation-Final-Report-1112.pdf

31 System Data | Capital Bikeshare

### *Determining Trip Demand*

Once typologies were created, micro-mobility trips per acre and micro-mobility trips per bike per acre can be calculated for each typology. Table 11 summarizes the final micromobility demand trip rates through the following steps:

1. Intersect Capital Bikeshare stations with the typologies, so each station is associated with a typology.
   a. Lower ridership stations within a ¼-mile of a higher ridership station will fall into the typology of the higher ridership station. For example, less than 5,000 trips started at the station located at Wilson Blvd & N Quincy St, but the station is located within the High Ridership Demand typology because it is within a ¼ mile of the Ballston Metro Capital Bikeshare Station, where more than 5,000 trips began in 2019.
2. Calculate the total number of trips that started in each typology.
3. Calculate the average daily trips per typology (total annual trips divided by 365 days).
4. Determine the acreage of each typology.
   a. A Capital Bikeshare service area was determined for each typology. The service area is not equivalent to the full area of the typology but is limited to the areas within a ¼-mile of each Capital Bikeshare station.
   b. If a station is within a ¼-mile of a typology buffer, the buffer area outside of the typology is not included in the total service area.
5. Calculate trips per acre (sum of trips starting at stations in a typology divided by the total acreage of each typologies Capital Bikeshare service area.
6. Scale-up typology trips per acre for shared micromobility vehicles.
   a. In 2019, Arlington had about 1.75 dockless mobility trips (e.g., dockless scooters) per Capital Bikeshare trips.

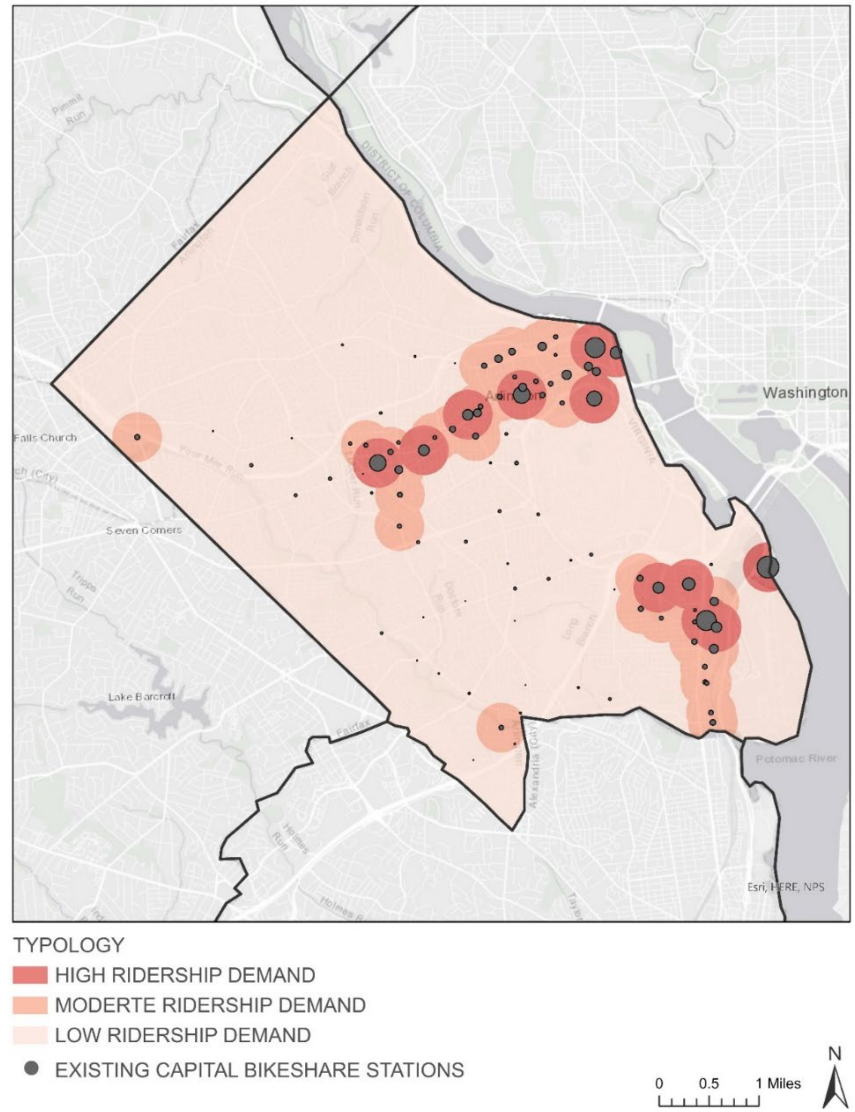



**Figure 16. Micromobility Demand Typologies in Arlington**

**Table 11. Micromobility Demand Estimation Summary**

| Micromobility Typology | Example | Capital Bikeshare Daily Trips | Shared Micromobility Daily Trips | Capital Bikeshare Daily Trips per Acre | Shared Micromobility Trips per Acre | Total |
|---|---|---|---|---|---|---|
| **High Ridership Demand** | Central business districts and major transportation hubs | 433 | - | 0.36 | 0.63 | **0.99** |
| **Moderate Ridership Demand** | Densely developed neighborhoods in proximity to key activity centers | 171 | - | 0.12 | 0.21 | **0.32** |
| **Low Ridership Demand** | Areas with suburban and more auto-oriented land-uses | 105 | - | 0.03 | 0.05 | **0.08** |
| **Arlington County Total** | | **709** | **1,243** | | | |

### *Temporal Consideration*

The micromobility demand was estimated at the daily level. A time-of-day factor was then applied to convert the daily demand to specific time-period demand. Figure 17 and Figure 18 depict the number of Shared Mobility Device (SMD) trips in Arlington County by the time of the day for weekdays and weekends, respectively. The SMD trip distribution time profile data were analyzed via a data extraction tool[32] and are summarized in Table 12.

**Table 12. Micromobility Daily to Period Ratio**

| Demand Period | Daily to Period Ratio |
|---|---|
| **Morning Weekday** | 0.146 |
| **Evening Weekday** | 0.290 |
| **Midday Weekday** | 0.374 |
| **Night-time Weekday** | 0.190 |
| **Morning Weekend** | 0.081 |
| **Evening Weekend** | 0.285 |
| **Midday Weekend** | 0.435 |
| **Night-time Weekend** | 0.199 |

32 https://automeris.io/WebPlotDigitizer/index.html

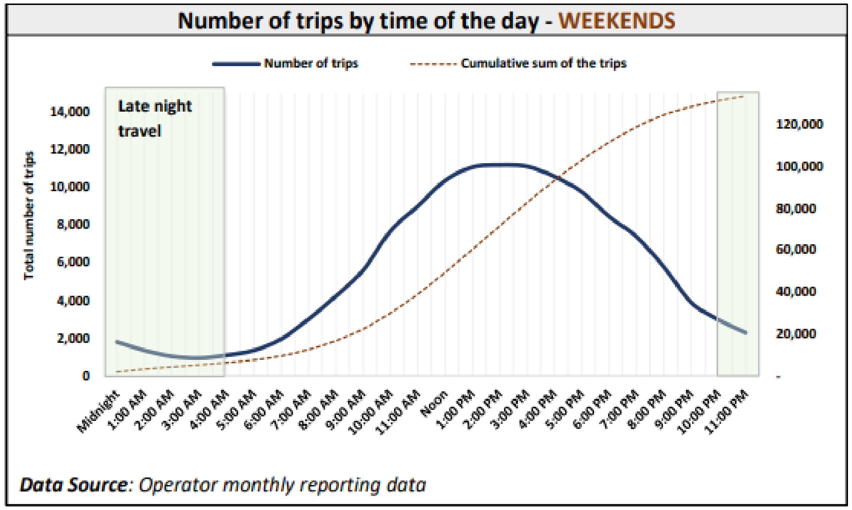



**Figure 17. Distribution of Shared Mobility Device trips by the time of the day on weekends**
*Source: Figure 21, Arlington County Shared Mobility Devices Pilot Evaluation Report, September 2019*

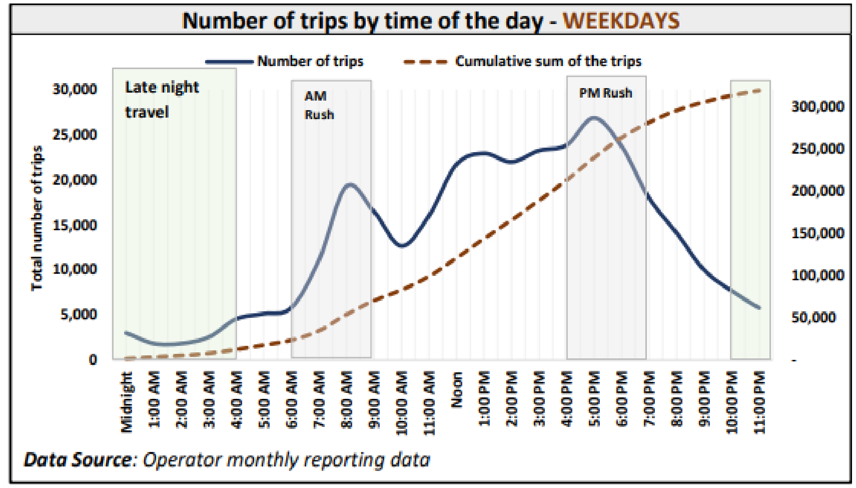



**Figure 18. Distribution of Shared Mobility Device trips by the time of the day on weekdays**
*Source: Figure 21, Arlington County Shared Mobility Devices Pilot Evaluation Report, September 2019*

## NON-TRANSPORTATION USES

While the usage of curb side space for non-transportation use such as parklets had grown in popularity over the last 10 to 15 years, during the COVID-19 pandemic, the demand for this space grew substantially, especially to be used as "streateries," which are defined as parklets with curbside table service. Due to the quickly evolving nature of the use of curb space for parklets and streateries, combined with the lack of available data and understanding that the use of curb space as a parklet or streatery largely depends on the fronting business type along with other considerations such as safety and local policy, it was decided that user input in the model would determine constraints on the demand for these uses.


**Figure 19. Parklet/Streatery in Arlington County**

# ALLOCATING THE CURB SPACE

After identifying the demand for each of the six modes, the model needs to allocate the curb uses within the available space by maximizing the potential curb space allocation's economic and societal values. This section describes the constraints placed on this allocation, including the curb space requirements for each curb space use, the effective capacity, and the identified economic and societal values for maximizing the allocation.

## CURB SPACE REQUIREMENTS

The length of required curb space for each mode was identified through conversations with County staff involved in development review and right-of-way design. Through these conversations, a standard curb length was identified for each curbside use. It is understood that the location of the curbside use on the blockface influences the length necessary for each particular use. For instance, a transit stop located mid-block requires 130 feet of curb space to allow the bus to pull in and pull out, while a transit stop located farside at an intersection only requires 70 feet of curb space because the bus can pull into the transit stop while traveling through the intersection.

A future version of the curb space model could require users to input the existing length of each curb segment and the location of each segment on a block face to allow for the tool to use varying curb lengths for each mode. However, at this time, the model assumes a practitioner would adjust the curb space allocation outputs spatially as the identified allocation is applied. Table 13 summarizes the identified curb space length requirements by use.

## EFFECTIVE CAPACITY

An effective maximum number of trips or events that can use the curb for each mode was calculated to provide a constraint on the number of trips or events reasonably expected to use the curb under a peak hour condition. While the true capacity is likely higher for each mode, the effective capacity was intended to use reasonable data to estimate the capacity under "productive" but not "overwhelming" conditions of available curbside space. A rideshare capacity of 18.91 trips/hour was derived using dwell time data from the Cincinnati Curb Study[33] and equations from the Transit Capacity and Quality of Service Manual (TCQSM).[34] A commercial loading zone capacity of 0.83 deliveries/hour was calculated using the length of stay (50 minutes) observed in the loading zone dataset. The transit stop capacity of 25 stops/hour was found in the TCQSM using reasonable assumptions based on the County's context. The on-street parking capacity of 0.73 parked cars/hour was based on data from the Cincinnati Curb Study and cross-checked with data from parkDC.[35] Table 14 displays the effective capacity of the curb space uses.

33 https://issuu.com/fehrandpeers/docs/cincinnaticurbstudy_2019-01

34 Transit Cooperative Research Program (TCRP) Report 165: Transit Capacity and Quality of Service Manual, Third Edition

35 https://trid.trb.org/view/1741681

**Table 13. Identified Curb Space Length Requirements**

| Use | Curb Space Desired | Curb Length Used in Allocation Tool | Notes |
|---|---|---|---|
| **Ride-hailing Service** | 25 feet (Farside)<br>30 feet (Nearside)<br>40 feet (Mid-block) | 40 feet | Assumptions based on guidance in the ITE Curbside Management Practitioners Guide |
| **Commercial Loading** | 40 feet | 40 feet | Forty feet is long enough for either one single-unit 30-foot truck (SU-30) or two standard vehicles. |
| **Transit Service** | 40 feet (Stop in travel lane)<br>70 feet (Farside)<br>100 feet (Nearside)<br>130 feet (Mid-block) | 100 feet | Space is required for a bus to pull in and out of the bus stop. |
| **Micromobility** | 10 feet | 10 feet | No current standards or guidelines exist. These are generally installed in leftover space that wouldn't fit a parking stall. |
| **On-Street Parking** | 20 feet | 20 feet | ADA stalls require 26 feet |
| **Non-Transportation Uses** (Parklets and Streateries) | 40 feet | 40 feet | 40 feet includes a minimum of a 30-foot long parklet and a 5-foot buffer on both sides of the parklet per County requirements |
| **Walking** (Not included in model) | N/A | | N/A |

**Table 14. Effective capacity of curb space uses**

| Use | Effective Capacity |
|---|---|
| **ide-hailing Service** | 18.91 PUDOs/ hour (3 minutes, 10 seconds per pick-up/drop-off) |
| **Commercial Loading** | 0.83 deliveries/ hour (50 minutes per delivery) |
| **Transit Service** | 25 stops/hour (2 minutes, 24 seconds per stop) |
| **Micromobility** | 200 trips/day |
| **On-Street Parking** | 0.73 parked cars/ hour (43 minutes, 48 seconds per stay) |
| **Non-Transportation Uses (Parklets and Streateries)** | N/A |

## ECONOMIC VALUE

Using the previously discussed economic methodology, the economic value associated with each mode was calculated. While the preference was to estimate the economic value for each mode based on the identified location of the curb space, because users would not have access to the number of residents and employees or retail and eat/drink sales that are available through ESRI: Business Summary and Retail MarketPlace, an alternative method was developed. Because most of the tool usage is expected to be in Arlington's three high-density, transit-oriented planning corridors, the economic methodology was used to calculate the economic value by mode for each of the three corridors. Using this methodology, a location at least partially within one of the three corridors will use the economic value specific to that corridor. A selected location completely outside of the three corridors will use a countywide average, while a location that overlaps two corridors will utilize a weighted average of the economic value of the areas selected. For each of the three corridors, mode split assumptions by trip type (resident, worker, visitor) were developed based on the data from the Fremont neighborhood in Seattle and adjusted using Walk Score[36] and Transit Score.[37] The total number of residents and employees and the inflow and outflow of retail and eat/drink sales were used to calculate the total daily spending by market segment and mode per trip.

The economic value of the parklet/streatery was derived using a restaurant industry metric, suggesting that lease costs should account for no more than 5% of a restaurant's total revenue. Using an approximate lease cost of $55/square foot/year for Arlington (the mid-range of numbers in the County based on a high-level scan of several restaurant lease websites), and then accounting for a parklet/streatery being 100% "dining room" space rather than "back of house" (kitchen or storage) space, along with an estimated size of 210 square feet (30-foot curb length and 7-foot width), estimated daily sales of $1,265.75/parklet were calculated. This estimate serves as the average estimate of daily sales and considers some restaurants open only a limited number of hours or days of the week.

Table 15 displays the calculated economic value per person trip by Arlington planning corridor by mode.

**Table 15. Economic value per-person trip by curb space use**

| Use | Economic Value (spending per person-trip) | | |
|---|---|---|---|
| | Rosslyn-Ballston Corridor | Richmond Highway Corridor | Columbia Pike Corridor |
| **Ride-hailing Service** | $12.88 | $53.07 | $7.75 |
| **Commercial Loading** | $500/delivery | | |
| **Transit Service** | $11.38 | $48.10 | $6.83 |
| **Micromobility** | $18.31 | $40.58 | $7.76 |
| **On-Street Parking** | $12.88 | $53.07 | $7.75 |
| **Non-Transportation Uses (Parklets and Streateries)** | $1265.75 daily sales per parklet/streatery | | |
| **Walking** (Not included in model) | $28.72 | $42.23 | $8.45 |

36 https://www.walkscore.com/methodology.shtml

37 https://www.walkscore.com/transit-score-methodology.shtml

## SOCIETAL VALUE

The societal value provides the number of people expected to access the curb space with each mode. The commercial loading and micromobility modes were estimated as one rider/trip based on the user characteristics of those modes. The ride-hailing estimate of 1.24 persons/trip was based on a mid-range of average vehicle occupancy information found in the reviewed literature, and the on-street parking estimate of 1.5 persons/trip was based on a general rule of thumb concerning vehicle occupancy data by the travel demand modeling community. The estimate of 160 daily patrons/parklet/streatery was calculated using a general rule of thumb of 14 square feet/patron/hour and factored using an assumed 210 square feet along with the percent of sales by time of day from an example restaurant and quick-service establishment to calculate a daily number. Table 16 displays the calculated societal value by mode.

**Table 16. Societal value per trip by curb space use**

| Use | Societal Value |
|---|---|
| **Ride-hailing Service** | 1.24 persons/ trip |
| **Commercial Loading** | 1 person/ trip |
| **Transit Service** | 4 persons/ trip |
| **Micromobility** | 1 person/trip |
| **On-Street Parking** | 1.5 persons/ trip |
| **Non-Transportation Uses (Parklets and Streateries)** | 160 persons/ day |
| **Walking** (Not included in the model) | 1 person/ trip |

# Section 5
# Using the Curb Space Allocation Tool

# USING THE CURB SPACE ALLOCATION TOOL

## NEED FOR CURB SPACE ALLOCATION

As described in the Introduction, new modes and technologies have fundamentally changed the demand for curb space away from a sole focus towards on-street parking to a broader set of land-use and transportation goals, including multimodal safety, ADA compliance, parking policy, congestion, and trip generation, urban freight movement and delivery, and emerging mobility options. As stated in the ITE *Curbside Management Practitioners Guide*[38]: "Curb space is flexible—while physically moving the curb usually requires expensive capital construction, curb use can be changed quickly, temporally, and iteratively."

The need for determining the allocation of curb space can arise from multiple sources, including a streetscape effort, development project, or larger small area plan or corridor study. Jurisdictions like Arlington County have developed methodologies for determining the allocation of curbside space, which, as summarized by the ITE *Curbside Management Practitioners Guide*[39], generally consist of the steps shown in Figure 20.


**Figure 20. General curb space allocation selection process**
*(Curbside Management Practitioners Guide (ite.org))*

[38] Curbside Management Practitioners Guide (ite.org)

[39] ibid

# ROLE OF THE CURB SPACE ALLOCATION TOOL

To allow practitioners to identify appropriate curb space treatment alternatives and assess and present the alternatives for public feedback (steps 3 and 4 of the general curb space allocation selection process shown in Figure 20), mechanisms to facilitate consistency and objectivity, along with a quantifiable comparison between curb space allocation alternatives needs to be available.

The Curb Space Allocation Tool was developed to provide practitioners working in Arlington County with a means for identifying and assessing the societal and economic value associated with a variety of curb space allocations.

The tool can allocate curb space for an identified location based on the input parameters that maximize the curb's economic and societal value. Practitioners can use the pre-determined default input parameters or adjust the input parameters to refine the analysis as needed.

## RANGE OF ANALYSES

The Curb Space Allocation Tool is intended for conducting planning-level analyses of curb space allocation alternatives in the early stages of identifying curb space strategies. The tool allows the user to quickly identify initial options for curb space allocation and understand the economic and societal values associated with these options. The tool is intended to serve as one of many inputs for making decisions on curbside regulations and helps to facilitate the delivery of information for decision-makers and the public when presenting curb space allocation alternatives.

## RELATIONSHIP TO OTHER TOOLS

While the Curb Space Allocation Tool provides a means for evaluating a wide range of curb space allocation alternatives in a consistent and reproducible manner, the Curb Space Allocation Tool is not intended to replace the functionality of more detailed analyses using more recent or robust data and inputs. The Curb Space Allocation Tool only provides a planning-level analysis and understanding of the economic and societal values associated with various curb space allocation alternatives.

# FUNCTIONALITY AND REQUIREMENTS

The Curb Space Allocation Tool is a web-based tool currently hosted on the Heroku cloud-based platform until it is relocated to Arlington County servers.

**The tool is available at the following URL:**
https://curbside-analysis-tool.herokuapp.com/

## WELCOME PAGE

The *Welcome* page, shown in Figure 21, introduces the Curb Space Allocation and the tool's use and capabilities. The user can begin a new analysis or open an existing analysis using a saved analysis file. The page also provides contact information and additional information about the tool.

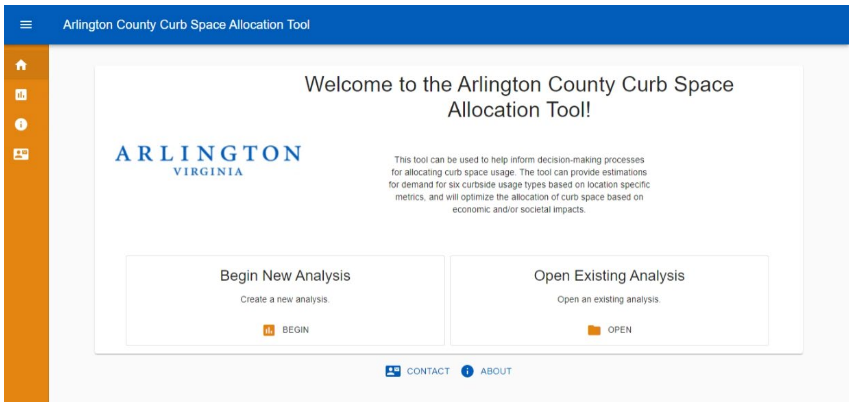



**Figure 21. Welcome Page**

## EXPORT AND OPEN PROJECT FILE

The "Open Existing Analysis" feature on the Welcome page allows the user to export a project file to return to a previous allocation or easily share an allocation with others, along with the ability to open an exported project file. Figure 22 shows a pop-up screen allowing a previous analysis file to be opened.

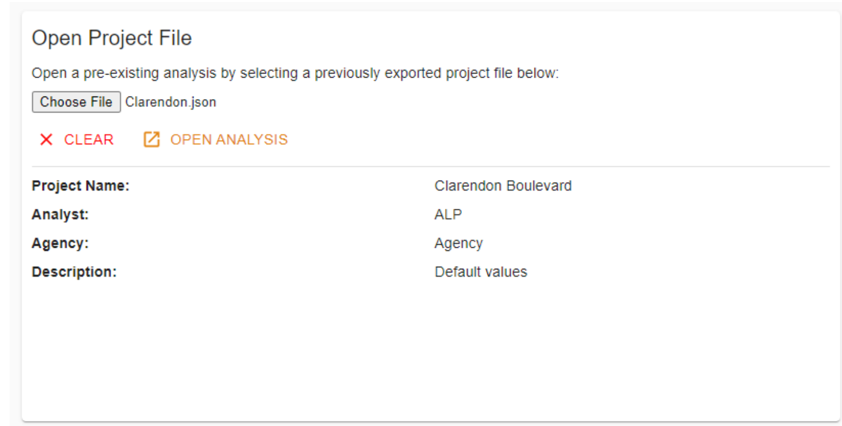



**Figure 22. Open Project File**

## PROJECT INFORMATION (STEP 1) PAGE

The *Project Information (Step 1)* page allows the user to enter identifying information for the curb space allocation, as shown in Figure 23.

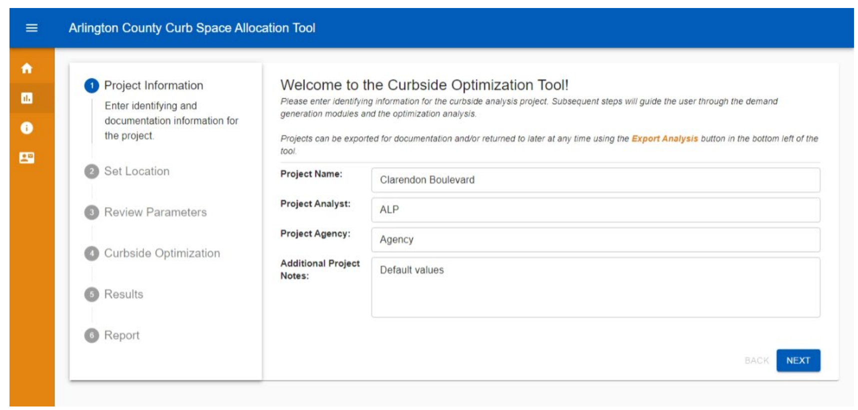



**Figure 23. Project Information (Step 1) Page**

## SET LOCATION (STEP 2) PAGE

The *Set Location (Step 2)* page, shown in Figure 24, allows the user to select the project location on the map by either using the "Snap to Road" or "Custom Area" features. The "Snap to Road" feature generates a roadway polyline by placing two or more points along the desired route. A 100-foot buffer is drawn around the line to indicate the area considered by the regression analysis. The route is generated using the Bing Maps Directions API and only occurs once the user has completed drawing the line. The "Custom Area" feature allows the user to select a custom area using the rectangle or custom polygon drawing tool.

After the area is selected, the tool uses built-in statistical regression models to generate demand estimates for the curbside utilization types automatically. Selecting a location on the map allows the tool to aggregate data from area census and travel demand models to generate metrics utilized by the regressions in estimating these needs, which the user can review or override on the Curbside Optimization (Step 4) Page.

Alternatively, a user can bypass selecting a location on the map but will be required to manually provide demand needs for the curb utilization types on the Curbside Optimization (Step 4) Page.

The page provides a selection summary table that populates with aggregate parameters once an area has been selected on the map. Table 17 summarizes the curb space allocation parameters.

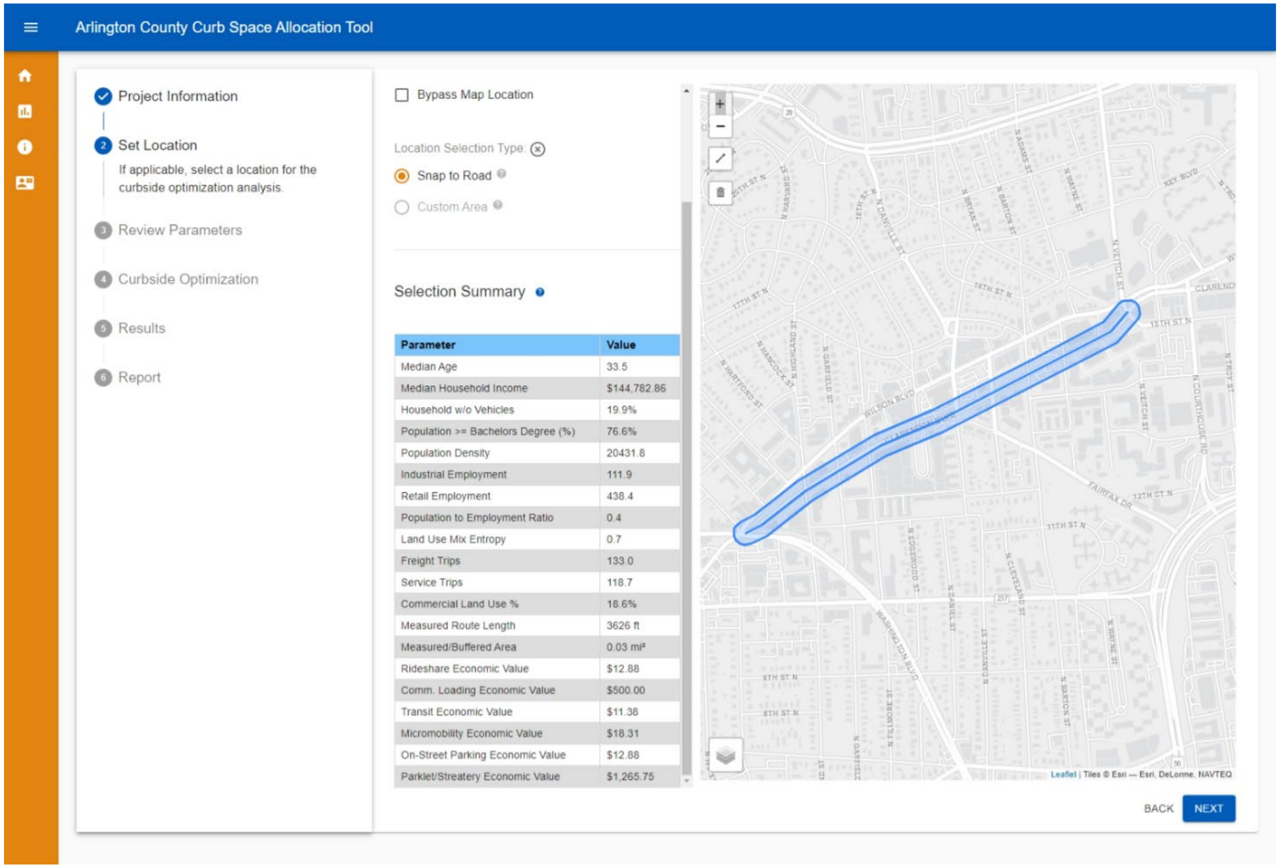



**Figure 24. Set Location (Step 2) Page**

Table 17. Curb Space Allocation Tool Selection Summary

| Parameter | Unit | Description |
|---|---|---|
| **Median Age** | *Years* | The median age of the population. |
| **Median Household Income** | *USD ($)* | Median household income of the population. |
| **Household w/o Vehicles** | *%* | Percentage of households without access to a vehicle. |
| **Population >= Bachelor's Degree (%)** | *%* | Percent of population with a bachelor's degree or higher. |
| **Population Density** | *persons/mi²* | Population density as people per square mile. |
| **Industrial Employment** | *persons* | Aggregated industrial employment for the target analysis area. |
| **Retail Employment** | *persons* | Aggregated retail employment for the target analysis area. |
| **Population to Employment Ratio** | -- | The ratio of population to employment in a given area. The value ranges from 0 to 1, with a lower value indicating the area is only residential or employment and a higher value indicating a balance between the two. Computed as: $\frac{Employment - 0.5 \times Population}{Employment + 0.5 \times Population}$ |
| **Land Use Mix Entropy** | -- | Aggregated metric that quantifies the diversity of land use of a given area. The value ranges from 0 (least diverse/single land use) to 1 (most diverse). Computed as: $\sum_{j=1}^{N} \frac{P_j \times \ln P_j}{\ln N}$ Where: $P_j$ is the proportion of land use of the $jth$ type, and $N$ is the total number of land-use types. |
| **Freight Trips** | *Deliveries/Day* | Estimated freight trips (deliveries per day) for the area. |
| **Service Trips** | *Service calls/day* | Estimated service trips (service calls per day) for the area. |
| **Commercial Land Use %** | *%* | Commercial Land Use % = Retail Employment / Total Employment |
| **Measured Route Length** | *ft* | The measured length of the selected route. |
| **Measured/Buffered Area** | *mi* | The measured area of the buffered route or study area. |
| **Rideshare Economic Value** | *$ / person* | Economic value associated with ridership demand. |
| **Comm. Loading Economic Value** | *$ / delivery* | Economic value associated with commercial loading demand. |
| **Transit Economic Value** | *$ /person / trip* | Economic value associated with transit demand. |
| **Micromobility Economic Value** | *$ / person / trip* | Economic value associated with micromobility demand. |
| **On-Street Parking Economic Value** | *$ / person / trip* | Economic value associated with on-street parking |
| **Parklet/Streatery Economic Value** | *$ / person / day* | Economic value associated with parklets or streateries. |

## REVIEW PARAMETERS (STEP 3) PAGE

The *Review Parameters (Step 3)* page, shown in Figure 25, allows the user to review the module parameters for the demand estimation equations and enter required curbside length availability inputs. At the top of the page, the user is provided information about the measured centerline length of the roadway(s) selected, along with the total measured area, including the 100-foot buffer if the "Snap to Road" feature was used. The user is asked to provide the length, in feet, of the continuous curb space for which the analysis will estimate the optimal allocation of curb usage treatments. This is the total length of curb space available for allocation after required uses, such as fire hydrants, driveways, or other areas not available for allocation have been accounted for.

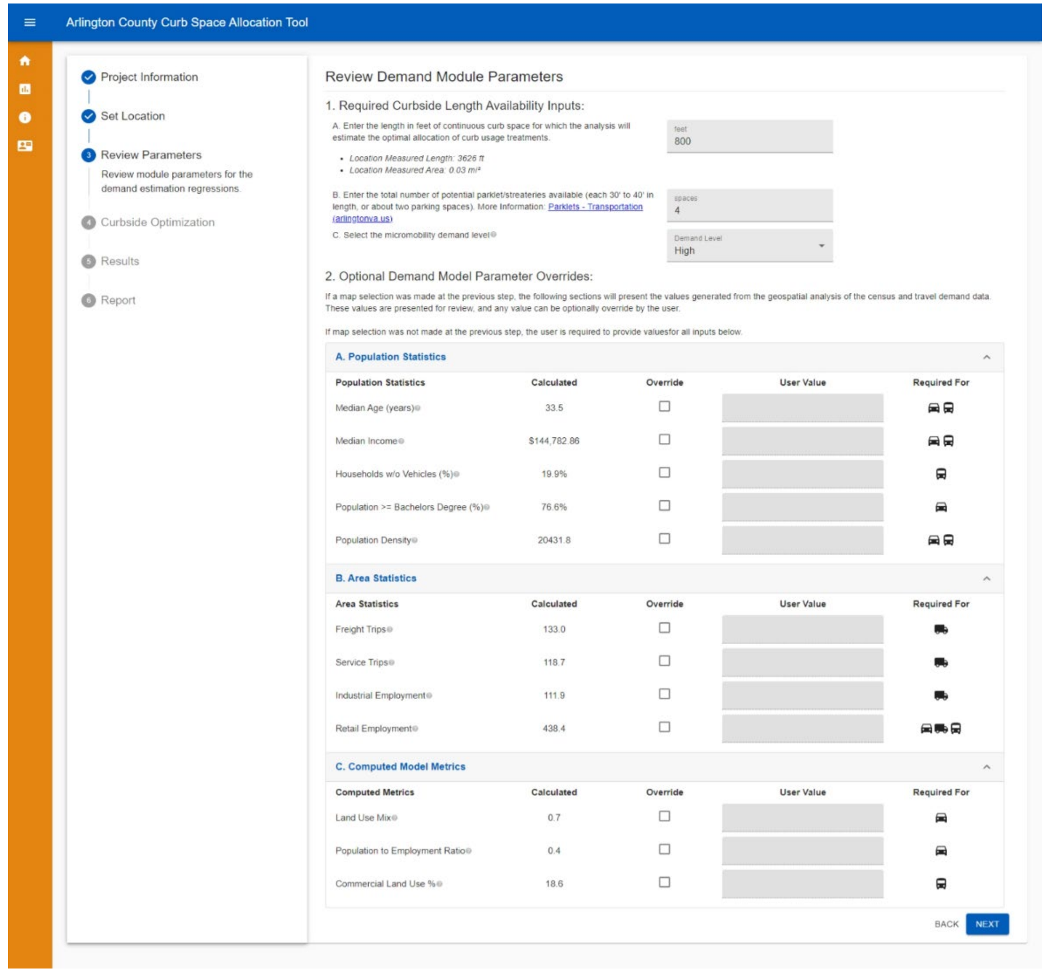



**Figure 25. Review Parameters (Step 3) Page**

Next, the user is asked to provide the total number of potential parklets/streateries in the area selected and are provided with a link to Arlington County information about Parklets. This allows the user to account for the number of restaurants, bars, cafés, or other uses that could accommodate a parklet/streatery in the study area.


**Figure 26. Micromobility Demand Level Pop-Up Box Information**

Last, the user is asked to provide the micromobility demand level to identify the potential micromobility demand for the selected area. A pop-up box, shown in Figure 26, provides information to help the user select an appropriate demand level

## CURBSIDE OPTIMIZATION (STEP 4) PAGE

The *Curbside Optimization (Step 4)* page, shown in Figure 27, allows the user to review the estimated demand for curb usage types and optimization model parameters for spatial requirements, economic values, and societal values. Suppose the user wants to perform a sensitivity analysis to see what adjustments to the calculated demand, curb length requirements, or economic or societal values have on the results. In that case, the adjustments can be made on this page. Further, this allows the user to adjust the curb length requirements if the site being analyzed has certain requirements that are different from the curb lengths shown in Table 13.

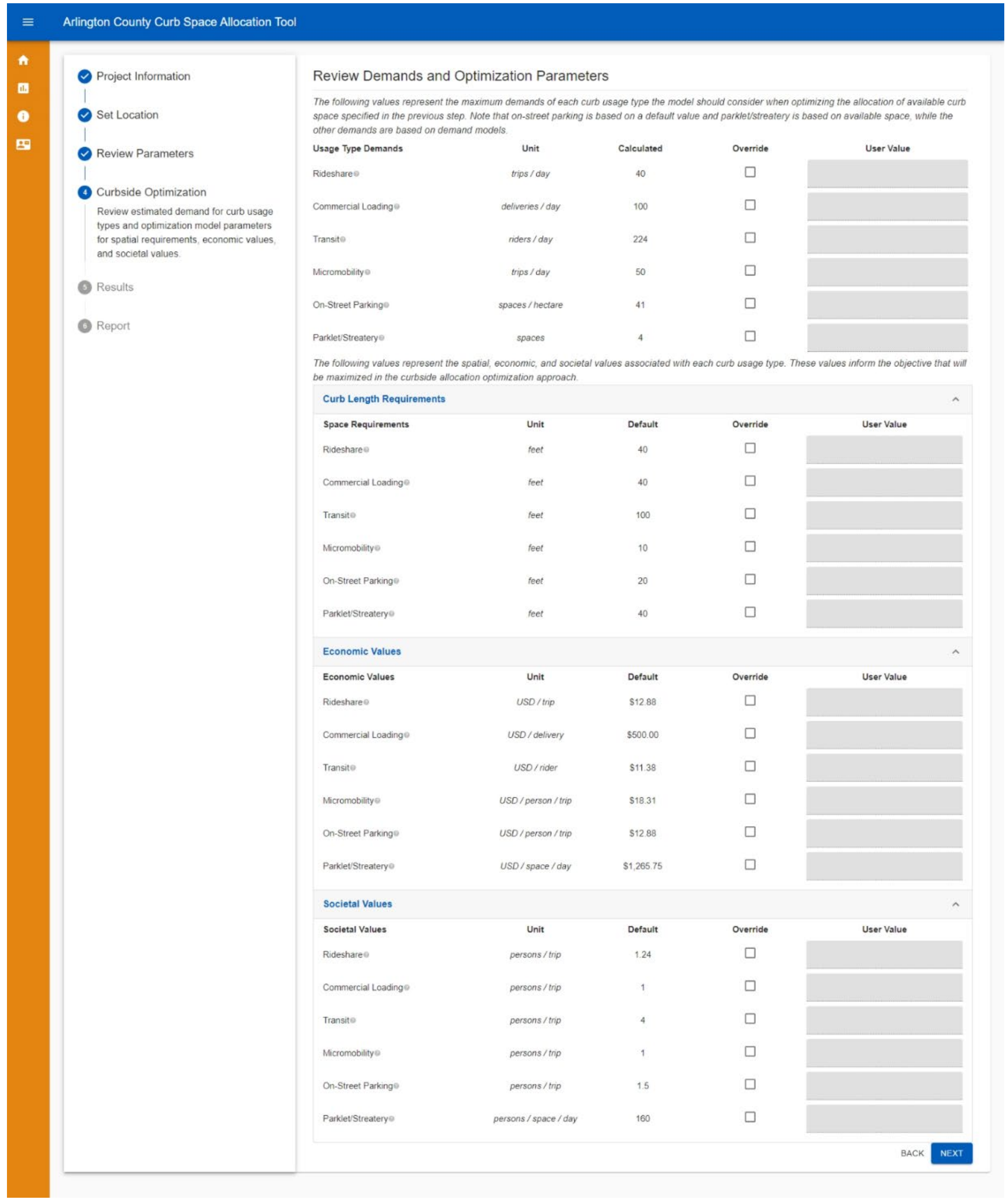


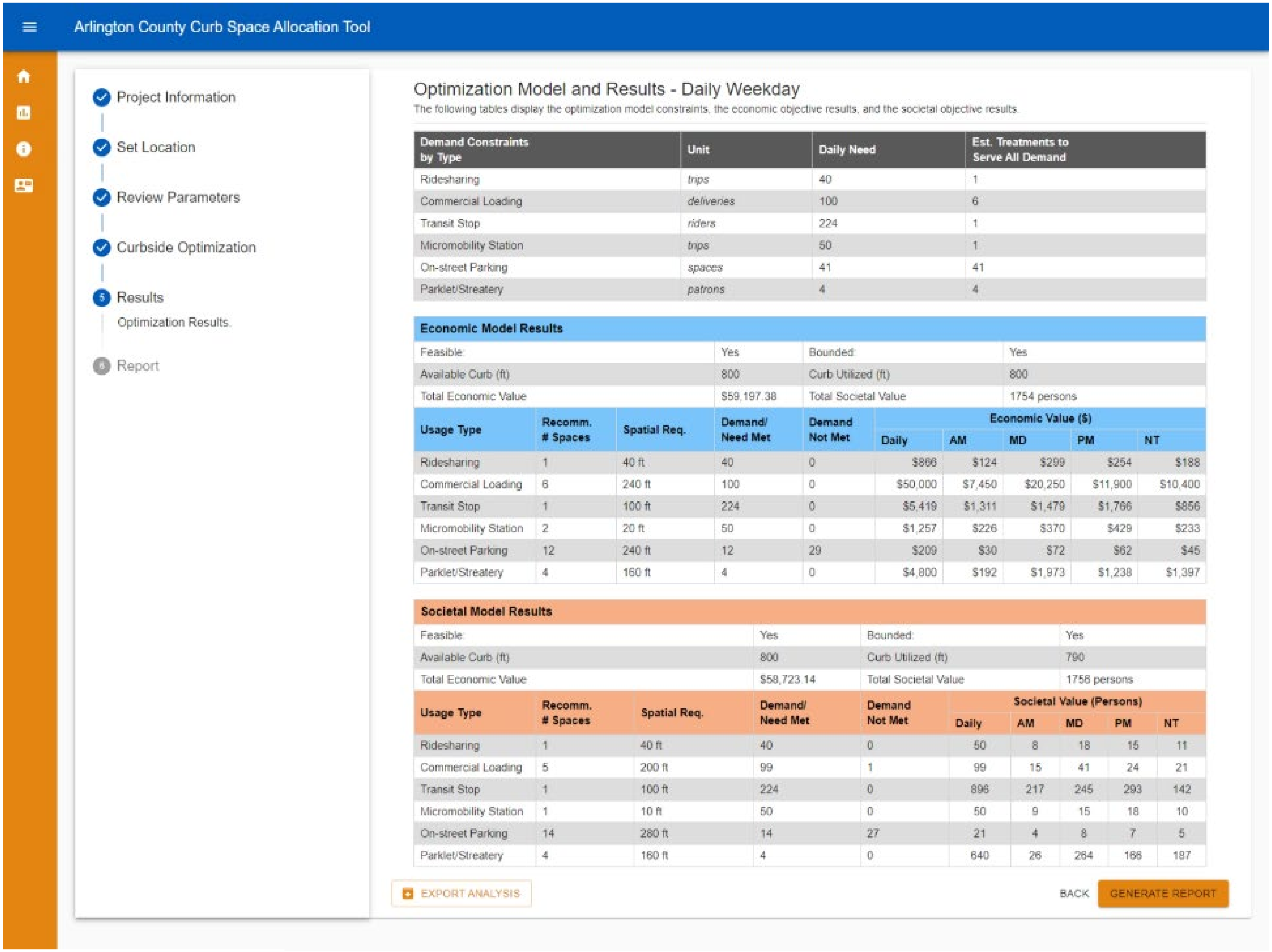

**Figure 27. Curbside Optimization (Step 4) Page**

## RESULTS (STEP 5) PAGE

The *Results (Step 5)* page, shown in Figure 28, provides the user the ability to review the results of the curbside allocation optimized to maximize the economic and societal values. For each model, the results are broken down by usage types, and the total spatial requirements, along with the demand that has been met and not met, are shown, along with the model outputs for the entire day and by the time of day. Table 18 shows the time of day definitions and corresponding time periods.

**Table 18. Weekday Time of Day Definitions and Time Periods**

| Time Of Day Definitions | Time Period |
|---|---|
| **AM (Morning)** | 6:00 AM to 9:00 AM |
| **MD (Midday)** | 9:00 AM to 3:00 PM |
| **PM (Evening)** | 3:00 PM to 7:00 PM |
| **NT (Nighttime)** | 7:00 PM to 6:00 AM |




| Demand Constraints by Type | Unit | Daily Need | Est. Treatments to Serve All Demand |
|---|---|---|---|
| Ridesharing | *trips* | 40 | 1 |
| Commercial Loading | *deliveries* | 100 | 6 |
| Transit Stop | *riders* | 224 | 1 |
| Micromobility Station | *trips* | 50 | 1 |
| On-street Parking | *spaces* | 41 | 41 |
| Parklet/Streatery | *patrons* | 4 | 4 |

**Economic Model Results**

| | | | |
|---|---|---|---|
| Feasible: | Yes | Bounded: | Yes |
| Available Curb (ft) | 800 | Curb Utilized (ft) | 800 |
| Total Economic Value | $59,197.38 | Total Societal Value | 1754 persons |

| Usage Type | Recomm. # Spaces | Spatial Req. | Demand/ Need Met | Demand Not Met | Economic Value ($) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Daily | AM | MD | PM | NT |
| Ridesharing | 1 | 40 ft | 40 | 0 | $866 | $124 | $299 | $254 | $188 |
| Commercial Loading | 6 | 240 ft | 100 | 0 | $50,000 | $7,450 | $20,250 | $11,900 | $10,400 |
| Transit Stop | 1 | 100 ft | 224 | 0 | $5,419 | $1,311 | $1,479 | $1,766 | $856 |
| Micromobility Station | 2 | 20 ft | 50 | 0 | $1,257 | $226 | $370 | $429 | $233 |
| On-street Parking | 12 | 240 ft | 12 | 29 | $209 | $30 | $72 | $62 | $45 |
| Parklet/Streatery | 4 | 160 ft | 4 | 0 | $4,800 | $192 | $1,973 | $1,238 | $1,397 |

**Societal Model Results**

| | | | |
|---|---|---|---|
| Feasible: | Yes | Bounded: | Yes |
| Available Curb (ft) | 800 | Curb Utilized (ft) | 790 |
| Total Economic Value | $58,723.14 | Total Societal Value | 1756 persons |

| Usage Type | Recomm. # Spaces | Spatial Req. | Demand/ Need Met | Demand Not Met | Societal Value (Persons) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Daily | AM | MD | PM | NT |
| Ridesharing | 1 | 40 ft | 40 | 0 | 50 | 8 | 18 | 15 | 11 |
| Commercial Loading | 5 | 200 ft | 99 | 1 | 99 | 15 | 41 | 24 | 21 |
| Transit Stop | 1 | 100 ft | 224 | 0 | 896 | 217 | 245 | 293 | 142 |
| Micromobility Station | 1 | 10 ft | 50 | 0 | 50 | 9 | 15 | 18 | 10 |
| On-street Parking | 14 | 280 ft | 14 | 27 | 21 | 4 | 8 | 7 | 5 |
| Parklet/Streatery | 4 | 160 ft | 4 | 0 | 640 | 26 | 264 | 166 | 187 |

**Figure 28. Results (Step 5) Page**

## REPORT (STEP 6) PAGE

The *Report (Step 6)* page, shown in Figure 29, allows the user to generate a PDF report of the analysis. The report includes the selected area, the demand module statistics, demand constraints and optimization values, and the analysis results.

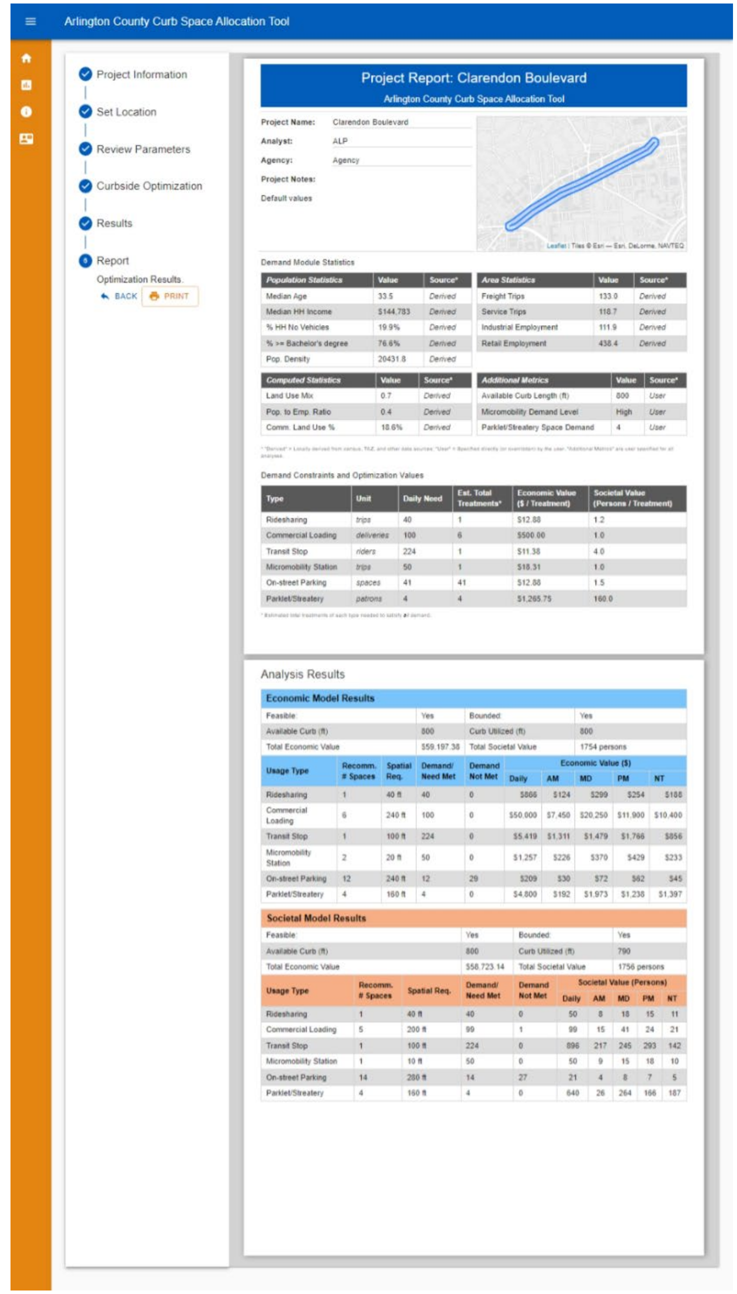



Figure 29. Report (Step 6) Page

Page Intentionally blank.

# Section 6
# Future Research and Identified Gaps

# FUTURE RESEARCH AND IDENTIFIED GAPS

As a result of this work, Arlington has developed the foundation for a tool that provides a mechanism for determining the optimal allocation of curb space given a block's existing or proposed land uses and transportation services. As expected, while the tool offers a reasonable starting point allocating the curb space, the limitations in available research and data have created gaps that, when addressed, could provide a far more powerful tool for County planners. This section identifies some of these gaps and potential future tool updates to enhance the tool's usability.

## GAPS IN RESEARCH AND DATA

Figure 31 displays the known gaps or shortcomings in the research and data used to develop the curb space allocation tool.

**Figure 30. Roadway elements adjacent to the curb including parking protected bike lanes are currently not included in the curb space allocation tool**

**General Considerations**

Rules of thumb, industry standards, and data from other regions were frequently used so that the project team could focus on developing the tool's methodology, equations, and user interface. Collecting local data, such as spending data by trip type and mode like the data collection efforts in Seattle, would provide a substantial upgrade to the calculations.

**Economic and Societal Benefits**

The tool relied on a narrow definition of direct economic benefits in consumer spending; future research and data gathering could be undertaken so that indirect economic benefits could be incorporated. The tool's consideration of societal benefits could also be expanded beyond individuals served to include the monetized value of other societal benefits.

**Ride-hailing Services**

An improved understanding of ride-hailing services, particularly in Arlington, would be beneficial, but the cost associated with collecting and processing enough data to provide a noticeable benefit is likely not worth the effort at this time.

**Commercial Loading**

A significant gap exists in available commercial loading data. An initiative by the County to collect and inventory on- and off-street loading zones and usage data, including time-of-day, length-of-stay, distance and proximity to customers, and supplemental information including the number of parcels delivered, the number of customers served, and collecting potential economic value information associated with loading zones would provide a substantial upgrade to the curb space allocation tool. This is likely the highest priority research gap.

**Off-Street Parking**

Incorporating off-street parking inventory and upgrading the parking demand module to consider the off-street parking supply in conjunction with demand for on-street parking would provide a much more reasonable constraint on the demand for on-street parking spaces.

**Micromobility**

An improved understanding of micromobility demand, especially if the demand estimation could be upgraded to a regression approach, would provide much more useful micromobility demand estimations and allocation outputs.

**Non-transportation mode (parklet/ streateries)**

Use new data on parklets and streateries, especially spending and usage information, to substantially upgrade the non-transportation mode module from the current back-of-the-envelope methodology to a regression model approach to predict usage and benefits more accurately. This is likely the second highest priority after commercial loading.

**Figure 31. Gaps in Research and Data**

# FUTURE TOOL UPDATES

Items below provide opportunities to upgrade the usability of the tool or expand the tool's potential functionality:

- Currently, the tool allocates the curb space in aggregate. The ability to break down the available curb space into smaller segments (the length of individual block faces or short sections between driveways) could be useful for allocating "leftover" space. This could be done by combining the tool with a curbside inventory conducted using a linear referencing system.
- Further enhancements could include a graphical output (like StreetMix) that provides visually appealing inputs and outputs.
- Incorporating pricing and time changes with the parking demand calculations could allow additional functionality as the County explores performance parking initiatives.
- The addition of enforcement information, including citation data and the amount of enforcement, could help identify the likelihood of compliance with various curb space allocations.
- The combination of pricing and time changes and enforcement information could also allow for calculating potential revenue from various curb space allocation options.
- Adding a supplemental electric vehicle charging component to the on-street parking module would allow the tool to consider electric vehicles' potential economic or societal benefits.
- Further considering the "Flex Zone" or the roadway lane immediately in front of the curb along with the sidewalk space adjacent to the curb could allow for the tool to analyze benefits associated with parking-protected bike lanes, transit lanes, an expanded sidewalk area, and landscaping including trees and shade.

**Figure 32. Roadway elements adjacent to the curb, including transit-only lanes, are currently not included in the curb space allocation tool**