Quantifying the Current Transportation Landscapes in Charlottesville to Evaluate the Effects of Shared Dockless E-Scooters on Mobility.

A Technical Report submitted to the Department of Computer Science

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Cameron Lloyd

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Technical Project Team Members

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

David Evans, Department of Computer Science

Introduction

Background/Motivation:

There is an increasing importance placed on mobility in urban areas, and the questions arising around the topic. I am interested in both the technical questions asked by quantifying mobility data and the broader sociotechnical context about society's ability to integrate a new mode of transportation into an existing transit landscape. My sociotechnical research paper focuses on "rules for integration" of a new form of mobility, the shared dockless e-scooters that are emerging in many urban cities. There, I explore the factors that contribute to how two cities: Charlottesville, VA, and San Francisco, CA, have integrated shared dockless e-scooters into their transit options. An emerging factor from that analysis is the importance of communication between local governments, private scooter companies, and community residents. That shared communication can take many forms, such as written reports, dashboards, and hearings. For my technical research, I sought to create a resource to showcase the availability of existing transit, and potential for adding additional modes such as e-scooters in Charlottesville.

Figure 1: Example of shared docless e-scooter from VeoRide, one of many startups entering the e-scooter scene. Source: VeoRide Website

Goals:

The goal of this project was to analyze the mobility of Charlottesville residents, with a focus on the potential mobility benefits shared dockless e-scooters could bring. That goal was broken down into stages: collecting publicly available data on the mobility of residents in Charlottesville, processing that data based on analysis by Jiao and Dillivan (Jiao & Dillivan, 2013) and presenting that data in a format that can be used by the city of Charlottesville and digested by community members, and lastly, to try and estimate what benefits to those mobility estimates shared dockless e-scooters would bring.

Literature Review:

There is significant importance placed on the facets of availability, equity, and safety of the transit systems in cities. (Sanchez & Brenman, 2008) In Charlottesville and other similar cities, there is increasing emphasis on how to grow as a city in a way that does not cause traffic congestion problems and promotes equitable transit access for residents. There are also studies into how new forms of micromobility (any mobility form that can share infrastructure space with bicycles) potentially fill mobility gaps. Smith & Schwieterman, using simulations of different e-scooter transit scenarios, found that the "benefits of e-scooters can differ widely between geographic areas that are only a few blocks apart due to the differential access of these areas to transit lines and bus routes." (Smith & Schwieterman, 2018) The high variation in potential benefits of introducing e-scooters is important to study and communicate, as clearer understandings and expectations can lead to better outcomes for the city.

Another focus of research surrounding micromobility vehicles seeks to find out how riders are choosing e-scooters or shared dockless bikes over other existing modes of transit. While marketed as being environmentally friendly, e-scooters fall in line as better options than personal automobiles and rideshares, but typically have more negative environmental impact than busses, and of course biking or walking. (Hollingsworth, Copeland, & Johnson, 2019) (Hawkins, 2019) The vehicle emissions to distribute, collect, and charge the e-scooters each day are significant. The environmental benefits are then mostly realized when trips via e-scooter are replacing those that would have been taken with personal vehicles, which accounts for about a third of trips. For about half of trips on e-scooters, riders cited they would have walked or biked instead. (Smith & Schwieterman, 2018) With that in mind, one needs to consider how various micromobility options can be distributed to maximize rides replacing personal vehicle trips instead of walking or taking mass transit via bus.

Data

Data Collection

The ACS community survey was a primary source of data for this project. I used both the online interface to select specific tables and the programmable API found at api.census.gov. Although some data was unavailable due to small sample size, I was able to retrieve the following variables at the block group level for each of Charlottesville's census block groups: Population Over 16, Population aged 12-15, Population living in group quarters, Vehicles Available, and Non-institutionalized population living in group quarters. For the group quarters counts, I used an average percentage for the state of Virginia for each block group. A script to fetch and format the data is shown in Appendix A. This data was the basis for estimating the transit demand in Charlottesville, and although it is missing some key geographic areas not covered by the American Community Survey, it is useful in painting a picture of who has access to transit and where there can be improvements.

I also retrieved data about Charlottesville Area Transit (CAT), the geography of the census groups from Charlottesville Open Data's Website (https://opendata.charlottesville.org). I imported the available shapefiles and GeoJSON files into an open-source GIS application QGIS. Combined with the University Transit Service data, these sources were useful in determining the supply of transportation resources from bus routes, bus stops, bicycle rack points, bicycle lane lines, and sidewalk availability. Ideally, I would have incorporated live data from where shared e-scooters were placed, but the global pandemic has halted VeoRide's operations in Charlottesville and many other cities. Bicycle rack points are well suited to use as a proxy for e-scooters as they represent the same class of vehicles "micromobility" and could be part of future iterations of incorporating e-scooters into Charlottesville. If the sidewalk blocking is too much of a nuisance, a possible remedy would be to explore docked scooters based on the bike racks locations. The available data was sufficient to approximate transit supply to the various block groups, and e-scooter availability could be treated in a similar fashion to bicycle rack points.

Data Processing

A variety of tools are available to process the aggregate population data, geographic boundaries, bus stops, routes, and bicycle rack points. I began by incorporating the layers of interest in QGIS, an open-source geographic information system. The desktop application can be used across platforms and

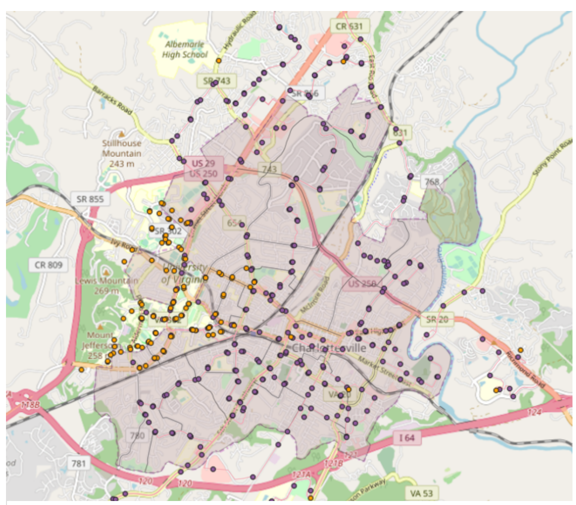


Figure 2: Screenshot of QGIS Map of Charlottesville with Bus Stops, Routes, and Census Block Group Boundaries

is easy to get up and running. The image to the right shows a few layers I used to calculate transit access. The different bus systems are represented by colored dots, and the shaded region represents the census block group boundaries for Charlottesville. Having the information in this format helped me tabulate figures needed, like bus stops, routes, and bike racks per block group.

Another component of my analysis was excel-based calculations based on analysis by Jiao and Dillivan's "clear, concise method for calculating and quantifying the supply of transportation service that can be used for any location." (Jiao & Dillivan, 2013) To quantify the gaps between Charlottesville's transit demand and supply, I used the formulas outlined in Jiao and Dillivan's report.

Household drivers = (population age 16 and over) – (persons living in group quarters)

Transit-dependent household population = (*household drivers*) – (vehicles available)

Transit-dependent population = (*transit-dependent household population*) + (population ages 12–15) + (non-institutionalized population living in group quarters)

Once I had all of the relevant variables for each block group in an excel spreadsheet, I computed the values according to the formulas above. The authors' reasoning for this strategy was to abstract away the reasons for individuals not driving, but rather highlight where there might be a shortage of vehicles for individuals to use. For display on a map, I normalized the density of transit-dependent Populations per square mile. With an approximation of demand calculated, I moved to calculate an estimate of the transit supply. I incorporated the number of bus stops (from both CAT and UTS) in each group, the frequency of service for those stops, the number of routes in each block group, and the length of bike routes and sidewalks in each block group. These were aggregated and normalized in a similar fashion to the demand. Tabulated data can be found in Appendix B.

Website for displaying results

While there are many applications like QGIS and ArcGIS to view geospatial data, I wanted to build a digestible and easily customizable website design so that the City of Charlottesville could easily integrate it into their existing Charlottesville Open Data Website. MapBox provides a collection of APIs and developer tools to build apps and websites using map data. Using the Mapbox library with the geospatial data retrieved from Charlottesville Open Data's website, I created a static website that shows various layers of transit features in Charlottesville. As shown in the screen capture above, a user can toggle various layers on and off, and if there are any changes to the layers updated on Charlottesville Open Data's website, they will be reflected here as well. The bike racks are shown as light blue dots and are concentrated around the downtown mall and university area. Bus stops are shown in a darker blue alongside the bus routes layer.

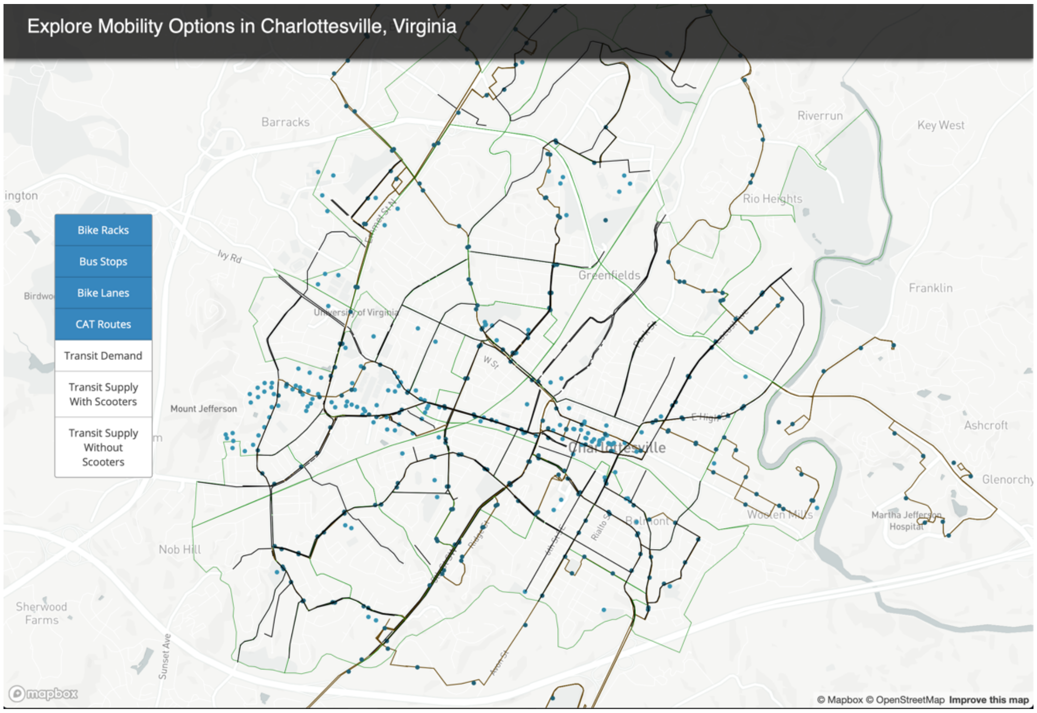
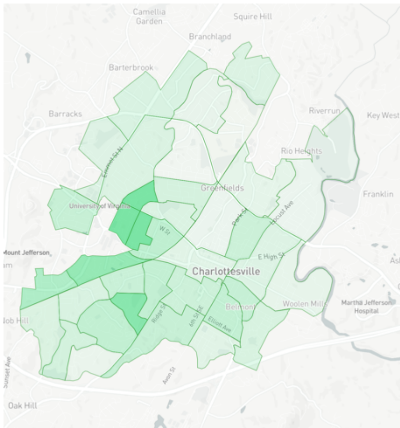


Figure 3: Screen capture of website displaying layers of transit data for the city of Charlottesville, VA

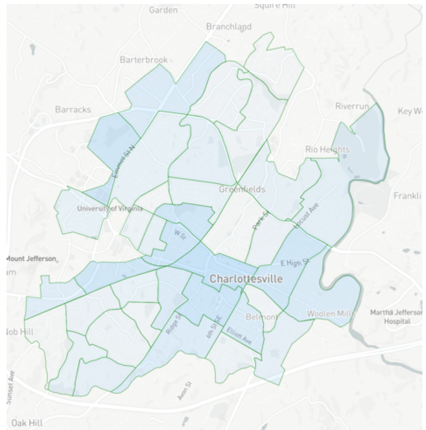
While layers showing the bus routes, stops, and bike racks are useful to understand how the supply of transit options are distributed throughout Charlottesville, they don't fully show the whole picture of transit needs. I also included choropleth maps to show the transit demand calculated from formulas above, and what supply estimates would look like with and without scooters, which were approximated using the locations of bike racks.

The three images below show in order from left to right: the transit demand by block group, transit supply without including bike racks to simulate scooters, and transit supply with bike racks. The biggest differences are in the areas surrounding the downtown mall, and university, which makes sense given that bike racks are placed in the areas expecting higher bicycle commuting.

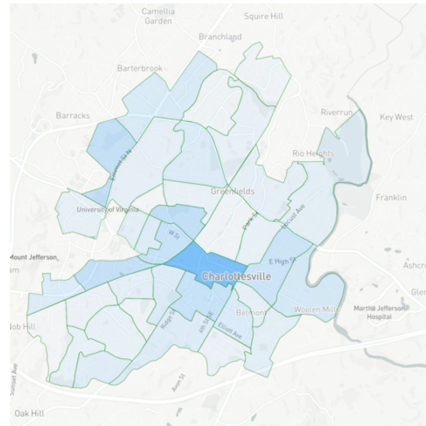
Transit Demand.



Transit Supply Without Scooters

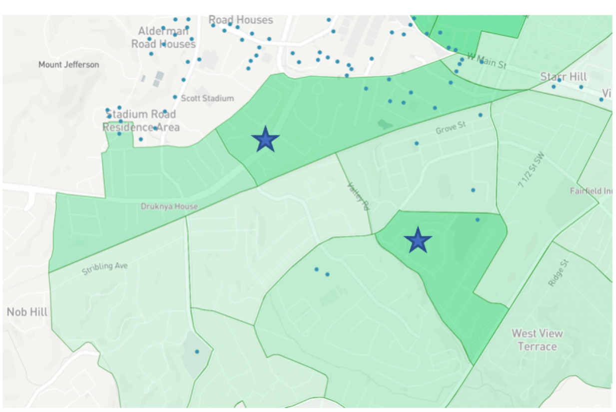


Transit Supply With Scooters

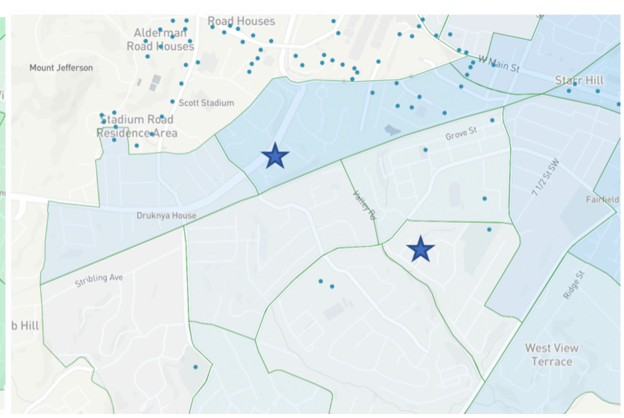


These maps show where the greatest difference in transit supply is when the counts of bicycle racks are included. The Downtown Mall and University Areas show the most significant changes in supply, which makes sense since they have the greatest concentration of currently placed bicycle racks. The interesting blocks to consider are those with more transit demand, but marginal or no improvements of transit supply when calculated to include bike racks/scooters. These include blocks neighboring the university area and in the residential areas, which are shown in the image below with stars. These blocks show the potential for increasing mobility access, but one should also consider that many of the residents in the blocks neighboring the university walk to classes and work.

Transit Demand



Transit Supply



Discussion and Recommendations

This project can hopefully serve as a motivating effort for multiple areas of development. The topics of mobility and transit equity will continue to be debated and researched as cities grow both in density and area, and transportation systems will need to respond to the growing traffic and environmental consequences to single driver commuting. Shared dockless e-scooters, while limited in reach and capacity, represent one facet of a new front of transit options in cities like Charlottesville, namely, micromobility. They spark debate over how new technologies can support or hinder communities' efforts to promote safety, efficiency, and equity in their transportation resources. This project highlights how even smaller-scale changes, such as installing bike racks across Charlottesville, can facilitate the integration of new transit options like shared e-scooters.

Another key aspect of both this technical project and the associated sociotechnical research is the openness and communications between related stakeholders, in this case, the private companies operating shared e-scooters and bikes, municipal authorities, and community residents. In order to make informed decisions about pilot programs introducing new transportation options, and the continuation and prolonged integration into existing infrastructure. The website contributes to an already growing emphasis on civic innovation and open data in Charlottesville, building from publicly available information, and presenting results and information in a clear manner.

While this project shows the possibilities for analysis given the currently available data, it also highlights where the future emphasis should be placed for collecting and sharing ongoing data about the usage and effects of new transportation options. For example, while there are live-feeds of the locations of available e-scooters made available via APIs, these do not expose historical distributions of e-scooters. Municipalities and developers are then left to tabulate historical datasets to evaluate when and where e-scooters are available to community members to determine if the distributions conform to requirements of operating contracts. Implementing an ongoing system that monitors how new forms of transportation like bike-shares, dockless e-scooters, and other new vehicles are accessed and used by the community would be beneficial to projects like this one, and to ongoing city planning efforts.

Future Work

To incorporate ongoing additions to transportation resources, it would be beneficial to set up a resource for community members to see where scooters are placed each day. E-Scooter companies have faced criticism in the past for distributing their vehicles in a way that excludes lower-income demographic areas. Charlottesville's pilot program seeks to remedy that by requiring a certain number of vehicles placed across areas. Incorporating historical distributions of vehicles in addition to the live feed would increase the transparency with the community of whether shared e-scooters are helping to promote equitable access to transit.

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Appendix

Appendix A: Script to retrieve ACS Data From the 2018 5-Year Summary for various variables

```
import urllib.request

import csv

import requests


census_blocks = {'000201': [1,2,3],

'000202': [1,2,3],

'000302': [1,2],

'000401': [1,2],

'000402': [1,2,3,4],

'000501': [1,2,3],

'000502': [1,2,3,4,5],

'000600': [1,2],

'000700': [1,2,3,4],

'000800': [1,2,3,4],

'000900': [1,2],

'001000': [1,2,3]

}


API_key = "key"

cville_FIPS = 540

VA_code = 51

variables = []

total_pop = "B01003_001E"

under_16 =
"B01001_003E,B01001_004E,B01001_005E,B01001_006E,B01001_027E,B01001_028E,B01001_
029E,B01001_030E"

under = ["B01001_003E","B01001_004E","B01001_005E","B01001_006E","B01001_027E",
"B01001_028E", "B01001_029E", "B01001_030E", "state","county","tract","block group"]
```

```
group_quarters = "B09001_010E"

vehicles_available = "B992512_001E"

institutionalized_group_quarters = "B26103_003E"

url_base =
"https://api.census.gov/data/2018/acs/acs5?get={}&for=block%20group:{}&in=state:51%20cou
nty:{}&in=tract:{}&key={}"

with open('data.csv', 'w', newline='') as file:

    writer = csv.writer(file)

    writer.writerow([total_pop, "state","county","tract","block group"])

    for tract in census_blocks:

        for block in census_blocks[tract]:

            block_url = url_base.format(total_pop, block, cville_FIPS, tract, API_key)


            with requests.Session() as s:

                download = s.get(block_url)

                decoded_content = download.content.decode('utf-8')

                cr = csv.reader(decoded_content.splitlines(), delimiter=',')

                my_list = list(cr)

                for row in my_list[1:]:

                    formatted = [row[0][2:(len(row[0]) -1)]]


                    for col in row[1:len(row) - 1]:

                        formatted.append(col)


                    block_group = row[len(row) -1][0]

                    formatted.append(block_group)


                    writer.writerow(formatted)
```

Appendix B: Tabulated Data for Transit Demand in Charlottesville, VA

Block Group Number	Pop < 16	Pop > 16	Averaged* Pop in Group Quarters	Number of Vehicles	Pop in Non-institutionalized Group Quarters (Averaged)	Household Drivers	Transit-Dependent Household Population	Transit Dependent Population	Square miles	Density of transit dependent population
2011	184	835	37.000	408.000	12.126	798.000	390.000	424.126	0.216	1964.482
2012	116	654	37.000	381.000	9.163	617.000	236.000	271.163	0.166	1630.139
2013	27	1051	37.000	425.000	12.828	1014.000	589.000	614.828	0.085	7204.106
2021	337	1380	228.000	613.000	20.432	1152.000	539.000	579.432	0.174	3325.687
2022	51	1915	228.000	510.000	23.395	1687.000	1177.000	1239.395	0.092	13507.488
2023	10	1788	228.000	290.000	21.396	1560.000	1270.000	1301.396	0.105	12446.674
3021	259	1229	6.000	743.000	17.707	1223.000	480.000	534.707	0.362	1475.969
3022	193	884	6.000	513.000	12.816	878.000	365.000	392.816	0.421	934.069
4011	345	1442	34.500	799.000	21.265	1407.500	608.500	656.765	0.270	2436.206
4012	628	1665	34.500	691.000	27.287	1630.500	939.500	1031.787	0.370	2789.592
4021	79	642	6.500	352.000	8.580	635.500	283.500	320.080	0.114	2801.712
4022	219	1233	6.500	689.000	17.279	1226.500	537.500	578.779	0.193	2991.690
4023	327	1196	6.500	807.000	18.124	1189.500	382.500	464.624	0.263	1768.601
4024	102	719	6.500	470.000	9.770	712.500	242.500	252.270	0.197	1279.531
5011	456	1257	3.667	701.000	20.385	1253.333	552.333	572.718	0.190	3022.066
5012	152	650	3.667	268.000	9.544	646.333	378.333	421.877	0.159	2654.439
5013	354	1184	3.667	505.000	18.302	1180.333	675.333	798.636	0.126	6359.641
5021	492	1632	3.500	725.000	25.276	1628.500	903.500	956.776	0.315	3039.779
5022	39	853	3.500	515.000	10.615	849.500	334.500	345.115	0.203	1700.819
5023	269	912	3.500	461.000	14.054	908.500	447.500	461.554	0.274	1684.651
5024	352	728	3.500	341.000	12.852	724.500	383.500	396.352	0.192	2062.357
5025	16	321	7.000	194.000	4.010	314.000	120.000	140.010	0.202	691.500
6001	25	2124	313.500	691.000	25.573	1810.500	1119.500	1145.073	0.202	5659.877
6002	54	1453	313.500	453.000	17.933	1139.500	686.500	708.433	0.172	4110.648
7001	229	901	274.500	526.000	13.447	626.500	100.500	139.947	0.386	362.140
7002	298	1329	n/a	545.000	19.361	1329.000	784.000	884.361	0.543	1628.925
7003	59	821	n/a	427.000	10.472	821.000	394.000	414.472	0.299	1388.493
7004	51	879	n/a	213.000	11.067	879.000	666.000	702.067	0.253	2770.723
8001	259	806	35.500	413.000	12.674	770.500	357.500	453.174	0.295	1537.781
8002	60	417	35.500	248.000	5.676	381.500	133.500	139.176	0.423	329.217
8003	97	586	35.500	279.000	8.128	550.500	271.500	279.628	0.345	810.227
8004	396	1568	35.500	699.000	23.372	1532.500	833.500	885.872	0.534	1660.375
9001	279	1024	3.500	619.000	15.506	1020.500	401.500	512.006	0.856	598.405
9002	140	800	3.500	387.000	11.186	796.500	409.500	420.686	0.416	1010.090
10001	128	1058	32.000	713.000	14.113	1026.000	313.000	342.113	0.277	1233.347
10002	133	743	32.000	500.000	10.424	711.000	211.000	231.424	0.357	647.781
10003	170	978	32.000	499.000	13.661	946.000	447.000	514.661	0.205	2504.947