MEMO

Date: April 27th, 2020

To: Steering Committee, Planning Partners

From: Cassidy Boulan

Subject: Southeastern Pennsylvania Pedestrian Cyclical Count Program Summary (Publication Number PM19029)

PROJECT OVERVIEW

The Delaware Valley Regional Planning Commission (DVRPC) began developing the Southeastern Pennsylvania Pedestrian Cyclical Count Program in the fall of 2018, supported by discretionary funding through the PennDOT CONNECTS initiative. The purpose of the pedestrian cyclical count program is to count pedestrians at a number of set locations per year in order to monitor pedestrian travel trends in representative contexts throughout the region over time. Future uses of the data may include developing estimates of pedestrian activity for all road segments and tracking of changes in travel after infrastructure investments.

PROJECT BACKGROUND

This project builds on DVRPC's Bicycle Cyclical Count program, which was initiated in 2014. To improve upon the location selection methodology that was used to develop the bicycle program, staff sought to use statistical analysis to select representative locations in the five Pennsylvania counties. To balance the size of the project, only on-street locations with sidewalk on at least one side of the street were included, no trails. All counts were seven-day automatic counts using existing EcoCounter equipment.

REPRESENTATIVE SAMPLING

One important goal of the program is to collect data that can be extrapolated out to provide estimates for levels of walking across the Southeastern Pennsylvania area. To achieve this goal, it was critical to develop a program where count locations were selected for their representative attributes. Therefore, the program methodology was created to ensure that the count locations were representative of different patterns in land use and transportation.

METHODOLOGY DEVELOPMENT

The first step to develop a methodology to select representative locations was a review of existing literature and programs. For the first half of the process, a method was adapted from North Carolina State's Institute for Transportation Research and Education to use regression analysis to identify the primary drivers or variables affecting pedestrian activity. Three variables were identified as significant for the suburban counties (population density, percentage of college students, and road density) and two variables were significant in the city of Philadelphia (percentage of college students and transit activity density). San Diego State and the San Diego Metropolitan Planning Organization used a stratified sampling scheme to place permanent counters in their region and a similar framework was used for DVRPC's program. Using random selection, census tracts representing the mix of above and below median values for each variable were selected in the city and the suburbs. This resulted in eight strata in the suburban counties and four strata in the City of Philadelphia. Ten locations in each stratum were selected to ensure a robust sample size. Planning partners at each county and in the city were then asked to identify representative locations in each census tract where counters could be placed.

In addition to the census tract locations, three more strata were created in the suburbs to understand road types or locations that may have unique patterns. The first is a schools stratum. For these locations, counts were taken within a quarter mile of a public K-8 school. There were 10 locations counted for this stratum spread across the counties and across the underlying census tract strata. The second two additional strata were major and minor arterials with and without surface transit.

In Philadelphia, two additional strata were defined in addition to the census tract strata: high and low transit ridership streets segments. Segments are defined by their levels of transit activity, specifically the sum of boards and alights on road segments that are within 500 feet of a bus, trolley, or heavy rail stop.

An in depth explanation of the statistical analysis and testing of the methodology can be found in a paper presented at the 2020 Annual Meeting of the Transportation Research Board and shared in Appendix C.

<u>OUTCOMES</u>

Program locations and counts are described in the first two appendices. Additional information about each count can be searched for through DVRPC's bicycle and pedestrian count portal, which can be found at https://www.dvrpc.org/webmaps/PedBikeCounts/.

Appendix A:

The tables in Appendix A summarize each location and the resultant count, and include a link to the count location in Google Maps. There is a data dictionary for the tables at the beginning of the appendix.

Appendix B:

Maps in Appendix B show the count locations by county and in the city of Philadelphia and are summarized in Map 1. The counties are ordered alphabetically. The results of completed counts are shown. Some remaining counts will be taken in spring and summer of 2020. These locations are primarily in the City of Philadelphia.

Appendix C:

A paper detailing the statistical analysis and the full methodology comprises Appendix C. It provides a more thorough explanation of the project development process.

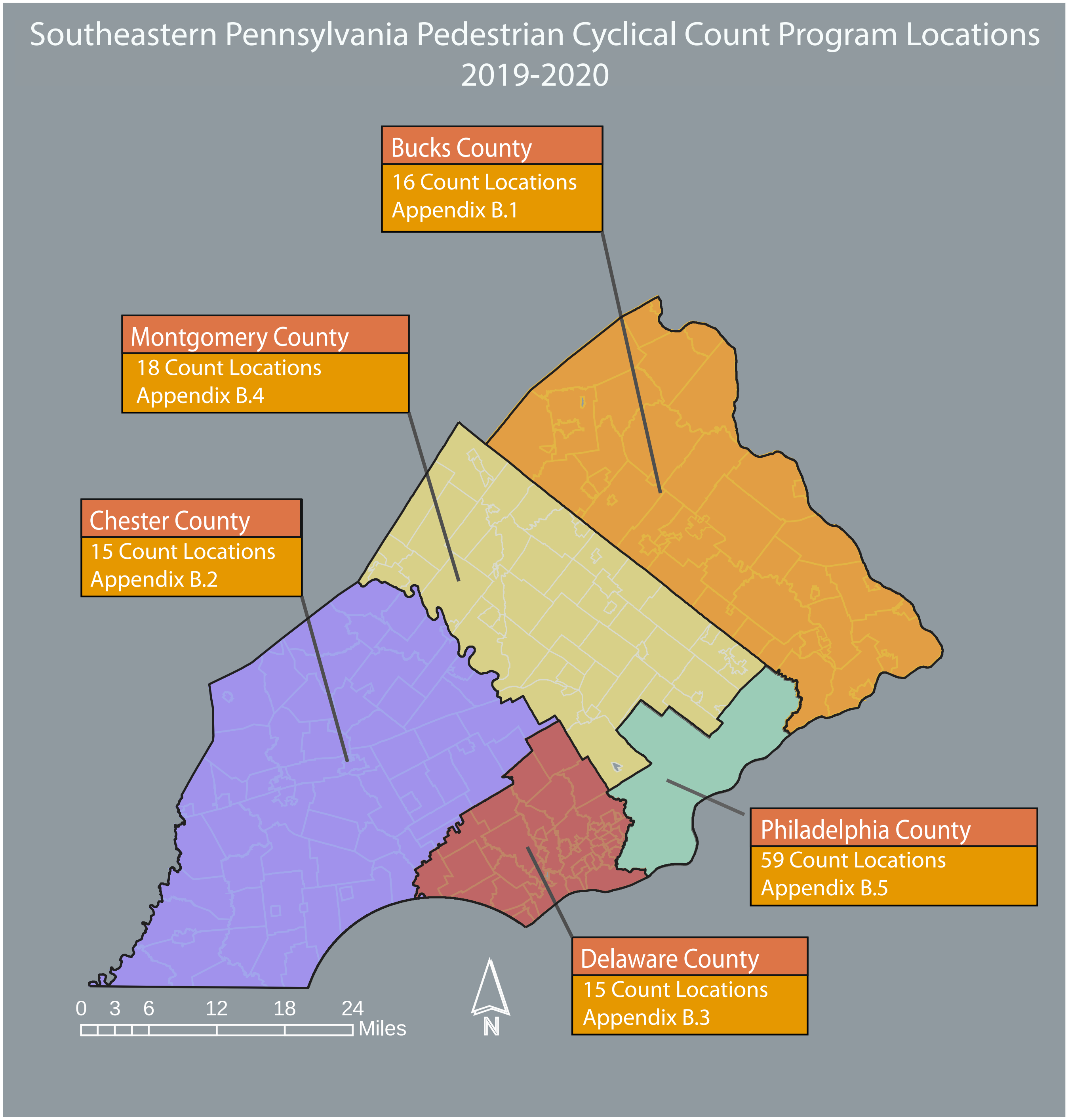
<u>NEXT STEPS</u>

The immediate next steps are to finish conducting counts at the remaining program locations. Once completed, DVRPC will begin developing a methodology for using the data to create estimates for pedestrian activity on all road segments. These estimates can be used for existing Transportation Improvement Program (TIP) project evaluation criteria.

DVRPC will also begin to count about 35 locations per year, each year, on a planned five-year schedule to monitor how the amount of walking is changing.

Planning partners can begin using the data to compare locations in the program, as well as seeing the variations over the day and day of the week that are illuminated by this data. This has the potential to be useful in planning studies or to provide general information on levels on walking.

Map 1: Summary of Regional Counts



APPENDIX A

INTRODUCTION

The count locations in the program are summarized in the following tables. The locations where data has yet to be collected, which only includes locations in Philadelphia, are listed last. For the tables, the data in the columns are defined as follows:

AADP	"Average annual daily pedestrian"- an average based on a series of counts and factors that estimate the average daily pedestrian traffic.
County	The county in which the count location is.
Google Link	A click-able link to the location in which the count was taken.
High Transit Street	This category of stratum is only for Philadelphia and includes streets with surface transit service that have above median boards plus alights.
In/Out Dir	The direction that pedestrians come in or out to the counter.
Low Transit Street	This category of stratum is only for Philadelphia and includes streets with surface transit service that have below median boards plus alights.
Municipality	The municipality in which the count location is.
Non-Transit Arterial	This is a suburban category of stratum and represents a major or minor arterial road segment with no transit service.
Road Name	The road on which the count location is.
Set Date	The date when the count equipment was set and counting began.
Sidewalk	The location of the sidewalk that the count was taken on in regards to the centerline of the road.
Stratum	Stratum are a way to categorize different areas used for counts. For the suburbs, there are three categories that were used. Above and below median values for population density, road density, and percentage of college students. For Philadelphia, only two categories were used: above and below median values for transit activity density and percentage of college students. Zero represents below median values for each, and one represents an above median value.
Stratum Type	This is the category of stratum. There are several types, the largest being census tract. Others are school and high/low transit arterial in the suburbs and lower and higher transit streets in the city of Philadelphia.
To/From	The streets that bound the road segment where the count location is (e.g. a count was taken on Spruce Street from 6th to 7th streets).
Transit Arterial	This is a suburban category of stratum and represents a major or minor arterial road segment with surface transit.

Table A.1: Suburban Census Tract Count Locations

COUNTY	STRATUM TYPE	STRATUM	MUNICIPALITY	ROAD NAME	FROM	TO	OUTDIR	INDIR	SIDEWALK	AADP	SETDATE	Google link
Bucks	Census Tract	0.0.0	Lower Makefield Township	Dolington Road	Quarry Commons	Chase La	W	E	north	47	2019-06-19	https://goo.gl/maps/oAiGiqGDVKXqXYSv8
Bucks	Census Tract	0.0.0	Lower Makefield Township	Dolington Road	Quarry Commons	Chase La	E	W	south	10	2019-06-19	https://goo.gl/maps/DrQDLgeCV5AeeyHu6
Bucks	Census Tract	0.0.1	Middletown Township	Shasta Road	N Flowers Mill Rd	Municipal Way	W	E	north	28	2019-06-07	https://goo.gl/maps/tHtAhRm1qFJ53kt26
Bucks	Census Tract	0.0.1	Middletown Township	Shasta Road	N Flowers Mill Rd	Municipal Way	W	E	south	23	2019-06-07	https://goo.gl/maps/TaLWUfPrrCZZWKiU9
Bucks	Census Tract	0.1.0	Doylestown Township	Almshouse Road	Pa 611 Easton Rd	Eagle La	W	E	north	29	2019-06-07	https://goo.gl/maps/vkZnDCAscLLuaQzK6
Bucks	Census Tract	0.1.0	Doylestown Township	Almshouse Road	Pa 611 Easton Rd	Eagle La	E	W	south	4	2019-06-07	https://goo.gl/maps/47QU2V76ktwecwAS9
Bucks	Census Tract	0.1.1	Yardley Borough	E College Avenue	S Bell Ave	S Bell Ave	W	E	north	71	2019-06-19	https://goo.gl/maps/ZVVroXuCGbMDvVwN6
Bucks	Census Tract	0.1.1	Yardley Borough	E College Avenue	S Bell Ave	S Bell Ave	E	W	south	21	2019-06-19	https://goo.gl/maps/CQiBUhd7ju1n9DFb8
Bucks	Census Tract	1.0.0	Warminster Township	Centennial Road	Colonial Dr	William Tenent	W	E	north	50	2019-06-07	https://goo.gl/maps/WLDWKzjN3hxnvAH36
Bucks	Census Tract	1.0.0	Warminster Township	Centennial Road	Colonial Dr	William Tenent	E	W	south	42	2019-06-07	https://goo.gl/maps/SJeC8gzJKgUT1SLn8
Bucks	Census Tract	1.0.1	Sellersville Borough	Green Street	Penn St	High St	W	E	south	21	2019-06-07	https://goo.gl/maps/K8WdFAEP1k813EzY8
Bucks	Census Tract	1.0.1	Sellersville Borough	Green Street	Penn St	High St	E	W	north	16	2019-06-07	https://goo.gl/maps/Ex7z12b1LARop6To6
Bucks	Census Tract	1.1.0	Northampton Township	Saint Leonards Road	Summer Dr	Winter Rd	S	N	east	142	2019-06-07	https://goo.gl/maps/1rgHUXGTduUL6tzdA
Bucks	Census Tract	1.1.1	Bensalem Township	Declaration Drive	Mansion Dr	Adams Ct	E	W	north	67	2019-06-19	https://goo.gl/maps/E7HnRVNnhxskP1t97
Bucks	Census Tract	1.1.1	Bensalem Township	Declaration Drive	Mansion Dr	Adams Ct	W	E	south	57	2019-06-19	https://goo.gl/maps/E7HnRVNnhxskP1t97
Chester	Census Tract	0.0.0	Tredyffrin Township	W Valley Road	Woodcrest Rd	Colket La	N	S	east	50	2019-06-04	https://goo.gl/maps/LXJTaeWPX31z9wn57
Chester	Census Tract	0.0.1	Oxford Borough	Hodgson Street	Penn Ave	3Rd St	W	E	north	84	2019-06-04	https://goo.gl/maps/7HJk12ywAGstWLAJ6
Chester	Census Tract	0.0.1	Oxford Borough	Hodgson Street	Penn Ave	3Rd St	E	W	south	52	2019-06-04	https://goo.gl/maps/PZJbvLpTrT4EvNUi6
Chester	Census Tract	0.1.0	East Bradford Township	Mansion House Drive	Yorkminster Rd	Whispering	W	E	north	61	2019-06-05	https://goo.gl/maps/6wSJym8jPgmVaMmQ6
Chester	Census Tract	0.1.1	West Goshen Township	Halvorsen Drive	Huber Pl	Old Westtown Rd	N	S	west	12	2019-06-05	https://goo.gl/maps/LpMbhSSYcDhYBTTm7
Chester	Census Tract	0.1.1	West Goshen Township	Halvorsen Drive	Huber Pl	Old Westtown Rd	S	N	east	10	2019-06-05	https://goo.gl/maps/EJe4XZTCYCdedcJD8
Chester	Census Tract	1.0.0	Malvern Borough	Monument Avenue	Griffith Ave	Prospect Ave	W	E	north	85	2019-06-05	https://goo.gl/maps/Xup9V7KjMUxnB9vw6
Chester	Census Tract	1.0.0	Malvern Borough	Monument Avenue	Griffith Ave	Prospect Ave	E	W	south	77	2019-06-05	https://goo.gl/maps/iGSwWyPYNjn2Q3qb7
Chester	Census Tract	1.0.1	Coatesville City	N 6th Avenue	E Chestnut St	E Diamond St	N	S	west	156	2019-06-05	https://goo.gl/maps/EoSKA6Y7NpSrekLr7
Chester	Census Tract	1.0.1	Coatesville City	N 6th Avenue	E Chestnut St	E Diamond St	S	N	east	115	2019-06-05	https://goo.gl/maps/zV5z4gvdu4dRsyadA
Chester	Census Tract	1.1.0	Uwchlan Township	Devon Drive	Wilson Cir	Noel Cir	E	W	north	61	2019-06-05	https://goo.gl/maps/5WmXzy1JGQwYt853A
Chester	Census Tract	1.1.0	Uwchlan Township	Devon Drive	Wilson Cir	Noel Cir	W	E	south	55	2019-06-05	https://goo.gl/maps/Cnurei6GDuPEshsB7
Chester	Census Tract	1.1.1	Downingtown Borough	W Pennsylvania Avenue	Hunt Ave	Whelen Ave	W	E	south	68	2019-06-05	https://goo.gl/maps/ewPfbLKGchbzLvYr5
Chester	Census Tract	1.1.1	Downingtown Borough	W Pennsylvania Avenue	Hunt Ave	Whelen Ave	E	W	north	63	2019-06-05	https://goo.gl/maps/gTdFWH57vaSHcfYr8
Delaware	Census Tract	0.0.0	Bethel Township	Bethel Road	Foulk Rd	Hammond Dr	S	N	west	16	2019-05-15	https://goo.gl/maps/S1XSFZvkxn1p3Xn18
Delaware	Census Tract	0.0.1	Nether Providence	Wallingford Avenue	Forrest Ave	Anderson St	W	E	north	60	2019-05-15	https://goo.gl/maps/LwFjTdWs4ofvV4XM7
Delaware	Census Tract	0.1.0	Marple Township	Mac Larie Lane	Hedgerow Dr	Farmhouse Rd	N	S	west	41	2019-05-15	https://goo.gl/maps/UsuM1vT7hTs6C2jf8
Delaware	Census Tract	0.1.0	Marple Township	Mac Larie Lane	Hedgerow Dr	Farmhouse Rd	N	S	east	18	2019-05-15	https://goo.gl/maps/kB5hsFAiwUxqbdCX9
Delaware	Census Tract	1.0.0	Folcroft Borough	Taylor Drive	Carter Rd	Delmar Dr	N	S	west	133	2019-05-15	https://goo.gl/maps/fnbDhymkFcfRaaTe6
Delaware	Census Tract	1.0.0	Folcroft Borough	Taylor Drive	Carter Rd	Delmar Dr	S	N	east	90	2019-05-15	https://goo.gl/maps/JVYNwDBjDbQGb5aG7
Delaware	Census Tract	1.0.1	Media Borough	W State Street	S Lemon St	S Orange St	E	W	north	322	2019-05-15	https://goo.gl/maps/wxWmvD3ouUhtUasPA
Delaware	Census Tract	1.0.1	Media Borough	W State Street	S Lemon St	S Orange St	E	W	south	322	2019-05-15	https://goo.gl/maps/L9aoqcmY3qD2KBgN7
Delaware	Census Tract	1.1.0	Springfield Township	Glendale Circle	Joseph Place	Edgewood Dr	S	N	west	30	2019-05-23	https://goo.gl/maps/nQgQf2DYAMtUPTJT8
Delaware	Census Tract	1.1.0	Springfield Township	Glendale Circle	Joseph Place	Edgewood Dr	N	S	east	19	2019-05-23	https://goo.gl/maps/CJbh2we6JEMgJSFU8
Delaware	Census Tract	1.1.1	Sharon Hill Borough	Sharon Avenue	Woodlawn Ave	School St	S	N	east	245	2019-05-15	https://goo.gl/maps/tR3nq5pNCDmeUdk77
Delaware	Census Tract	1.1.1	Sharon Hill Borough	Sharon Avenue	Woodlawn Ave	School St	N	S	west	158	2019-05-15	https://goo.gl/maps/jZxavJpRXMAMebdh9
Montgomery	Census Tract	0.0.0	Franconia Township	N 4th Street	Pear Tree Circle	Church Rd	S	N	west	35	2019-05-25	https://goo.gl/maps/DeEiicqgvXeMWqqk9
Montgomery	Census Tract	0.0.1	Upper Dublin Township	Loch Alsh Avenue	Cedar Rd	Hoffman Rd	E	W	south	39	2019-05-25	https://goo.gl/maps/5nXTbQBHdqNJGjfr8
Montgomery	Census Tract	0.0.1	Upper Dublin Township	Loch Alsh Avenue	Cedar Rd	Hoffman Rd	W	E	north	38	2019-05-25	https://goo.gl/maps/fvStn7sFNfBBJ5Gb9
Montgomery	Census Tract	0.1.0	Upper Providence Town-	Vaughn Road	School La	Orchard Ct	N	S	east	80	2019-05-23	https://goo.gl/maps/NgXmvCA2VpsHBmFg9
Montgomery	Census Tract	0.1.0	Upper Providence Town-	Vaughn Road	School La	Orchard Ct	S	N	west	65	2019-05-23	https://goo.gl/maps/HaPbrP9GJe6BS4tBA
Montgomery	Census Tract	0.1.1	Lower Merion Township	Old Lancaster Road	Booth La	Montgomery Ave	E	W	north	78	2019-05-23	https://goo.gl/maps/4MN5pKWKGyroY6X87
Montgomery	Census Tract	1.0.0	Abington Township	Central Avenue	Spear Ave	Lincoln Ave	S	N	west	38	2019-05-28	https://goo.gl/maps/q1e7quUY8Uvs3WaJ8
Montgomery	Census Tract	1.0.0	Abington Township	Central Avenue	Spear Ave	Lincoln Ave	N	S	east	29	2019-05-28	https://goo.gl/maps/GZe4ym4C4m6dXuMv9
Montgomery	Census Tract	1.0.1	Norristown Borough	W Marshall Street	Kohn St	George St	E	W	north	1096	2019-05-23	https://goo.gl/maps/B7YLQSfLkvFSWCxU6
Montgomery	Census Tract	1.0.1	Norristown Borough	W Marshall Street	Kohn St	George St	W	E	south	846	2019-05-23	https://goo.gl/maps/Httk76sBMhFhAHnE6
Montgomery	Census Tract	1.1.0	Towamencin Township	Troxel Road	Sumneytown Pk	Mark Dr	S	N	west	6	2019-05-28	https://goo.gl/maps/SZCbzbs4bxXA1JGc8
Montgomery	Census Tract	1.1.0	Towamencin Township	Troxel Road	Sumneytown Pk	Mark Dr	N	S	east	4	2019-05-28	https://goo.gl/maps/HnrqWvnguE1mvJsa6
Montgomery	Census Tract	1.1.1	Ambler Borough	Hendricks Street	Tennis Ave	Edgewood Dr	E	W	south	86	2019-05-28	https://goo.gl/maps/bqijqJQU8ETLp68E6
Montgomery	Census Tract	1.1.1	Ambler Borough	Hendricks Street	Tennis Ave	Edgewood Dr	W	E	north	71	2019-05-28	https://goo.gl/maps/34Zsdkez6oPgoToDA

Suburban Stratum Categories:
Population density (1000s/sq. mi.)
Road density
Percentage of college students
Example: 0.1.1 would have below median pop. density, above median road density, and above median percentage college students

Philadelphia Stratum Categories:
Transit activity density
Percentage of college students
Example: 0.1 would have below median transit activity and above median percentage of college students.

Table A.2: Philadelphia Census Tract Count Locations

COUNTY	STRATUM TYPE	STRATUM	MUNICIPALITY	ROAD NAME	FROM	TO	OUTDIR	INDIR	SIDEWALK	AADP	SETDATE	Google link
Philadelphia	Census Tract	0.0	Philadelphia	W Norris Street	Leithgow St	4th St	E	W	north	523	2019-10-08	https://goo.gl/maps/iQcQPhXUbjQWVQFi7
Philadelphia	Census Tract	0.0	Philadelphia	W Norris Street	Leithgow St	4th St	W	E	south	197	2019-10-08	https://goo.gl/maps/5igSfWNDER5mJS9b8
Philadelphia	Census Tract	0.0	Philadelphia	Tremont Street	Calvert St	Leonard St	N	S	east	158	2019-09-12	https://goo.gl/maps/bTfvCPeftogUmgug8
Philadelphia	Census Tract	0.0	Philadelphia	Tremont Street	Calvert St	Leonard St	N	S	east	158	2019-09-12	https://goo.gl/maps/QirzVydqfmE9DoKa6
Philadelphia	Census Tract	0.0	Philadelphia	Marsden Street	Torresdale Ave	Ditman St	E	W	south	109	2019-09-23	https://goo.gl/maps/qfkqe5J6Yie2gDpd8
Philadelphia	Census Tract	0.0	Philadelphia	Marsden Street	Torresdale Ave	Ditman St	W	E	north	90	2019-09-24	https://goo.gl/maps/2GLrGrBBZFRXRLni8
Philadelphia	Census Tract	0.0	Philadelphia	Philmont Avenue	Bustleton Ave	Morgan Dr	N	S	south	64	2019-09-12	https://goo.gl/maps/ExLsk96DXP1Rxxvt5
Philadelphia	Census Tract	0.0	Philadelphia	Wissinoming Street	Lindel Ave	Arendell Ave	W	E	south	48	2019-09-24	https://goo.gl/maps/XicJ8EVNTfWxaytY9
Philadelphia	Census Tract	0.0	Philadelphia	Philmont Avenue	Bustleton Ave	Morgan Dr	S	N	north	28	2019-09-12	https://goo.gl/maps/Wd93uui2G893eYfF8
Philadelphia	Census Tract	0.0	Philadelphia	Galahad Road	Kentwood St	Garth Rd	S	N	east	27	2019-09-12	https://goo.gl/maps/AGKJgSSG5QTEn9x29
Philadelphia	Census Tract	0.0	Philadelphia	Stanwood Street	Colfax St	Arthur St	S	N	west	25	2019-09-12	https://goo.gl/maps/B8wm8o9XFpiEuz8S7
Philadelphia	Census Tract	0.0	Philadelphia	Stanwood Street	Colfax St	Arthur St	S	N	east	24	2019-09-12	https://goo.gl/maps/EDpMA187SHnwPADi7
Philadelphia	Census Tract	0.0	Philadelphia	Galahad Road	Kentwood St	Garth Rd	N	S	west	22	2019-09-12	https://goo.gl/maps/ysBwaXgx4cPvV9uJ6
Philadelphia	Census Tract	0.0	Philadelphia	Wissinoming Street	Lindel Ave	Arendell Ave	W	E	north	20	2019-09-24	https://goo.gl/maps/LbvfoJc5sHGPY8PG7
Philadelphia	Census Tract	0.1	Philadelphia	Church Street	Penn St	Griscom St	E	W	south	638	2019-09-24	https://goo.gl/maps/1i9b8he6hPy4Ja5H9
Philadelphia	Census Tract	0.1	Philadelphia	W Westmoreland Street	Lawrence St	45th St	E	W	north	348	2019-09-24	https://goo.gl/maps/d4zSXBtcYbNM4E1n6
Philadelphia	Census Tract	0.1	Philadelphia	W Westmoreland Street	Lawrence St	45th St	E	W	south	322	2019-09-24	https://goo.gl/maps/iAam2qn9CebDpMWP9
Philadelphia	Census Tract	0.1	Philadelphia	Church Street	Penn St	Griscom St	W	E	north	190	2019-09-24	https://goo.gl/maps/BePeTFs5ruBxtakZA
Philadelphia	Census Tract	0.1	Philadelphia	Franklin Street	Oxford St	Cecil B Moore	N	S	west	106	2019-10-08	https://goo.gl/maps/XbQgpgF7eKavnr1p7
Philadelphia	Census Tract	0.1	Philadelphia	Franklin Street	Oxford St	Cecil B Moore	N	S	east	42	2019-10-08	https://goo.gl/maps/TNMLu9U8swc6dksA8
Philadelphia	Census Tract	1.0	Philadelphia	N Marshall Street	Norris St	Diamond St	S	N	west	159	2019-10-08	https://goo.gl/maps/ZgnDKrkPA9NAGXi46
Philadelphia	Census Tract	1.0	Philadelphia	W Crown Avenue	Fordham Rd	Whitehall La	S	N	south	134	2019-09-12	https://goo.gl/maps/epQdHQfzWRR6joeY8
Philadelphia	Census Tract	1.0	Philadelphia	N 18th Street	73rd Ave	Ashley Rd	S	N	west	123	2019-10-08	https://goo.gl/maps/6Uz9yEomBoeK2ebe7
Philadelphia	Census Tract	1.0	Philadelphia	Magee Avenue	Bingham St	Tabor Ave	W	E	north	114	2019-09-24	https://goo.gl/maps/CAMbZrgyvW8nBLES8
Philadelphia	Census Tract	1.0	Philadelphia	N Marshall Street	Norris St	Diamond St	N	S	east	106	2019-10-08	https://goo.gl/maps/PYjMUooTnp948gvcA
Philadelphia	Census Tract	1.0	Philadelphia	Bowler Street	Witler St	Birwood St	N	S	north	101	2019-09-12	https://goo.gl/maps/CBj81vtM19mKQX5t6
Philadelphia	Census Tract	1.0	Philadelphia	W Wyoming Avenue	Windrim Ave	16th St	E	W	south	101	2019-10-08	https://goo.gl/maps/zQV47XiDZ6FRbzGC7
Philadelphia	Census Tract	1.0	Philadelphia	Nanton Drive	Biscayne Dr	Nanton Pl	S	N	east	94	2019-09-12	https://goo.gl/maps/FV9sMqcBPpiXymR1A
Philadelphia	Census Tract	1.0	Philadelphia	Nanton Drive	Biscayne Dr	Nanton Pl	S	N	west	87	2019-09-12	https://goo.gl/maps/RKk8P6W8NeCEs2yt9
Philadelphia	Census Tract	1.0	Philadelphia	E Walnut Park Drive	Claremont Rd	Fariston Dr	W	E	north	85	2019-09-24	https://goo.gl/maps/FheCMPsUtgtpCT7T6
Philadelphia	Census Tract	1.0	Philadelphia	Magee Avenue	Bingham St	Tabor Ave	W	E	south	85	2019-09-24	https://goo.gl/maps/JpKckdCzZz4P1KaNA
Philadelphia	Census Tract	1.0	Philadelphia	Bowler Street	Witler St	Birwood St	N	S	south	80	2019-09-12	https://goo.gl/maps/mcBprsjrrgLwDfQo7
Philadelphia	Census Tract	1.0	Philadelphia	E Walnut Park Drive	Claremont Rd	Fariston Dr	E	W	south	79	2019-09-24	https://goo.gl/maps/rZ8CpzzjqSJJQuPx6
Philadelphia	Census Tract	1.0	Philadelphia	W Wyoming Avenue	Windrim Ave	16th St	E	W	north	77	2019-10-08	https://goo.gl/maps/TvRag8yMmWcdBp8A7
Philadelphia	Census Tract	1.0	Philadelphia	N 18th Street	73rd Ave	Ashley Rd	N	S	east	68	2019-10-08	https://goo.gl/maps/ru4zbgJdT6c9oYjL9
Philadelphia	Census Tract	1.0	Philadelphia	W Crown Avenue	Fordham Rd	Whitehall La	N	S	north	57	2019-09-12	https://goo.gl/maps/dzKzXLMiWQYbXKGBA
Philadelphia	Census Tract	1.1	Philadelphia	Powelton Avenue	34th St	33rd St	west	east	south	1287	2011-09-27	https://goo.gl/maps/3ZJ5Kp86gzJyv6bV6
Philadelphia	Census Tract	1.1	Philadelphia	Powelton Avenue	34th St	33rd St	west	east	north	795	2011-09-27	https://goo.gl/maps/ACRu716jfoHN48K8A
Philadelphia	Census Tract	1.1	Philadelphia	W Chew Avenue	5th St	Lawrence St	E	W	south	698	2019-09-23	https://goo.gl/maps/9G4VU3ohSCmepRu59
Philadelphia	Census Tract	1.1	Philadelphia	W Chew Avenue	5th St	Lawrence St	W	E	north	297	2019-09-24	https://goo.gl/maps/Zu8nB71A9HJmQEe88
Philadelphia	Census Tract	1.1	Philadelphia	N 4th Street	Master St	Harlan St	N	S	east	179	2019-10-08	https://goo.gl/maps/Mrq8VNEjGFXZwJ1t7
Philadelphia	Census Tract	1.1	Philadelphia	N 4th Street	Master St	Harlan St	S	N	west	178	2019-10-08	https://goo.gl/maps/ZDdkereQjqeMoSrF9

Table A.3: Higher and Lower Transit Street Count Locations

COUNTY	STRATUM TYPE	STRATUM	MUNICIPALITY	ROAD NAME	FROM	TO	OUTDIR	INDIR	SIDEWALK	AADP	SETDATE	Google link
Philadelphia	Higher Transit Street	0.0	Philadelphia	E Allegheny Avenue	Salmon St	Tilton St	N	S	east	365	2019-06-29	https://goo.gl/maps/5Xwz3DVekJLDBPCR8
Philadelphia	Higher Transit Street	0.0	Philadelphia	Castor Avenue	Emerson St	Hoffnagle St	S	N	north	241	2019-06-29	https://goo.gl/maps/JraRwsDWYnnLVdvK8
Philadelphia	Higher Transit Street	0.0	Philadelphia	E Allegheny Avenue	Salmon St	Tilton St	S	N	west	146	2019-06-29	https://goo.gl/maps/DjrwnL9dNPZnxhCm7
Philadelphia	Higher Transit Street	0.0	Philadelphia	Castor Avenue	Emerson St	Hoffnagle St	N	S	south	94	2019-06-29	https://goo.gl/maps/NBHqzbw3e2rgxMoe8
Philadelphia	Higher Transit Street	0.1	Philadelphia	Woodland Avenue	Yocum St	58th St	W	E	north	3689	2019-07-12	https://goo.gl/maps/jVDcve1PxDmR8Ame7
Philadelphia	Higher Transit Street	0.1	Philadelphia	W Dauphin Street	Mascher St	Howard St	E	W	south	536	2019-07-12	https://goo.gl/maps/pDDBUpyRY5J52o4R6
Philadelphia	Higher Transit Street	0.1	Philadelphia	Woodland Avenue	Yocum St	58th St	E	W	south	338	2019-07-12	https://goo.gl/maps/A9z9nxmqFV66Di3s6
Philadelphia	Higher Transit Street	0.1	Philadelphia	W Dauphin Street	Mascher St	Howard St	W	E	north	304	2019-07-12	https://goo.gl/maps/Qmb9FHvHFYRbJAzx7
Philadelphia	Higher Transit Street	0.1	Philadelphia	S 3rd Street	Sears St	Wharton St	N	S	west	219	2019-07-19	https://goo.gl/maps/evivvxPQXkHiSjug8
Philadelphia	Higher Transit Street	0.1	Philadelphia	S 3rd Street	Sears St	Wharton St	N	S	east	213	2019-07-19	https://goo.gl/maps/f5TAjRjZm2A288y99
Philadelphia	Higher Transit Street	1.0	Philadelphia	Passyunk Avenue	Elmwood Ave	73rd St	N	S	south	276	2019-07-12	https://goo.gl/maps/2k7LCk67JWHkK3cE8
Philadelphia	Higher Transit Street	1.0	Philadelphia	Passyunk Avenue	Elmwood Ave	73rd St	E	W	north	163	2019-07-12	https://goo.gl/maps/qv1VdafKyfRu8M4CA
Philadelphia	Higher Transit Street	1.0	Philadelphia	Frankford Avenue	Carteret Dr	Morrell Ave	S	N	east	89	2019-07-10	https://goo.gl/maps/zZB3kKWiE8tsLnkL6
Philadelphia	Higher Transit Street	1.0	Philadelphia	Frankford Avenue	Carteret Dr	Morrell Ave	S	N	west	60	2019-07-10	https://goo.gl/maps/rXyBjZ9MHXKWKMJS8
Philadelphia	Higher Transit Street	1.1	Philadelphia	S 7th Street	Sansom St	Chestnut St	S	N	east	1784	2019-07-10	https://goo.gl/maps/ecFxNFEGiDeKUF2p8
Philadelphia	Higher Transit Street	1.1	Philadelphia	S 7th Street	Sansom St	Chestnut St	N	S	west	1449	2019-07-10	https://goo.gl/maps/2E5TtWmfc4wNQUw7A
Philadelphia	Higher Transit Street	1.1	Philadelphia	Tasker Street	Dorrance St	S Cleveland St	W	E	south	380	2019-07-19	https://goo.gl/maps/93ivqu3SaEa9rgcF8
Philadelphia	Higher Transit Street	1.1	Philadelphia	Tasker Street	Dorrance St	S Cleveland St	E	W	north	373	2019-07-19	https://goo.gl/maps/e3iTo6q5cGi6W3P3A
Philadelphia	Higher Transit Street	1.1	Philadelphia	S 11th Street	Moore St	Pierce St	S	N	east	185	2019-07-12	https://goo.gl/maps/Gz6FVNfScz8cHe3WA
Philadelphia	Higher Transit Street	1.1	Philadelphia	S 11th Street	Moore St	Pierce St	S	N	east	185	2019-07-12	https://goo.gl/maps/ZaryFkCK7da1n3Cj9
Philadelphia	Lower Transit Street	0.0	Philadelphia	Medford Road	Belgreen Rd	Chilton Rd	W	E	south	90	2019-06-29	https://goo.gl/maps/e42WfZM1FL6ZQxDPA
Philadelphia	Lower Transit Street	0.0	Philadelphia	Central Avenue	Faunce St	Hasbrook Ave	S	N	east	82	2019-06-29	https://goo.gl/maps/dMYDwQwaVKJwi1SVA
Philadelphia	Lower Transit Street	0.0	Philadelphia	Medford Road	Belgreen Rd	Chilton Rd	E	W	north	50	2019-06-29	https://goo.gl/maps/25pqrT1Kxkhapqrn9
Philadelphia	Lower Transit Street	0.0	Philadelphia	Central Avenue	Faunce St	Hasbrook Ave	N	S	west	37	2019-06-29	https://goo.gl/maps/thB5JNhrvLWXBRpH6
Philadelphia	Lower Transit Street	0.1	Philadelphia	E Huntingdon Street	Kern St	Coral St	S	N	west	546	2019-07-12	https://goo.gl/maps/F377p6QdwJeYX9By5
Philadelphia	Lower Transit Street	0.1	Philadelphia	E Huntingdon Street	Kern St	Coral St	N	S	east	486	2019-07-12	https://goo.gl/maps/r83iSphHL6xyasNu9
Philadelphia	Lower Transit Street	0.1	Philadelphia	N 56th Street	W Oxford St	Us 30 Lancastor Ave	S	N	east	300	2019-07-10	https://goo.gl/maps/eWL2gdJh9VTCKySCA
Philadelphia	Lower Transit Street	0.1	Philadelphia	N 56th Street	W Oxford St	Us 30 Lancastor Ave	S	N	east	300	2019-07-10	https://goo.gl/maps/6UhiVhNHnhWKLMQa8
Philadelphia	Lower Transit Street	1.0	Philadelphia	Walnut Street	42nd St	41st St	W	E	south	1164	2019-07-10	https://goo.gl/maps/dfhd7Q2xNvensuk1A
Philadelphia	Lower Transit Street	1.0	Philadelphia	Walnut Street	42nd St	41st St	E	W	north	672	2019-07-10	https://goo.gl/maps/gKvt6UexBK9VMqxx5
Philadelphia	Lower Transit Street	1.0	Philadelphia	Henry Avenue	Wendover St	Jamestown St	N	S	west	293	2019-06-29	https://goo.gl/maps/hyFq3iB8AAbrdnUH8
Philadelphia	Lower Transit Street	1.0	Philadelphia	Henry Avenue	Wendover St	Jamestown St	S	N	east	158	2019-06-29	https://goo.gl/maps/vyzZWvgsrHH7Tn5U7
Philadelphia	Lower Transit Street	1.0	Philadelphia	Manayunk Avenue	Dupont St	Krams Ave	N	S	east	62	2019-06-29	https://goo.gl/maps/1f7HHUCWUeBUF6cX6
Philadelphia	Lower Transit Street	1.0	Philadelphia	Manayunk Avenue	Dupont St	Krams Ave	S	N	west	48	2019-06-29	https://goo.gl/maps/SkXeubCpU65nWuJr5
Philadelphia	Lower Transit Street	1.1	Philadelphia	N 4th Street	Poplar St	W Wildley St	N	S	west	285	2019-07-10	https://goo.gl/maps/bLcPVLDBUPLrxvM58
Philadelphia	Lower Transit Street	1.1	Philadelphia	N 4th Street	Poplar St	W Wildley St	S	N	east	238	2019-07-10	https://goo.gl/maps/DduWTgwcGdWrgof28
Philadelphia	Lower Transit Street	1.1	Philadelphia	66th Avenue	N Park Ave	13th St	W	E	north	195	2019-10-08	https://goo.gl/maps/eRsPiBfJSHvpiGRF7
Philadelphia	Lower Transit Street	1.1	Philadelphia	66th Avenue	N Park Ave	13th St	E	W	south	124	2019-10-08	https://goo.gl/maps/wZt6sKaFH6i5YDxt7

Suburban Stratum Categories:
Population density (1000s/sq. mi.)
Road density
Percentage of college students
Example: 0.1.1 would have below median pop. density, above median road density, and above median percentage college students

Philadelphia Stratum Categories:
Transit activity density
Percentage of college students
Example: 0.1 would have below median transit activity and above median percentage of college students.

Table A.4: Transit and Non-Transit Arterial Count Locations

COUNTY	STRATUM TYPE	STRATUM	MUNICIPALITY	ROAD NAME	FROM	TO	OUTDIR	INDIR	SIDEWALK	AADP	SETDATE	Google link
Chester	Transit Arterial	0.0.0	Tredyffrin Township	Lancaster Avenue	E Conestoga Rd	Devon Driveway	E	W	south	46	2019-04-25	https://goo.gl/maps/oH6ehFknu745A5b18
Chester	Transit Arterial	0.0.0	Tredyffrin Township	Lancaster Avenue	E Conestoga Rd	Devon Driveway	W	E	north	40	2019-04-25	https://goo.gl/maps/N3pMRTa1knyB1E636
Chester	Transit Arterial	0.0.0	East Pikeland Township	Schuylkill Road	Mowers Rd	Meadow La	S	N	west	37	2019-05-03	https://goo.gl/maps/pGSapC4CCuNZymdr8
Chester	Transit Arterial	0.0.0	East Pikeland Township	Schuylkill Road	Mowers Rd	Meadow La	N	S	east	14	2019-05-03	https://goo.gl/maps/43NgxDkVfvwjEHtm8
Bucks	Transit Arterial	0.0.1	Bensalem Township	E Street Road	Rail Ave	Reading Ave	E	W	south	24	2019-05-15	https://goo.gl/maps/yarDm1rzHESs1You8
Bucks	Transit Arterial	0.0.1	Bensalem Township	E Street Road	Rail Ave	Reading Ave	W	E	north	12	2019-05-15	https://goo.gl/maps/zWtma9tQC3NWCdqZ8
Delaware	Transit Arterial	0.1.0	Newtown Township	West Chester Pike	Ellis Ave	School La	E	W	north	54	2019-04-25	https://goo.gl/maps/SiVBC8FoRuwgYx2YA
Delaware	Transit Arterial	0.1.0	Newtown Township	West Chester Pike	Ellis Ave	School La	W	E	south	52	2019-04-25	https://goo.gl/maps/QMUJkqbzuULF8TVv6
Bucks	Transit Arterial	0.1.1	Falls Township	W Trenton Avenue	Nicoles Way	Valarie Rd	N	S	east	5	2019-05-15	https://goo.gl/maps/kPRJgpMBA9Q9wBqf8
Chester	Transit Arterial	1.0.0	Malvern Borough	E King Street	Church St	Ruthland Ave	W	E	south	321	2019-04-25	https://goo.gl/maps/K6zYjfBjLCe6Cd1NA
Chester	Transit Arterial	1.0.0	Malvern Borough	E King Street	Church St	Ruthland Ave	E	W	north	109	2019-04-25	https://goo.gl/maps/4YbFs2b4WbVMJkVH7
Bucks	Transit Arterial	1.0.1	Doylestown Borough	S Main Street	W State St	W Oakland Ave	S	N	west	839	2019-04-27	https://goo.gl/maps/qxjp1VQmFYqcmRpS8
Bucks	Transit Arterial	1.0.1	Doylestown Borough	N Main Street	E State St	E Court St	N	S	east	694	2019-04-27	https://goo.gl/maps/u1BvrsqJG4wK6Zdf8
Montgomery	Transit Arterial	1.1.0	Collegeville Borough	E Main Street	W 9th Ave	W 8th Ave	W	E	south	52	2019-05-23	https://goo.gl/maps/cMSoj6WZhHozXuGX6
Montgomery	Transit Arterial	1.1.0	Collegeville Borough	E Main Street	W 9th Ave	W 8th Ave	W	E	north	28	2019-05-23	https://goo.gl/maps/6UsJMxkxvPuVnmJN9
Delaware	Transit Arterial	1.1.1	Lansdowne Borough	W Baltimore Avenue	Runnemede Ave	Owens Ave	E	W	north	226	2019-05-23	https://goo.gl/maps/Wa3RDaW6F3NhWU6E6
Delaware	Transit Arterial	1.1.1	Lansdowne Borough	W Baltimore Avenue	Runnemede Ave	Owens Ave	W	E	south	147	2019-05-23	https://goo.gl/maps/k4kRRdPSEFvdthgv8
Montgomery	Transit Arterial	1.1.1	Cheltenham Township	Old York Road	Briar House Condo	Meetinghouse Rd	N	S	west	66	2019-06-19	https://goo.gl/maps/2J8aDB2BMN8LQUeM9
Montgomery	Transit Arterial	1.1.1	Cheltenham Township	Old York Road	Briar House Condo	Meetinghouse Rd	N	S	east	13	2019-06-19	https://goo.gl/maps/7JMKqSUZ1wfYVmQE7
Chester	Non-Transit Arterial	0.0.0	South Coatesville Borough	S 1st Avenue	Gibbons Ave	New St	N	S	west	82	2019-05-15	https://goo.gl/maps/a9ESzrJUUPXsNLKE6
Chester	Non-Transit Arterial	0.0.0	South Coatesville Borough	S 1st Avenue	Franklin St	Gibbons Ave	N	S	east	59	2019-05-15	https://goo.gl/maps/2JRwW5kuttVKoHhSA
Chester	Non-Transit Arterial	0.0.1	Willistown Township	Paoli Pike	Moreland Rd	Manor Rd	E	W	south	30	2019-04-25	https://goo.gl/maps/HtqeC3mrjuSorfuX8
Montgomery	Non-Transit Arterial	0.1.0	Upper Dublin Township	Susquehanna Road	Fort Washington Ave	Joel Dr	E	W	north	20	2019-06-19	https://goo.gl/maps/nbQz6ZbPeneL5w4L8
Bucks	Non-Transit Arterial	0.1.1	Yardley Borough	S Main Street	Yardly Town Center	Buttonwood Dr	N	S	east	750	2019-05-15	https://goo.gl/maps/ho5W8etewfeAw6ax7
Chester	Non-Transit Arterial	1.0.0	Downingtown Borough	E Lancaster Ave	Park Alley	Beech St	E	W	north	341	2019-05-03	https://goo.gl/maps/25AXkwhixokHpNXB9
Chester	Non-Transit Arterial	1.0.0	Downingtown Borough	E Lancaster Ave	Wallace Ave	Beech St	E	W	south	90	2019-05-03	https://goo.gl/maps/ZMxAEWai62cLkFcp6
Delaware	Non-Transit Arterial	1.0.1	Prospect Park Borough	Lincoln Avenue	15th Ave	16th Ave	S	N	east	114	2019-04-25	https://goo.gl/maps/zAhJNVLqdmA9P9Da8
Delaware	Non-Transit Arterial	1.0.1	Prospect Park Borough	Lincoln Avenue	15th Ave	16th Ave	S	N	west	76	2019-04-25	https://goo.gl/maps/vnkGcq51azEn2FG66
Montgomery	Non-Transit Arterial	1.1.0	Towamencin Township	Allentown Road	S Valley Forge Rd	Nash Ave	N	S	east	91	2019-05-15	https://goo.gl/maps/jZyWoAdbzDiMTLZh8
Montgomery	Non-Transit Arterial	1.1.0	Towamencin Township	Allentown Road	S Valley Forge Rd	Nash Ave	S	N	west	16	2019-05-15	https://goo.gl/maps/21o1uwvrPQTUvJSr8
Delaware	Non-Transit Arterial	1.1.1	Darby Borough	Springfield Road	E Lynbrook Rd	W Lynbrook Rd	E	W	north	179	2019-05-23	https://goo.gl/maps/eoyDyXyFmD2xcW7j6
Delaware	Non-Transit Arterial	1.1.1	Swarthmore Borough	N Swarthmore Avenue	Ogden Ave	N Chester Rd	S	N	west	69	2019-04-25	https://goo.gl/maps/JAnEWbpMjEJ7b45SA
Delaware	Non-Transit Arterial	1.1.1	Collingdale Borough	Springfield Road	E Lynbrook Rd	W Lynbrook Rd	E	W	south	36	2019-05-23	https://goo.gl/maps/pHmMiDWhhbNebwVE7

Suburban Stratum Categories:
Population density (1000s/sq. mi.)
Road density
Percentage of college students
Example: 0.1.1 would have below median pop. density, above median road density, and above median percentage college students

Philadelphia Stratum Categories:
Transit activity density
Percentage of college students
Example: 0.1 would have below median transit activity and above median percentage of college students.

Table A.5: School Count Locations

COUNTY	STRATUM TYPE	STRATUM	MUNICIPALITY	ROAD NAME	FROM	TO	OUTDIR	INDIR	SIDEWALK	AADP	SETDATE	Google link
Bucks	School	0.0.0	Milford Township	Sleepy Hollow Road	Pfaff Elementary	Spinnerstown Rd	N	S	east	29	2019-04-27	https://goo.gl/maps/sh7iG69kaMWP9dSM6
Bucks	School	0.0.0	Milford Township	Sleepy Hollow Road	Pfaff Elementary	Pfaff Elementary	S	N	west	4	2019-04-27	https://goo.gl/maps/GMFycFCKdR5CFSsNA
Montgomery	School	0.0.1	Lower Merion Township	Hagys Ford Road	Old Gulph Rd	Righters Mill Rd	S	N	west	52	2019-05-23	https://goo.gl/maps/jGNKR8fgY3ia5VEy7
Montgomery	School	0.0.1	Lower Merion Township	Righters Mill Road	Margo La	Hagys Ford Rd	W	E	north	37	2019-05-23	https://goo.gl/maps/KcUtQrXumLqpj1d8A
Delaware	School	0.1.0	Marple Township	Paxon Hollow Road	Pine Tree Dr	School Driveway	E	W	south	24	2019-04-25	https://goo.gl/maps/Hg815CbrNXQHTzPH6
Montgomery	School	0.1.1	Cheltenham Township	Longfellow Road	Underwood Rd	Tennis Courts	S	N	west	26	2019-06-19	https://goo.gl/maps/3dLRzqFBFypwLVM57
Montgomery	School	0.1.1	Cheltenham Township	Rock Creek Drive	Cedarbrook Middle School	Old Arm Rd	E	W	south	9	2019-06-19	https://goo.gl/maps/fZQAhhjti32VmgRk8
Delaware	School	1.0.0	Lower Chichester Township	Huddell Avenue	Ridge Rd	Pechman Dr	N	S	east	179	2019-05-15	https://goo.gl/maps/HkkebxWgipdXVSGi9
Delaware	School	1.0.0	Lower Chichester Township	Huddell Avenue	Worrilow St	Palmer Dr	N	S	east	54	2019-05-15	https://goo.gl/maps/fKqgPGaJcv78Sjqx5
Chester	School	1.0.1	Phoenixville Borough	2nd Avenue	Lincoln Ave	Quick St	W	E	south	241	2019-05-15	https://goo.gl/maps/4wCu4bN4LgpkfKUo8
Chester	School	1.0.1	Phoenixville Borough	2nd Avenue	Lincoln Ave	Quick St	W	E	south	189	2019-05-15	https://goo.gl/maps/HJeuSFvPw5YjJVQ68
Bucks	School	1.0.1	Doylestown Borough	Linden Avenue	Rohr Dr	Linden Elementary	W	E	west	146	2019-04-27	https://goo.gl/maps/x2SdhqNm9BEjtduA8
Bucks	School	1.0.1	Quakertown Borough	S 7th Street	Park Ave	Quakertown Elementary	N	S	west	140	2019-04-27	https://goo.gl/maps/5r1LunpBQHf5ADtB9
Bucks	School	1.0.1	Quakertown Borough	S 7th Street	Unnamed Alley	Juniper St	N	S	east	137	2019-04-27	https://goo.gl/maps/mso4NBb374wb1HL4A
Bucks	School	1.0.1	Doylestown Borough	Linden Avenue	East St	Linden Elementary	S	N	east	16	2019-04-27	https://goo.gl/maps/rWVa9a5JkDmkW6JV8
Montgomery	School	1.1.0	Towamencin Township	Allentown Road	Woodlawn Dr	Weikel Rd	N	S	east	29	2019-05-15	https://goo.gl/maps/9VjiM8ySQJUUnbwE6
Montgomery	School	1.1.0	Towamencin Township	Allentown Road	Woodlawn Dr	Weikel Rd	W	E	east	17	2019-05-15	https://goo.gl/maps/kyoASot4SHTh6nv89
Montgomery	School	1.1.1	East Norriton Township	Springview Road	Montgomery Ave	Cole Manor Elementary School	E	W	east	77	2019-04-27	https://goo.gl/maps/68MPo3xJnxjHZtN67
Montgomery	School	1.1.1	East Norriton Township	Springview Road	Lawnton Rd	Cole Manor Elementary School	E	W	west	40	2019-04-27	https://goo.gl/maps/koQHaCek2avdrwoi8

Suburban Stratum Categories:
Population density (1000s/sq. mi.)
Road density
Percentage of college students
Example: 0.1.1 would have below median pop. density, above median road density, and above median percentage college students

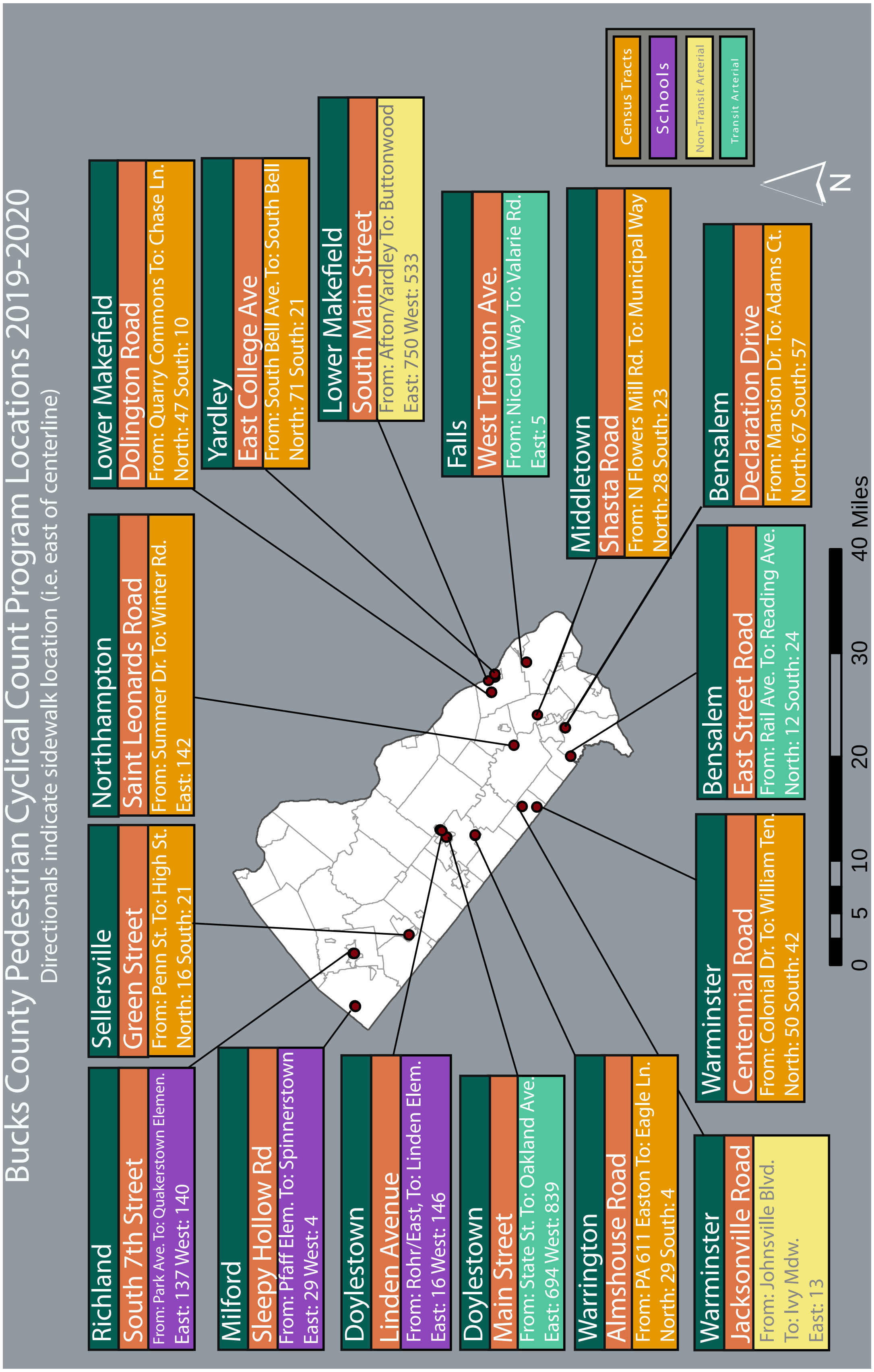
Philadelphia Stratum Categories:
Transit activity density
Percentage of college students
Example: 0.1 would have below median transit activity and above median percentage of college students.

Table A.6: Remaining Philadelphia Locations to be Counted

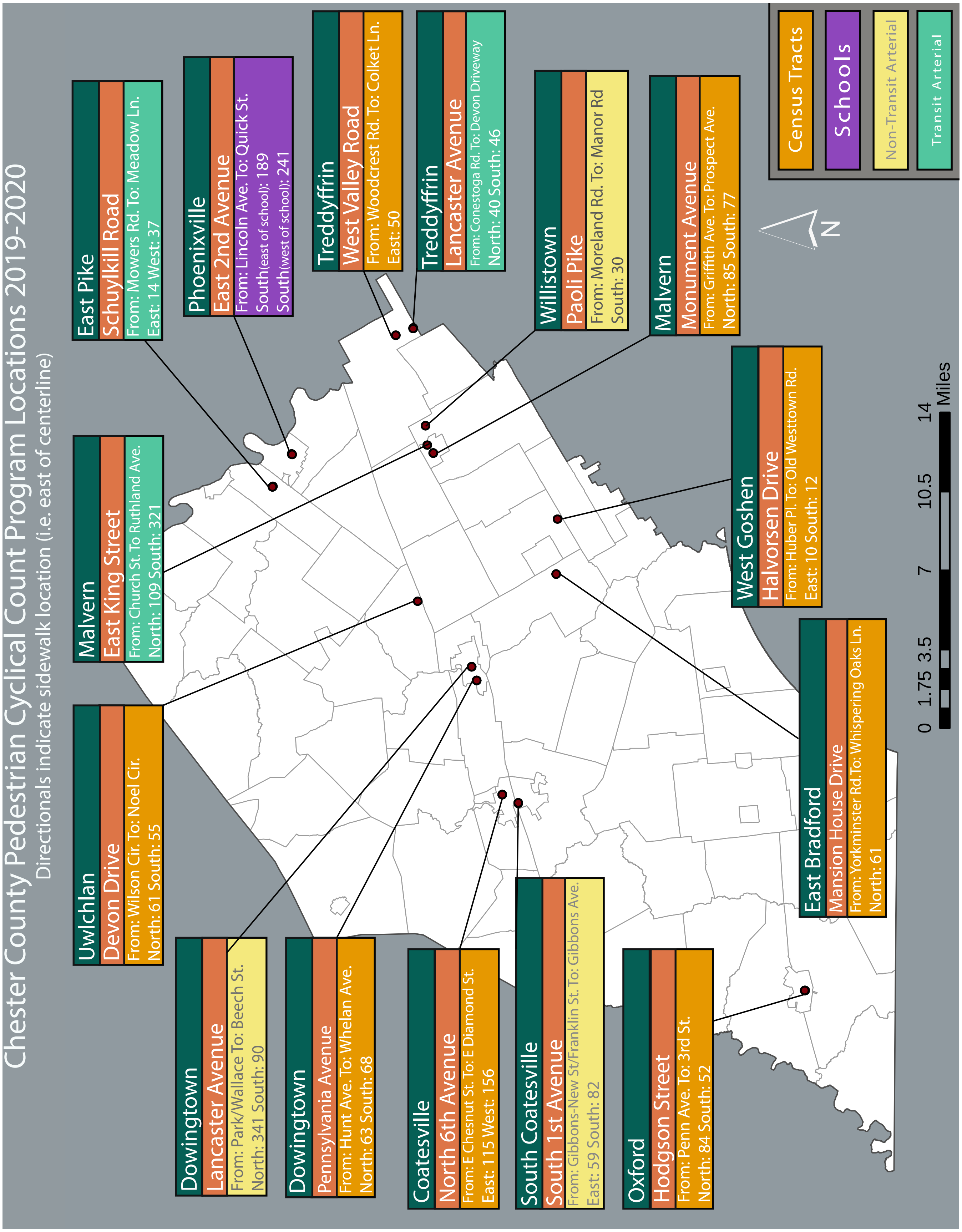
STRATUM TYPE	STRATUM	COUNTY	MUNICIPALITY	ROAD NAME	FROM	TO	SIDEWALK	AADP	SETDATE	Google link
Census Tract	0.0	Philadelphia	Philadelphia	Greene Street						https://goo.gl/maps/MYqYhNcQe5Cg5yqe8
Census Tract	0.0	Philadelphia	Philadelphia	Greene Street						https://goo.gl/maps/1ZAftKB788CqrVBH8
Census Tract	0.0	Philadelphia	Philadelphia	N 65th Street						https://goo.gl/maps/vBddHW7ANbtfzjTPA
Census Tract	0.0	Philadelphia	Philadelphia	N 65th Street						https://goo.gl/maps/QAjXnFpgcE3ds81J8
Census Tract	0.1	Philadelphia	Philadelphia	S 15th Street						https://goo.gl/maps/ziAtsoaS28Tzj73f9
Census Tract	0.1	Philadelphia	Philadelphia	S 15th Street						https://goo.gl/maps/tawajy2hEw81jUst6
Census Tract	0.1	Philadelphia	Philadelphia	Locust Street						https://goo.gl/maps/24Az8LZ6HsAQDWiW8
Census Tract	0.1	Philadelphia	Philadelphia	Locust Street						https://goo.gl/maps/tdthfC2tKFjhvkyZ9
Census Tract	0.1	Philadelphia	Philadelphia	N 20th Street						https://goo.gl/maps/XisvDHzmocQi8Wu27
Census Tract	0.1	Philadelphia	Philadelphia	N 20th Street						https://goo.gl/maps/p3ugE6s38DxKuxhN6
Census Tract	0.1	Philadelphia	Philadelphia	E Indiana Avenue						https://goo.gl/maps/9e7c8Z8KEPwiWaae9
Census Tract	0.1	Philadelphia	Philadelphia	E Indiana Avenue						https://goo.gl/maps/4CR3DLDZLWXEuHH68
Census Tract	0.1	Philadelphia	Philadelphia	N 45th Street						https://goo.gl/maps/tSg973asTsvvbstx7
Census Tract	0.1	Philadelphia	Philadelphia	N 45th Street						https://goo.gl/maps/6ZnbNeYVPK42Mpaw5
Census Tract	1.0	Philadelphia	Philadelphia	Greenhill Road						https://goo.gl/maps/fzoyEuVPLp9zowtM9
Census Tract	1.0	Philadelphia	Philadelphia	Greenhill Road						https://goo.gl/maps/KbJdbxd6aYBno5RW9
Census Tract	1.0	Philadelphia	Philadelphia	W Country Club Road						https://goo.gl/maps/DT8Pa1FomDN6yE6y9
Census Tract	1.0	Philadelphia	Philadelphia	W Country Club Road						https://goo.gl/maps/Aq9FkfKuHyQtF7Rj6
Census Tract	1.1	Philadelphia	Philadelphia	Reed Street						https://goo.gl/maps/yYbqnqkYBL7uVptG9
Census Tract	1.1	Philadelphia	Philadelphia	Reed Street						https://goo.gl/maps/H9LhStuoGt9NX7gD7
Census Tract	1.1	Philadelphia	Philadelphia	S 10th Street						https://goo.gl/maps/Kh6pgyhc7h5NU63f6
Census Tract	1.1	Philadelphia	Philadelphia	S 10th Street						https://goo.gl/maps/MX428wHxy25oc5gF6
Census Tract	1.1	Philadelphia	Philadelphia	S 10th Street						https://goo.gl/maps/HXeUNGeXy1T5rNRU7
Census Tract	1.1	Philadelphia	Philadelphia	S 10th Street						https://goo.gl/maps/RrKYb62vxjd1Ak489
Census Tract	0.0	Philadelphia	Philadelphia	Carpenter Lane						https://goo.gl/maps/1LE5erufF5jw64oh7
Census Tract	0.0	Philadelphia	Philadelphia	Carpenter Lane						https://goo.gl/maps/uAEZfEATikqRDFKFA
Census Tract	0.1	Philadelphia	Philadelphia	S 56th Street						https://goo.gl/maps/2D2rByyktmd6b1kK7
Census Tract	0.1	Philadelphia	Philadelphia	S 56th Street						https://goo.gl/maps/YeVurv4Sot31ByqHA
Census Tract	0.1	Philadelphia	Philadelphia	W Cambria Street						https://goo.gl/maps/P19GoMFJE7A3ttCy5
Census Tract	0.1	Philadelphia	Philadelphia	W Cambria Street						https://goo.gl/maps/3hdiGYbQeJzgdoam7
Census Tract	1.1	Philadelphia	Philadelphia	Moore Street						https://goo.gl/maps/bDY6FuCmPMb9s889A
Census Tract	1.1	Philadelphia	Philadelphia	Moore Street						https://goo.gl/maps/yg8VVJYShbbsxEhf8
Census Tract	1.1	Philadelphia	Philadelphia	Sansom Street						https://goo.gl/maps/NgC5RzncunY6PvT4A
Census Tract	1.1	Philadelphia	Philadelphia	Sansom Street						https://goo.gl/maps/vDXPXufXtt5ko31G6
Census Tract	1.1	Philadelphia	Philadelphia	Pine Street						https://goo.gl/maps/Bdpk1CfzZRy4CQxV8
Census Tract	1.1	Philadelphia	Philadelphia	Pine Street						https://goo.gl/maps/wMqR7VubgH2hb9cZ8
Census Tract	1.1	Philadelphia	Philadelphia	Locust Walk						https://goo.gl/maps/oy2Qz797KQiHJoDj6
Census Tract	1.1	Philadelphia	Philadelphia	Locust Walk						
Lower Transit Street	0.0	Philadelphia	Philadelphia	Haverford Avenue						https://goo.gl/maps/MqXpkHTXpcK6NoNF9
Lower Transit Street	0.0	Philadelphia	Philadelphia	Haverford Avenue						https://goo.gl/maps/C91qcgAQd3vCV9Eo8

APPENDIX B

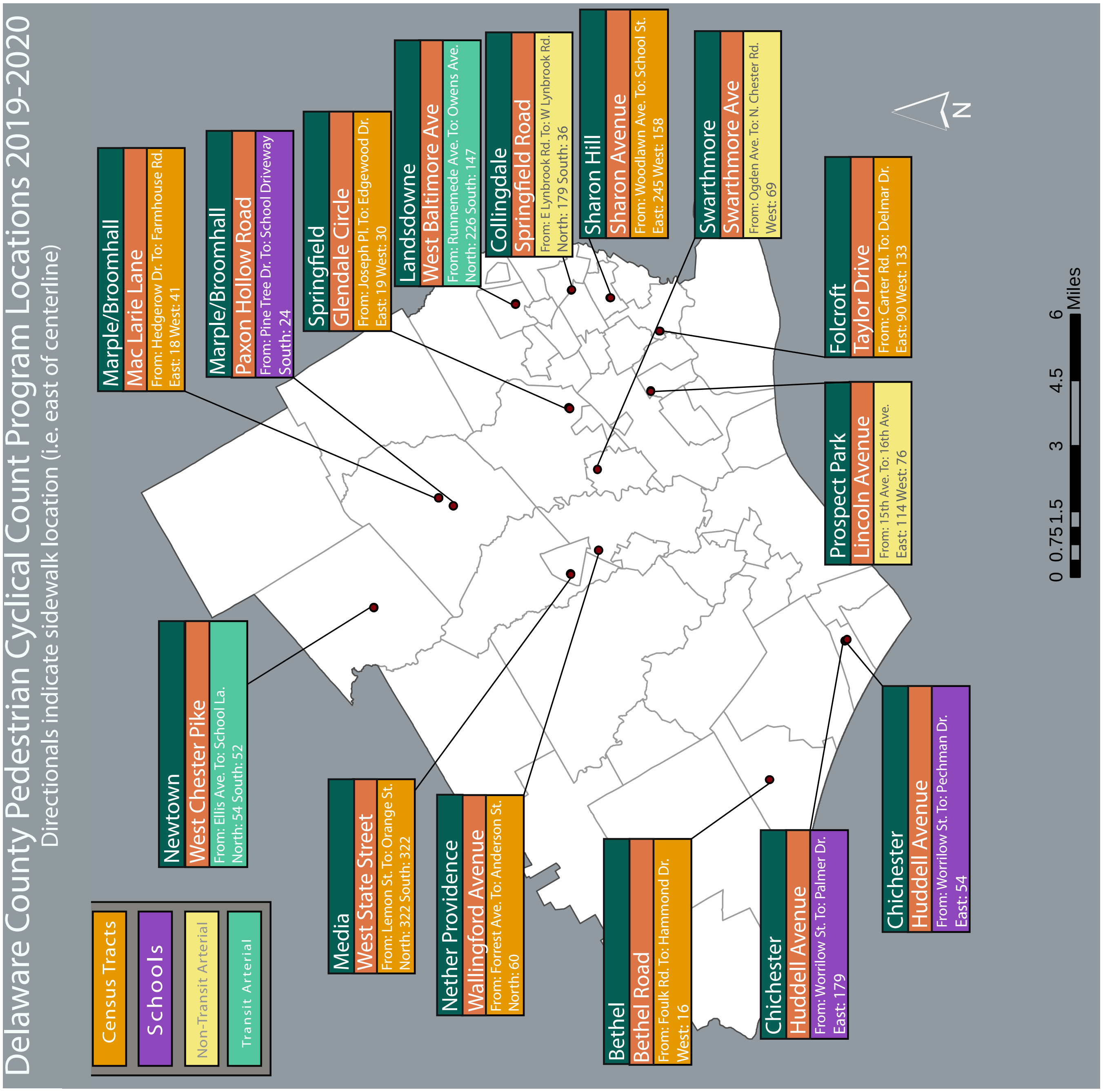
Map B.1: Bucks County Pedestrian Cyclical Count Locations



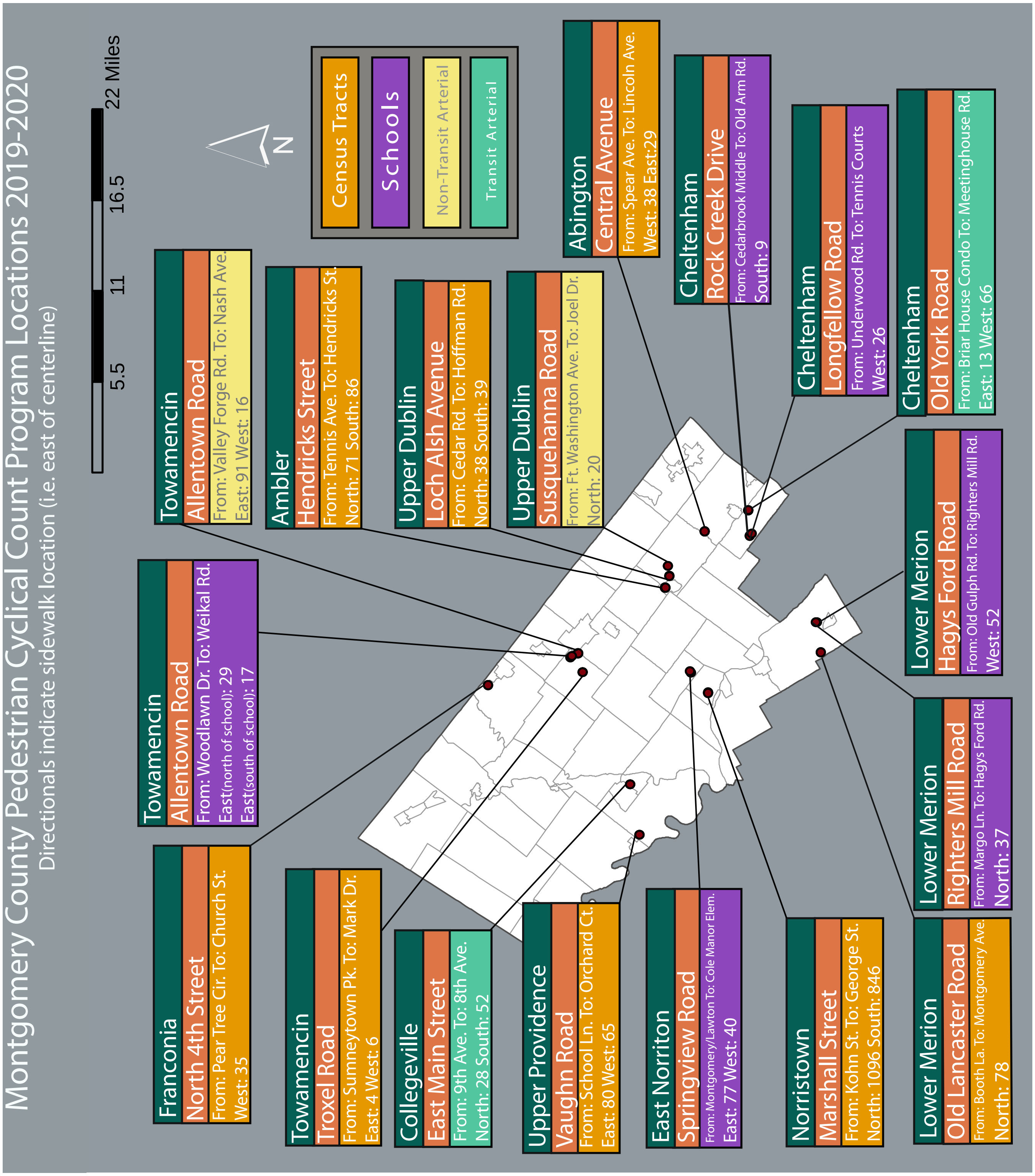
Map B.2: Chester County Pedestrian Cyclical Count Locations



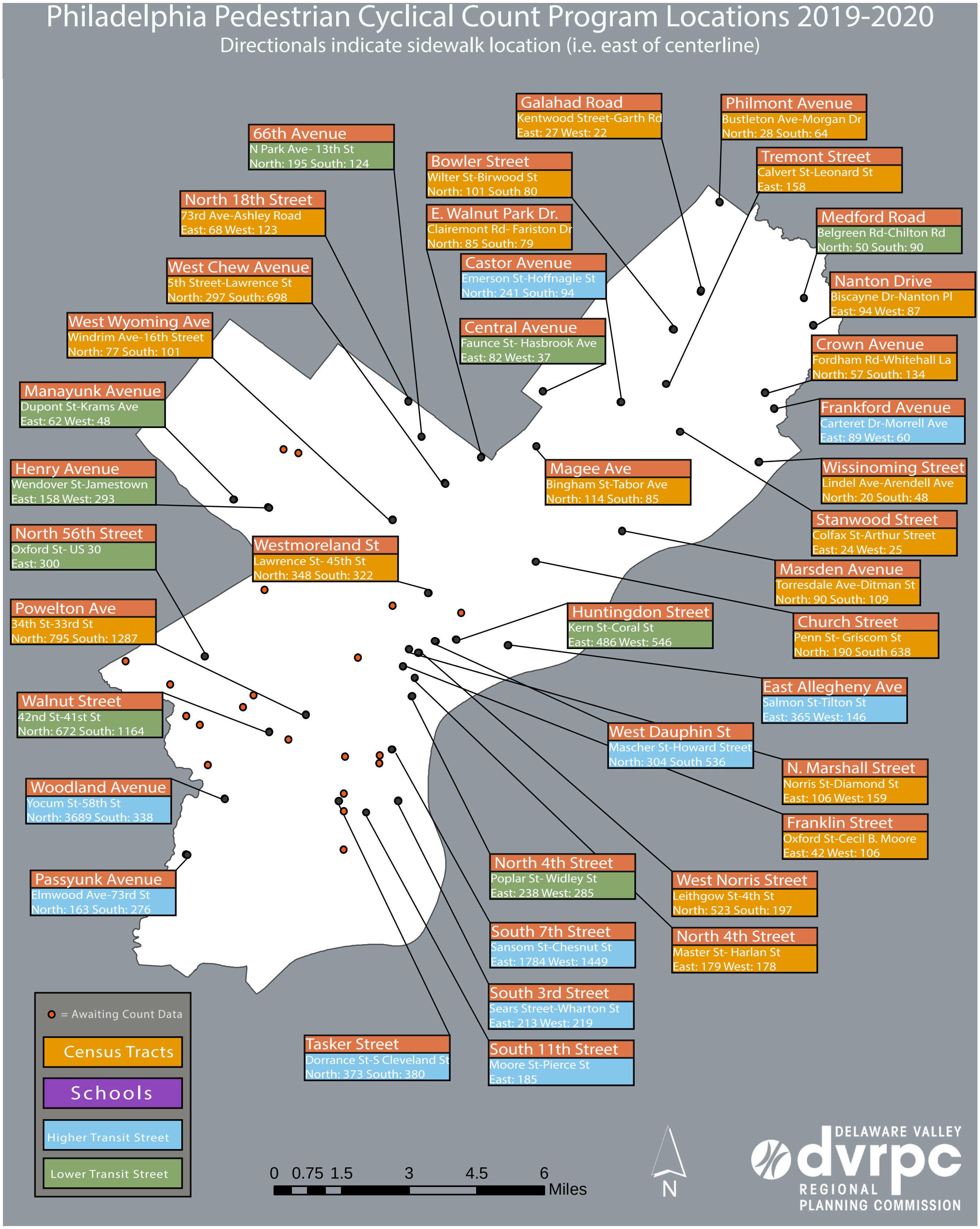
Map B.3: Delaware County Pedestrian Cyclical Count Locations



Map B.4: Montgomery County Pedestrian Cyclical Count Locations



Map B.5: Philadelphia Pedestrian Cyclical Count Locations



APPENDIX C

Towards Stratified Random Sampling: Design and Implementation of a Count Program to Monitor On-Street Pedestrian Activity

Addison Larson
Planning Data Scientist
Delaware Valley Regional Planning Commission
190 North Independence Mall West
8th Floor
Philadelphia, PA 19106
Tel: (432) 559-8686; Email: larsonaddison01@gmail.com

Cassidy Boulan, AICP [Corresponding Author]
Senior Transportation Planner
Office of Transit, Bicycle, and Pedestrian Planning
Delaware Valley Regional Planning Commission
190 North Independence Mall West
8th Floor
Philadelphia, PA 19106
Tel: (215) 238-2832; Fax: (215) 592-9125; Email: cboulan@dvrpc.org

Word Count: 6,737 words + 3 tables = 7,487 words

Submitted July 30, 2019

ABSTRACT

This paper discusses the design and implementation of the site selection process for the Delaware Valley Regional Planning Commission (DVRPC)'s on-street pedestrian counting program in a five-county area in Southeastern Pennsylvania. A stratified sampling scheme is used to select a representative set of 170 locations for seven-day infrared pedestrian counts, control for activity around schools and along road segments with transit service, and improve statistical rigor while maintaining a relatively small sample size. The site selection process is automated in R except for the verification of physical count locations, enhancing reproducibility and reducing the possibility of error.

INTRODUCTION

Monitoring on-street pedestrian activity is a challenging task because pedestrian movements are less constrained and exhibit more granular spatial fluctuation than automobiles or bicycles. While pedestrian counts could theoretically be conducted at a nearly infinite number of locations throughout a study area, and counts at a random sample of hundreds or thousands of locations would enable a more thorough understanding of on-street pedestrian activity, the realities of limited staff time, equipment, and budget force limitations on sample size. This paper discusses the design and implementation of the Delaware Valley Regional Planning Commission (DVRPC)'s Southeastern Pennsylvania Cyclical Pedestrian Counting Program, which includes counts at 170 on-street locations that capture the breadth of pedestrian activity in the region. At the time of writing, we are in the process of conducting seven-day infrared counts with EcoCounter equipment at the selected locations.

The study area for the count program includes Bucks, Chester, Delaware, Montgomery, and Philadelphia counties in Southeastern Pennsylvania. The geographic breadth of the study area and its range of land use and planning contexts—including the City of Philadelphia, suburban, and rural areas—make it difficult to select representative locations for pedestrian counts. Two key design elements, stepwise regression and stratified random sampling (SRS), reduce bias in site selection and ensure a range of contexts and types of count locations. While the site selection process is the main area of focus, we also demonstrate a method to transform point-level pedestrian counts to area-based pedestrian densities as a part of this process.

This paper proceeds as follows. First, the literature review provides an overview of five site selection approaches in non-motorized counting and the lessons we learned from these approaches. The methods section discusses each step of our site selection process, including the creation of sampling strata, selection from these strata, and identification of the final counting sites. Finally, the conclusion discusses potential improvements to the program design and anticipated uses of the pedestrian counts obtained through this program.

LITERATURE REVIEW

Existing guidance advises that non-motorized counts should be conducted in representative locations, especially when these data are used to monitor activity trends over time. Three aspects of representativeness appear throughout the guidance: counts can be considered representative because of their spatial distribution, range of physical contexts, and expected non-motorized activity, or some combination of these. In terms of spatial distribution, representative counts are spread as evenly as possible throughout the study area (*1*). Counts are considered representative when conducted in a range of physical contexts, including urban, suburban, and rural settings; land use context; facility type; and socioeconomic characteristics (*1,2*). Lastly, counts are considered representative when they measure the average, and not the highest or lowest, non-motorized activity in the study area (*1,3*).

Random and representative sampling are common site selection methods to ensure a representative set of count locations (*1*). While random selection is the most statistically rigorous approach, simple random selection may result in selecting locations where counting is impossible or there is very little pedestrian activity, resulting in volatile temporal data (*2,4*). Stratified random sampling is a preferred alternative to count in areas that exhibit characteristics of interest and to maintain a statistically rigorous approach that minimizes intra-group variability with a smaller sample size. However, even when counts are conducted in a representative set of locations—and the definition of "representative" depends on the researcher—there is little evidence that these estimates can be used either to create area-based estimates of non-motorized activity or to predict activity in areas where counts are not already being conducted (*2-4*).

Non-motorized count programs must maximize representativeness with finite budgets. Below is a survey of five approaches—some proposed, others implemented—to ensure a representative set of count locations.

DVRPC's cyclical bicycle counting program is an example of purposeful sampling among predetermined characteristics of interest (*5*). The program was designed to monitor changes in bicycling activity over time and space by conducting seven-day pneumatic tube counts every three years at 144 locations. Count locations were selected to ensure a mixture of trail and on-road facility types and spatial distribution across the nine-county region.

Jones et al.'s study of non-motorized activity in San Diego is a second example of purposeful sampling among predetermined characteristics (*4*). Manual peak period counts were conducted at 80 locations, including 40 existing locations and 40 new locations. These locations were purposefully selected to ensure a full range of representation across different land uses, demographic patterns, and facility types. Additional target and control sites included areas with high pedestrian crash rates, areas identified for future smart growth, and areas near transit stops and recent and planned bicycle and pedestrian facility improvements.

Schneider, Arnold, and Ragland's study of pedestrian intersection crossing volumes in Alameda County, CA is an example of purposeful selection of observations among sampling strata (*6*). The authors selected 50 intersections for two-hour manual counts; five infrared sensors were also rotated among 13 of these intersections for longer-term counts. Of the 50 intersections, 30 of 528 possible intersections along arterials were purposefully chosen from a 27-strata classification scheme. Each intersection's population density, median income, and proximity to commercial properties were categorized as high, medium, or low, creating 27 unique strata combinations. These three variables were selected after conducting a literature review of the correlates and drivers of pedestrian activity. The remaining 20 intersections were selected purposefully to represent neighborhoods near rapid transit stations, schools, central business districts, and intersections with trails.

O'Brien et al. propose a data-driven approach to creating sampling strata (*7*). In Appendix B of their report on creating a non-motorized count program for a 10-county region in North Carolina, the authors describe their ideal site selection plan. The plan includes methodology for estimating pedestrian trips by census tract and regression analysis to determine the major correlates of pedestrian activity in the study area. These correlates then inform the creation of factor groups.

Zhang, Jennings, and Aultman-Hall propose a method for stratified random sampling of locations along shared-use facilities (*8*). In their study of bicycle and pedestrian volumes along shared-use facilities in Chittenden County, Vermont, the authors divided the study area into 0.5-kilometer grid cells and used K-means clustering to categorize cells with nonzero facility length into five groups based on the surrounding land use types. Though their study focused on the relationship between land use patterns and bicycle and pedestrian volumes, the authors suggest that SRS could be used to select locations for counting among each land use type.

DVRPC's approach exemplifies a common approach to achieve an even spatial distribution and a range of facility types through purposeful site selection. Jones et al. implement a similar approach while also using sampling from target and control sites. Schneider et al.

demonstrate the creation of sampling strata based on the physical context surrounding count locations. O'Brien et al. improve upon the creation of sampling strata by using regression analysis to justify the variables used to construct these strata. Lastly, Zhang et al. propose that sampling strata can be used to implement SRS in non-motorized counting activities. We implement elements of these studies in the design of the cyclical pedestrian counting program, including target and control sites, sampling strata informed by regression analysis, and SRS.

METHODS

Our process of selecting count locations through SRS requires several steps, including: 1) using publicly available data to estimate average daily pedestrian trips at the census tract level; 2) comparing estimated pedestrian densities to observed pedestrian densities using DVRPC's existing pedestrian counts and testing refinements to the pedestrian estimation; 3) using the pedestrian estimation and stepwise regression to create a stratified sampling scheme that divides the region's census tracts into meaningful sampling strata and controls for activity around schools and along road segments with transit service; and 4) selecting observations within each sampling stratum and requirements for selecting a count location.
The analysis is fully automated in a series of R scripts until selecting physical sites for counting, which requires verification of count locations using aerial imagery and site selection in partnership with DVRPC's member governments. The process is summarized below in (**Figure 1**).

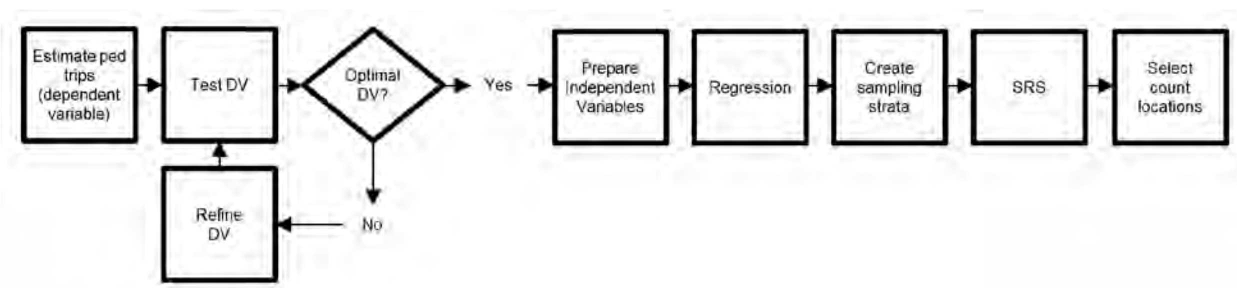


Figure 1 Summary of the methods used to select pedestrian count locations using SRS.

Estimate Average Daily Pedestrian Trips at the Census Tract Level

To begin selecting locations, we are immediately confronted with a chicken-and-egg problem: counts are required to understand pedestrian activity in the study area, but we must understand the study area's pedestrian activity to design an effective count program. As a starting point, we follow the methodology proposed by O'Brien et al. (*7*) to estimate the number of daily pedestrian trips at the census tract level. This number, though imperfect, gives a sense of the way pedestrian activity fluctuates throughout the study area. Pedestrian trips are estimated in two phases by first calculating the number of pedestrian commute trips and then adjusting the number to estimate total pedestrian trips. The pedestrian estimation formula relies entirely on publicly available data from 2012-2017 American Community Survey (ACS) 5-Year Estimates and the 2017 National Household Travel Survey (NHTS).

First, ACS and NHTS data are combined to estimate the sum of one-way pedestrian trips for four population groups: employed adults, school children, college students, and people who work from home. Each census tract receives a count of the number of one-way trips made for work purposes by these four population groups. For employed adults, the count of residents who typically walk to work by census tract is available directly from the ACS. For school children, the percentage of pedestrians among respondents traveling to or from school is calculated from the NHTS; this percentage is multiplied by the estimated count of children ages 5 through 14 by census tract. For college students, the pedestrian mode share of employed adults is multiplied by the number of students enrolled in college or graduate school by census tract. Lastly, the number of residents who work from home by census tract is divided by 4, with the assumption that 25 percent of people who work from home make work-related pedestrian trips. This is different from O'Brien et al. (*7*), who assume 50 percent of people who work from home make work-related pedestrian trips; given the prevalence of suburban and rural contexts in our study area, we thought it suitable to reduce this percentage. The sum of daily one-way pedestrian commute trips made by employed adults, school children, college students, and people who work from home is an estimate of pedestrian commute trips in the study area. This sum of pedestrian commute trips is scaled up to total pedestrian trips using NHTS information on the share of commute trips among all pedestrian trips.

The result is an estimate of the number of pedestrian trips, regardless of purpose, by census tract. It is a useful barometer of pedestrian activity across the region, but it has two shortcomings.

First, ACS journey to work data reports workers' origins by commute mode. This means that, for a single pedestrian respondent, only the tract where the respondent lives receives an additional estimated pedestrian. However, many people do not work in the census tract where they live; they likely cross at least one census tract boundary in order to get to their destination, and the ACS does not account for the destination tract or the tracts a pedestrian passes through on the commute. The problem of not accounting for pedestrians outside of their origin census tracts is compounded in dense areas such as Center City Philadelphia, where census tracts are smaller in size. Ironically, the neighborhoods comprised of dense and mixed-use census tracts where we expect the most pedestrian commuters are also the neighborhoods where we expect the most pedestrian commuters to not be counted using this input data and estimation method.

Second, the purpose of much pedestrian activity has nothing to do with work. We rescale tract-level pedestrian commute trips by NHTS responses to obtain a sum of all pedestrian trips, but this is mathematical sleight of hand, as the rescaling applies uniformly to the study area. Non-work pedestrian trips are not uniformly distributed across the study area; they are driven by destinations such as shopping and restaurants (*9*).

Test and Refine Pedestrian Estimation

Because of the shortcomings of the pedestrian estimation, we evaluate the quality of estimated average daily pedestrian trips at the census tract level. We use inverse distance weighted (IDW) interpolation to enable comparison between existing pedestrian counts and the results of the pedestrian estimation formula, plot linear regression residuals over the study area to visualize the contexts where estimated and existing pedestrian densities converge and diverge, and test the effectiveness of refinements to the pedestrian estimation using correlation analysis.

IDW Interpolation

DVRPC has conducted 981 pedestrian counts in 494 unique locations in Southeastern Pennsylvania from 2011 to 2018. All counts are seven-day infrared counts adjusted to annual average daily pedestrians (AADP) using vehicle seasonal adjustment factors. However, point-level pedestrian counts are not immediately comparable to census tract-level pedestrian estimates. IDW interpolation and zonal statistics operations transform DVRPC's point-level pedestrian counts to census-tract level pedestrian densities, enabling comparison between DVRPC's existing counts and estimated average daily pedestrian trips.

IDW creates a continuous raster surface encompassing the maximum extent of existing pedestrian counters. Each cell in the IDW raster represents the number of expected pedestrians if a count were conducted in that cell. The value of each cell in the raster is imputed from the values of all existing counts in the study area, and existing counts closer to a given cell receive more influence than counts farther away. Where $d_{x,y,i}$ is the distance between $z_{x,y}$ and z_i and $-\beta$ is the inverse distance weighting power, the interpolated value $z_{x,y}$ is calculated as in **Equation 1**:

$$z_{x,y} = \frac{\sum_{i=1}^{n} z_i d_{x,y,i}^{-\beta}}{\sum_{i=1}^{n} d_{x,y,i}^{-\beta}} \quad (1)$$

To create an IDW raster of pedestrian counts, we create a grid with 100,000 evenly-sized cells that encompasses the extent of the study area. We then randomly drop a sample point in each grid cell and compute the expected count of each sample point using Equation 1. Existing count locations with multiple counts over time are assigned the mean of all counts at that location. Leave-one-out cross-validation (LOOCV) is used to select an optimal inverse distance weighting power of 1.5 (*10*). The resulting layer of 100,000 sample points with imputed pedestrian counts is then converted to an IDW raster of pedestrians per cell and overlaid with rasterized census tracts at the same spatial extent and resolution. Finally, the mean expected count by census tract is calculated using the zonal mean. An illustration of the computation process for two grid cells whose boundaries are coterminous with a single census tract is shown in (**Figure 2**).

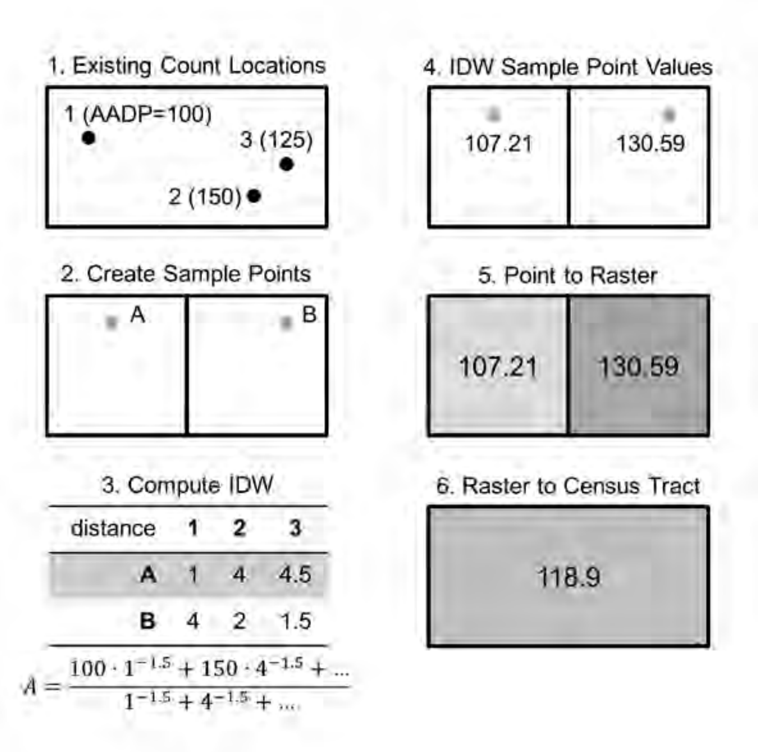


Figure 2 Simplified example of IDW interpolation.

IDW interpolation is used to test the pedestrian estimation formula. It cannot substitute for the tract-level pedestrian estimations for three reasons. First, the geographical extent of DVRPC's pedestrian counts is smaller than the study area. The maximum *x*- and *y*-extent of the pedestrian counts does not cover much of Chester and Bucks counties. Substituting the IDW raster for pedestrian estimations would require extrapolating outside the extent of the existing pedestrian counts to cover the entire study area.

Second, the spatial coverage of existing pedestrian counts is uneven. A map of pedestrian count locations used to compute the IDW raster in the City of Philadelphia is shown in (**Figure 3**). While IDW cells in Center City Philadelphia rely on the actual values of several nearby counts, many cells in the suburban counties rely on counts conducted several miles away, in physical contexts possibly quite different.

Third, IDW is an exact interpolator, meaning that a sample point that intersects with an existing count location must inherit that count's value. This method makes cell values subject to outliers; a singularly high or low count affects the value of the cell in which the count falls and all cells in its vicinity. We attempt to address outliers by excluding counts within 100 meters of a trail and with comments designating special or anomalous events.

Figure 3 Existing pedestrian count locations excluding trails in the City of Philadelphia, 2011-2018.

Linear Regression Residuals
Each census tract has an estimated pedestrian density and an observed pedestrian density. For a given census tract, the estimated pedestrian density is the estimated number of pedestrian trips standardized by land area, and the observed pedestrian density is obtained through IDW interpolation; both are expressed as the number of pedestrians per square mile. A simple linear regression model is used to compare the fit of the estimated pedestrian density to the observed pedestrian density.

While the model fit is good overall (r^2 = 0.636), a map of the regression residuals indicates that the pedestrian estimation formula greatly overestimates and underestimates pedestrian densities in a handful of Center City Philadelphia census tracts (**Figure 4**). Census tracts with large negative residuals are areas where the estimated pedestrian density is far less than the observed pedestrian density obtained through IDW. Based on the adjacency of these tracts to the central business district, we suspect the underestimation occurs because the pedestrian estimation formula does not account for "last-mile pedestrian commuters," those who commute into Center City Philadelphia for school or work and walk the last few blocks to their destination. In these dense, mixed-use areas, other types of trips are also likely; however, they are more difficult to approximate than "last-mile pedestrian commuters."

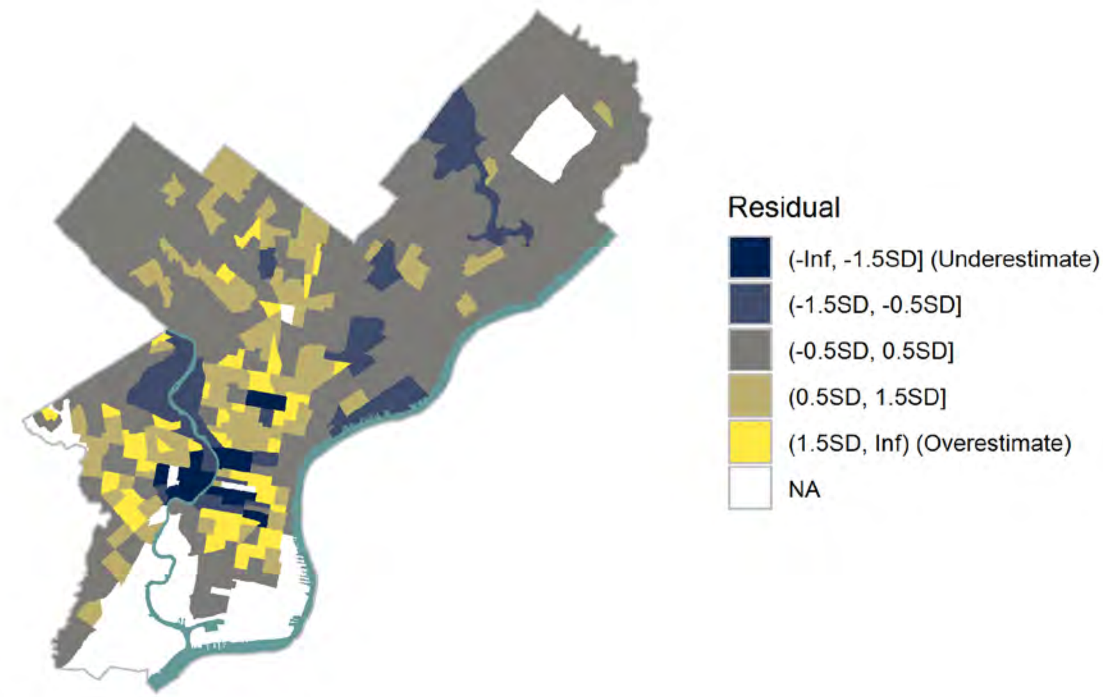


Figure 4 Fit of the pedestrian estimation formula in the City of Philadelphia.

Pedestrian Estimation Refinements and Correlation Analysis

Given the underestimations in Center City, "last-mile pedestrian commuters" were estimated in five ways, added to the estimated average daily pedestrian trips, and compared to the observed pedestrian density obtained through IDW interpolation. The list below describes each refinement and its correlation with observed pedestrian densities in the five-county study area.

1. *No change*: implement methodology from O'Brien et al. (*7*). *r* = 0.817.
2. *R1*: Percentage transit commuters in the DVRPC Region * Count of Regional Rail stations in tract * Number of jobs in tract. *r* = 0.769.
3. *R2*: Percentage transit commuters in the DVRPC Region * Boolean indicating presence of Regional Rail station in tract * Number of jobs in tract. *r* = 0.782.
4. *R3*: Sum of station-level Regional Rail alights in tract. *r* = 0.429.
5. *R4*: Use a proportionality constant between station-level Regional Rail alights and the number of jobs in the tract to infer Regional Rail alights where ridership data is missing. *r* = 0.480.
6. *R5*: Same as R4, but assume that Regional Rail riders have work destinations not only in tracts containing Regional Rail stations, but also tracts that share a border with Regional Rail station tracts. *r* = 0.592.

The correlation between estimated and observed pedestrian densities is highest for the original pedestrian estimation. Therefore, the original pedestrian estimation is used in regression analysis, for Center City and the rest of the study area.

Strata Creation

Four types of sampling strata are created to ensure a representative mix of locations and contexts for pedestrian counting, including census tract strata, transit and non-transit arterials, high- and low-ridership transit street segments, and schools. Because of the differences in pedestrian activity between Philadelphia and the four suburban counties, strata are created separately for the city and the suburbs.

Census Tract Sampling Strata

Census tract sampling strata are comprised of census tracts differentiated by the highest correlates of pedestrian activity. These correlates are selected using stepwise regression among several demographic, land use, and transportation-related attributes of each census tract. By using regression analysis to inform the creation of our sampling strata, the region's census tracts are grouped in a way that correlates with changes in estimated pedestrian trips.

Creating a stratified random sampling scheme for census tracts requires three steps. First, a series of independent variables at the census tract level are prepared for use in regression analyses. These variables include demographic, land use, and infrastructure characteristics of each census tract. Second, stepwise regressions determine the primary correlates of pedestrian activity, where the dependent variable is the pedestrian estimation. Once the correlates are identified, they are used to group census tracts into sampling strata. Regressions are computed separately for the City of Philadelphia and the region's suburban counties, as these are expected to have different pedestrian patterns. As a result, the City of Philadelphia and the suburban counties have separate sets of census tract sampling strata.

First we prepare tract-level independent variables for regression analysis. Many independent variables require data preparation, areal interpolation, and computing densities. Details on independent variables, including descriptions and data sources, are available in (**Table 1**). All variables are computed at the tract level, which sometimes requires aggregating point data or areal interpolation of smaller geographic units, such as blocks or Traffic Analysis Zones (TAZs), to the census tract level. These instances are noted in the Calculation column. Density-based measures use two different land area calculations in the denominator. The first, *waterless*, excludes water from the total census tract area. The second, *unprotected*, excludes both water and protected land uses from the total census tract area. The denominator is noted in the Source column.

Table 1: Calculations and Source Data to Compute Independent Variables

Variable	Calculation	Source
Population density*‡	Persons (1,000s) per sq. mi.	ACS B01003, *unprotected*
Pct. enrolled in college*		ACS B14001
Job density*‡	Jobs (1,000s) per sq. mi.	LODES, *unprotected*
Pct. of households below the Federal Poverty Level (FPL)*		ACS B17001
Transit activity density	Sum of transit boards and alights per sq. mi.	SEPTA and PATCO Ridership, *unprotected*
Sidewalk density		DVRPC Sidewalk Network, *waterless*
Median household income, $1000s*		ACS B19013
Pct. of zero-car households		ACS B08014
Pct. of nonwhite residents		ACS B03002
No. of pedestrian crashes in tract	Point aggregated to tract	PennDOT Crash Statistics
Philadelphia Litter Index†	Block interpolated to tract	
DVRPC Transit Score (*11*)	TAZ interpolated to tract	
Land use mix	Herfindahl-Hirschman Index / 100	DVRPC Land Use
Pct. of pedestrian commuters		ACS B08111
Sidewalk-to-road ratio	Sidewalk length / road centerline length	DVRPC Sidewalk Network, PA Centerline
Road density*	Length per sq. mi.	*waterless*
People density†	Pop. dens. + job dens.	ACS B01003, LODES
People interaction effect†	Pop. dens. * job dens.	ACS B01003, LODES
Notes	* Variable proposed by O'Brien et al. (*7*, Appendix B) † Variable used only in City of Philadelphia regressions. ‡ Variable used only in suburban counties regressions.	

Once independent variables are computed, stepwise regressions identify the strongest correlates of pedestrian activity separately in Philadelphia and the four suburban Pennsylvania counties. Some variables are highly skewed; when the skewness exceeds 1.5, the natural logarithm of the variable is used in regressions. In the City of Philadelphia, the percentage of college students and transit activity density are most highly correlated with estimated pedestrian densities. These are the two variables used to create census tract sampling strata in Philadelphia. No other variable was found to be statistically significant. Regression results are shown in (**Table 2**).

Table 2: Estimated Pedestrian Density by Tract, Philadelphia

	ln(Estimated Pedestrian Density by Tract)
ln(Percentage college students)	0.412*** (0.061)
ln(Transit activity density)	0.562*** (0.042)
Constant	3.232*** (0.364)
N	370
R^2	0.423
Adjusted R^2	0.419
Residual Std. Error	0.958 (df = 366)
F-Statistic	89.531*** (df = 3; 366)
Notes	***Significant at the 1 percent level.

In the four suburban counties, the population density, percentage of college students, and road density are most highly correlated with estimated pedestrian densities. These three variables are used to create census tract sampling strata. Regression results are shown in (**Table 3**).

Table 3: Estimated Pedestrian Density by Tract, Four Suburban Counties

	ln(Estimated Pedestrian Density by Tract)
ln(Population density)	0.846*** (0.037)
ln(Percentage college students)	0.314*** (0.030)
Road density	0.031*** (0.005)
Constant	5.020*** (0.074)
N	607
R^2	0.864
Adjusted R^2	0.864
Residual Std. Error	0.435 (df = 603)
F-Statistic	1281.406 (df = 3; 603)
Notes	***Significant at the 1 percent level.

The strongest correlates of estimated pedestrian densities in Philadelphia and the four suburban counties informed their SRS designs. In Philadelphia, there are four possible sampling strata formed by the unique combinations of the census tract’s share of college students and transit activity density classified into “high” and “low” values. For example, census tracts with an above-median percentage of college students and an above-median transit activity density fall in the HH stratum; census tracts with a below-median percentage of college students and an above-median transit activity density fall in the LH stratum. A map of the census tract sampling strata in the City of Philadelphia is shown in (**Figure 5**).

In the four suburban counties, there are eight possible sampling strata formed by the unique combinations of population density, the percentage of college students, and road density classified into "high" and "low" values. For example, a census tract with below-median population density, percentage of college students, and road density will fall in the LLL stratum.

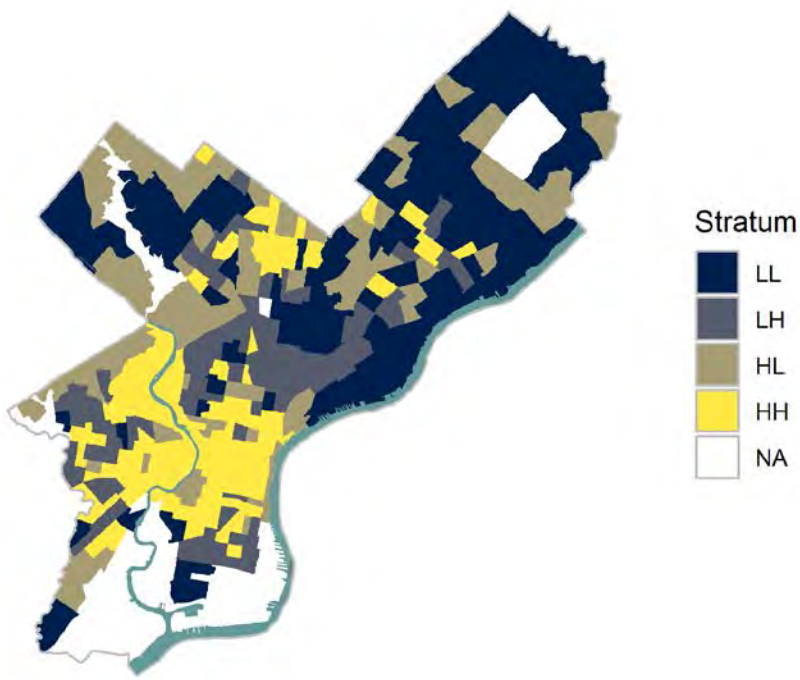


Figure 5 Census tract sampling strata in the City of Philadelphia.

Philadelphia Transit Streets Strata

In the City of Philadelphia, high- and low-ridership street segments are road segments differentiated by their levels of transit activity. Road segments within 500 feet of a bus, trolley, or heavy rail stop or station are eligible for consideration as "transit streets," and each road segment receives the sum of transit ridership in the surrounding area. A road segment is considered high-ridership if its aggregated boards and alights are above the median of Philadelphia's road segments with transit service; otherwise, it is a low-ridership segment. These sampling strata capture differences in pedestrian activity between road segments with high or low boards and alights. They also serve as a proxy for corridors with more or less destinations in the city, including shopping and schools.

Suburban Transit Arterial Strata

Transit arterial strata are road segments differentiated by the presence or absence of surface transit service (bus and trolley). It is expected that transit service drives pedestrian activity at a spatial level more granular than the census tract. For example, a pedestrian counter placed along a road segment with a trolley station is expected to have more pedestrian activity than a road segment one block away with no transit service, all else held equal. Transit arterials are major and minor arterial segments with at least one transit stop within 0.25 miles; non-transit arterials are arterial segments farther than 0.25 miles from the nearest transit stop. Arterial segments must have sidewalk on at least one side of the road to be eligible for consideration. This strata also seeks to measure activity in mixed use or commercial corridors in the suburbs, as these are most commonly located on arterials and may have different pedestrian patterns than other land uses.

Suburban School Stratum

The school sampling stratum is created only for the suburban counties. Similar to transit arterials, elementary and middle schools are expected to drive local pedestrian activity. The school stratum is comprised of 2013 public schools serving students in any of the grades K through 8, including charter and magnet schools. Data was obtained from the National Center of Education Statistics. Each school is buffered by 0.25 miles to encompass the school grounds and access streets.

There is no school stratum for the City of Philadelphia. Because school children use the local public transport system to commute to and from school, we already control for some activity using the transit streets strata.

Selection of Count Locations

Because the selection process in the City of Philadelphia is ongoing, this section focuses on the process of selecting counts among sampling strata in the four suburban counties. In the suburban counties, there are 11 total sampling strata, including eight census tract sampling strata, transit and non-transit arterial sampling strata, and a school sampling stratum. We select 10 counts per stratum for a total of 110 counts.

The site selection process includes two major steps. First, census tracts, arterial segments, and schools are randomly selected from among their sampling strata. Then, the physical attributes of each selected observation are individually inspected to identify a suitable location for pedestrian counting. This section provides an overview of these two major steps.

Random Selection

Davis and Wicklatz advise that each sampling stratum should have a minimum of 10 counts and that each geographic subarea of the study area should have at least three counts per stratum (*12*). We select 10 counts per stratum across a four-county study area. Ideally, we would have a minimum of 12 counts per stratum so that each county has at least three observations. Because of the limited number of counts, we seek to maximize geographic representativeness by ensuring a roughly equal distribution of counts in each stratum across the study area.

We first allocate 80 total census tract counts from the eight census tract sampling strata. Among census tracts with nonzero sidewalk length, two census tracts are randomly selected per stratum per county, for a total of 64 counts (2 counts * 8 strata * 4 counties = 64 counts). This leaves 16 unassigned counts. A "pool" of unassigned counts is created, and selection from the pool will be discussed later. Delaware County has 0 LLH observations, so its two census tract counts for this strata are placed in the pool as well. Therefore, the pool includes 18 total counts (2 counts * 8 strata + 2 LLH counts = 18 counts).

Among the transit and non-transit arterial strata, 10 counts of each stratum are allocated as evenly as possible among the underlying census tract strata. Because our eight census tract strata have been demonstrated through regression analysis to correlate with changes in estimated pedestrian activity, allocating transit and non-transit arterial counts evenly among the census tract strata is a way to test whether pedestrian activity is different along transit versus non-transit arterials, regardless of the census tract characteristics. 16 of 20 counts are randomly selected (1 count * 2 arterial strata * 8 census tract strata = 16 counts), and the remaining two counts per stratum are placed into the pool.

The 10 counts of the school sampling stratum are distributed as evenly as possible among the underlying census tract strata, for a total of 8 of 10 total school counts (1 count * 8 strata = 8 counts). The decision to allocate schools evenly among the census tract sampling strata follows the logic of the transit and non-transit arterial sampling strata. The remaining two counts are placed into the pool.

The pool includes 24 unassigned counts. The remaining counts are allocated to reflect the composition of the four suburban counties. For example, LLL census tracts comprise 27% of Bucks, 52% of Chester, 7% of Delaware, and 26% of Montgomery County census tracts. The remaining LLL counts in the pool are randomly selected from Bucks and Chester Counties. A sample map of selected census tracts, arterial segments, and schools in Delaware County is shown in (**Figure 6**). Note that selected arterial segments have been buffered to enhance visibility.

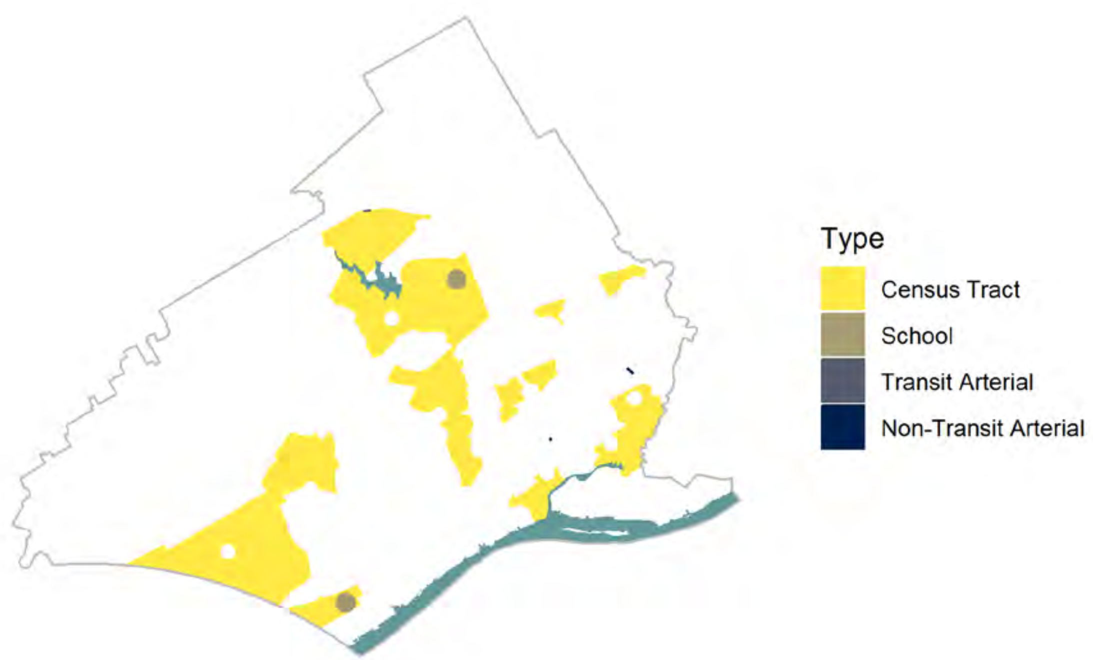


Figure 6 Selected Census tracts, arterial segments, and schools in Delaware County.

Verifying Site Eligibility

After SRS to select observations from the census tract sampling strata, we contacted the planning departments of each suburban county with maps of the selected census tracts and guidelines for site selection. For suburban counties, these guidelines included that count locations must have sidewalk along at least one side of the street; cannot be on census tract boundaries; and cannot be along major or minor arterials or within the 0.25-mile school buffers, as we have created strata for arterials and schools. Each of these counties responded with a set of physical count locations within the selected census tracts.

Some randomly selected observations appear to have no suitable locations for counting. For example, Census Tract 42045405000 in Chester City had several schools and the Chester Transportation Center; the prevalence of schools erased much of the tract's eligible land area, and the remaining areas around the Chester Transportation Center could not be considered representative of the tract's pedestrian activity as a whole. In Census Tract 42045407000 in Chester Heights borough, the only suitable count location was inside a private apartment complex; it would be difficult to obtain permission to conduct a count in this location, and the count would likely only capture pedestrian patterns within the complex. These observations were replaced with other randomly selected observations in the same sampling strata within Chester County.

As for transit arterials, non-transit arterials, and schools, we selected the physical count locations from the randomly selected observations. The requirements for selecting a physical count location include: sidewalk on at least one side of the selected arterial segment; a fixed object on which to securely fasten the infrared pedestrian counting equipment pointing away from the road; reasonable distance away from places where people might be "milling about," e.g. a bench along a downtown street or mailboxes; and nearest the bus stop with highest ridership if the transit arterial segment contains multiple bus stops.

CONCLUSION

The goal of the site selection process of DVRPC's SE Pennsylvania Cyclical Pedestrian Counting Program was to maximize the representativeness of on-street pedestrian count locations while minimizing bias. Our site selection process has accomplished this goal through stepwise regression and SRS, and counts are currently being conducted in the four suburban counties of the study area at the time of writing. We also minimize bias and maximize reproducibility by automating all steps of the site selection process in R except the verification of count locations.

Two unique elements of our site selection process are the pedestrian estimation formula adapted from O'Brien et al (*7*), which enables the creation of census tract-level estimates of pedestrian trips where counts are unavailable; and inverse distance weighted interpolation of existing counts, which allows rudimentary area-based estimates to be approximated from point-level counts. Both of these elements are worth highlighting for their potential applications outside of site selection in a pedestrian count program.

In the future, we will be able to assess the representativeness of our site selection process using the counts collected from this program. For example, the sampling strata could be evaluated through a cluster analysis of all counts. If the sampling strata and the resulting clusters are similar, this may indicate that the sampling strata represent different pedestrian activity patterns. These results might then be used to extrapolate on-street pedestrian patterns to other locations where counts have not yet been conducted.

That said, there are opportunities for improvement in the design of this site selection process. While SRS of census tracts is good in that it allows member governments to become involved in the site selection process and the pedestrian count program more generally, it also increases the chances of biased site selection, as many census tracts have several eligible areas to conduct a pedestrian count. SRS of eligible road segments would reduce the potential for bias in site selection and enable us to consider road functional classification aside from major and minor arterials.

Our IDW interpolation method did not include any distance constraint. This means that the value assigned to a given grid cell of the 100,000 grid cells in the study area depended on the values of all on-street pedestrian counts in the region. It would be preferable to add a distance constraint so that the values of grid cells not within a reasonable distance of an existing count are not predicted. While this would reduce the number of census tracts to compare observed and estimated pedestrian densities, the results would likely be more realistic.

IDW interpolation is used in this study because it is easy to implement, and it would likely be difficult to fit a semivariogram to existing pedestrian counts given the paucity of available data. However, if a study area already has several existing counts, then kriging can be used to fit a model directly to existing counts. In their tests of ordinary and universal kriging versus IDW interpolation, Zimmerman et al. find that kriging performs better than IDW interpolation on irregular surfaces and when sample points are less uniformly distributed (*13*)—both of which are expected attributes of non-motorized count data. The applications of ordinary kriging have been previously demonstrated by Wang and Kockelman in their spatial interpolation of vehicle counts along Texas highways (*14*). A regression-kriging approach would combine regression with ordinary kriging and potentially enable the creation of sampling strata without needing to estimate pedestrians at the census tract level (*15*).

IDW interpolation and kriging incorporate the distance between observations in calculation; we use straight-line distances in this paper. It would be preferable to incorporate network distance into future approaches, as demonstrated by Okabe and Sugihara for both IDW interpolation and kriging (*16*).

ACKNOWLEDGEMENTS

Dr. Krista Nordback at the University of North Carolina Highway Safety Research Center provided invaluable feedback on adequate observations per sampling stratum and on creating additional strata to control for local school and transit activity.

AUTHOR CONTRIBUTION STATEMENT

The authors confirm contribution to the paper as follows: study conception and design: C. Boulan, A. Larson; data collection: A. Larson; analysis and interpretation of results: A. Larson, C. Boulan; draft manuscript preparation: A. Larson, C. Boulan. All authors reviewed the results and approved the final version of the manuscript.

REFERENCES

1. Ryus, P., E. Ferguson, K. M. Laustsen, R. J. Schneider, F. R. Proulx, T. Hull, and L. Miranda-Moreno. *NCHRP Report 797: Guidebook on Pedestrian and Bicycle Volume Data Collection*. Transportation Research Board of the National Academies, Washington, D.C., 2014.

2. *National Bicycle and Pedestrian Documentation Project Instructions*. National Bicycle and Pedestrian Documentation Project. http://bikepeddocumentation.org/application/files/3314/6671/8088/NBPD_Instructions_2010.pdf . Accessed July 22, 2019.

3. *Traffic Monitoring Guide*. Publication FHWA-PL-17-003. FHWA, U.S. Department of Transportation, 2016.

4. Jones, M. G., S. Ryan, J. Donlon, L. Ledbetter, D. R. Ragland, and L. Arnold. *Seamless Travel: Measuring Bicycle and Pedestrian Activity in San Diego County and its Relationship to Land Use, Transportation, Safety, and Facility Type*. Institute of Transportation Studies, University of California, Berkeley, 2010.

5. Boulan, C. *DVRPC Regional Cyclical Bicycle Count Program Summary*. Delaware Valley Regional Planning Commission, 2016.

6. Schneider, R. J., L. S. Arnold, and D. R. Ragland. A Pilot Model for Estimating Pedestrian Intersection Crossing Volumes. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2140, 2009, pp. 13-26. http://dx.doi.org/10.3141/2140-02.

7. O'Brien, S. W., K. Jackson, S. Searcy, S. Warchol, D. Rodriguez, C. Cunningham,…E. Stolz. *Bicycle and Pedestrian Data Collection - Pilot Phase*. Institute for Transportation Research and Education, North Carolina State University, 2016.

8. Zhang, C., L. Jennings, and L. Aultman-Hall. *More Robust Spatial Sampling Strategies for Non-Motorized Traffic*. Transportation Research Center, University of Vermont, 2010.

9. Ewing, R., and R. Cervero. Travel and the Built Environment: A Meta-Analysis. *Journal of the American Planning Association*, Vol. 76, No. 3, 2010, pp. 265-294. http://dx.doi.org/10.1080/01944361003766766.

10. Tomczak, M. Spatial Interpolation and Its Uncertainty Using Automated Anisotropic Inverse Distance Weighting (IDW) - Cross-Validation/Jackknife Approach. *Journal of Geographic Information and Decision Analysis*, Vol. 2, No. 2, 1998, pp. 18-30.

11. Lutin, J. M., G. R. Krykewycz, J. F. Hacker, and T. W. Marchwinski. Transit Score: Screening Model for Evaluating Community Suitability for Transit Investments. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2063, 2008, pp. 115-124. http://dx.doi.org/10.3141/2063-14.

12. Davis, G. A., and T. Wicklatz. *Sample-Based Estimation of Bicycle Miles of Travel*. Publication MN/RC - 2001-23. Minnesota Department of Transportation, 2001.

13. Zimmerman, D., C. Pavlik, A. Ruggles, and M. P. Armstrong. An Experimental Comparison of Ordinary and Universal Kriging and Inverse Distance Weighting. *Mathematical Geology*, Vol. 31, No. 4, 1999, pp. 375-390. http://dx.doi.org/10.1023/A:1007586507433.

14. Wang, X., and K. M. Kockelman. Forecasting Network Data: Spatial Interpolation of Traffic Counts Using Texas Data. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2105, 2009, pp. 100-108. http://dx.doi.org/10.3141/2105-13.

15. Hengl, T., G. B. M. Heuvelink, and D. G. Rossiter. About Regression-Kriging: From Equations to Case Studies. *Computers and Geosciences*, No. 33, 2007, pp. 1301-1315. http://dx.doi.org/10.1016/j.cageo.2007.05.001.

16. Okabe, A., and K. Sugihara. *Spatial Analysis along Networks: Statistical and Computational Methods*. John Wiley & Sons, Inc., Chichester, U.K., 2012.