1 Introduction

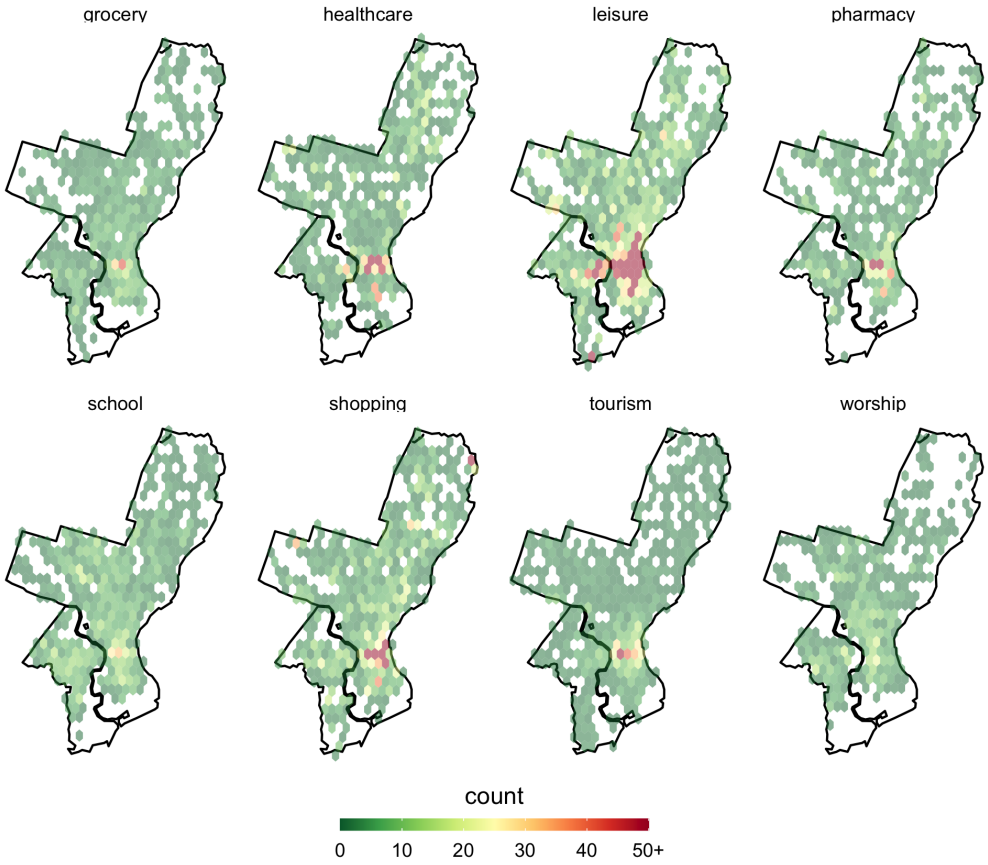
As the coronavirus spread in Philadelphia this year, mobility patterns changed. With this shock came fewer commutes to work; we changed where we shopped, where we dined and how we traveled. In order to understand the consequences of these changes, we use GPS data from mobile phones to track travel patterns before and during the pandemic.

To do so, we collect data from SafeGraph, a provider of mobility data from iPhone and Android smartphones. Note that SafeGraph gathers data on a representative sample (10%) of the population across the country, so our indicators are not the true number of visits or journeys, but a sample. The data model is explained in Figure 1.1. The number of **visitors** is the count of devices arriving at a **point of interest (POI)** while a **connection** is an origin-destination line between a Census Block Group and a point of interest. A **flow** is also a connection, but with a **weight** measuring the number of visitors traveling between origin and destination.

1.1 Key definitions

Each visit is a mobile device entering into a point of interest; these include parks and museums, restaurants and bars, or offices and hospitals. In Figure 1.2 we map the distribution of these venues and businesses for context. We classify each point of interest by its description, which SafeGraph provides. [1] We can see that most businesses cluster in Center City or nearby but no businesses cluster more than restaurants and bars.

1.2 Distribution of points of interest



To demonstrate how connections form a mobility network throughout Philadelphia, Figure 1.3 connects origins to destinations by month in Philadelphia.

1.3 Connections over time

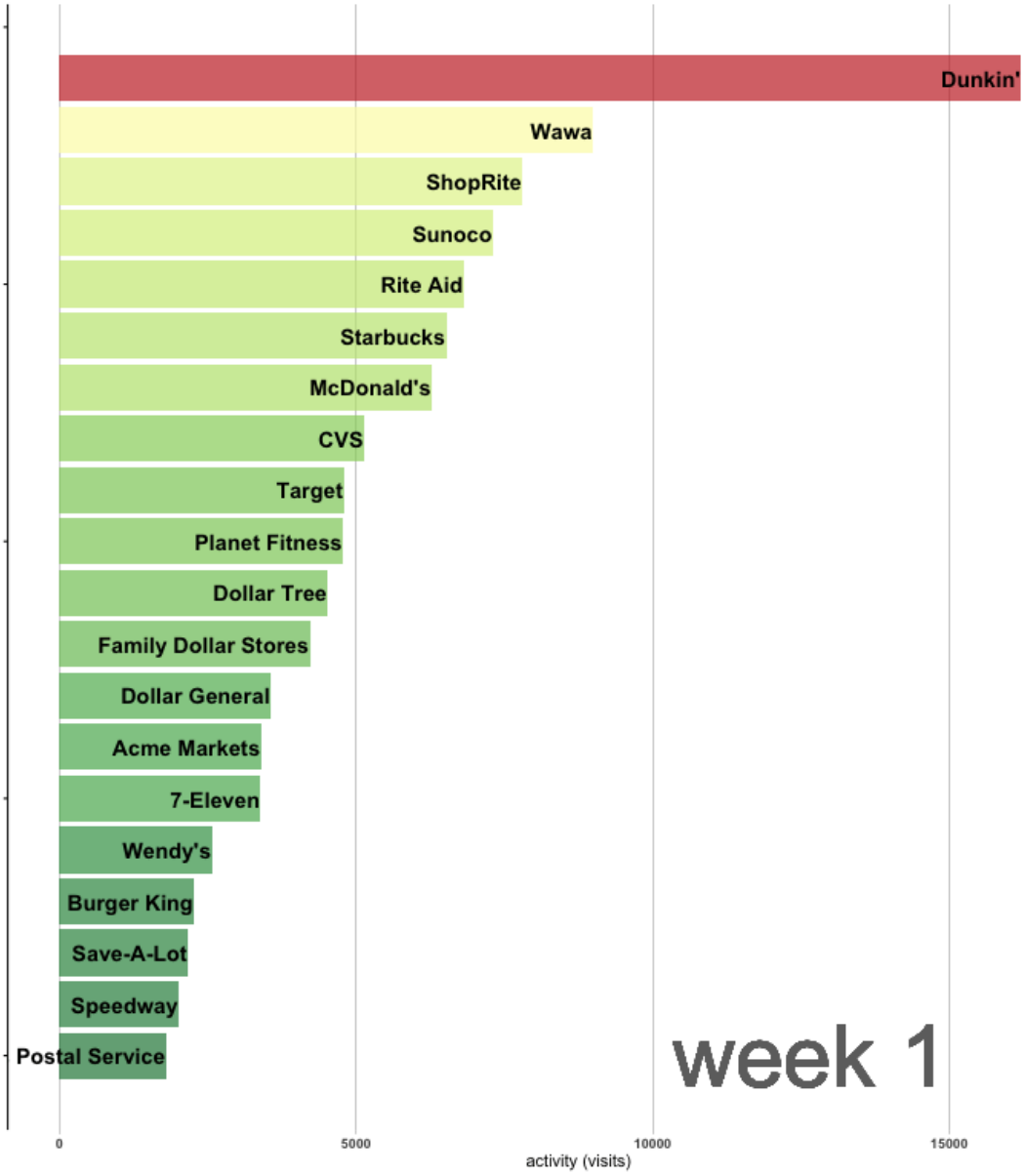
This analysis comprises different spatial scales: Citywide, Neighborhood and Point of Interest. We can look *globally*, across the city, to explore trends throughout; we can also think *locally*, dividing the city up into cells or neighborhoods to probe variations within the city. Finally, we can look at individual businesses or venues. Below, we attempt to understand patterns at each scale in order to understand how mobility has shifted since the onset of the pandemic.

2 How have visitations changed?

In this section we explore trends in *visits*, defined as the count of devices flowing to a point of interest or area, beginning with the city as a whole. To see how the business environment is for chains across the city, rather than any given location, we sum visits by brand. Figure 2.1 ranks chain retail stores by the number of visitors they received and animates this change through the pandemic. Visits to dollar stores rise gradually throughout the year; another important shift is away from non-essential retail towards essential businesses like pharmacies.

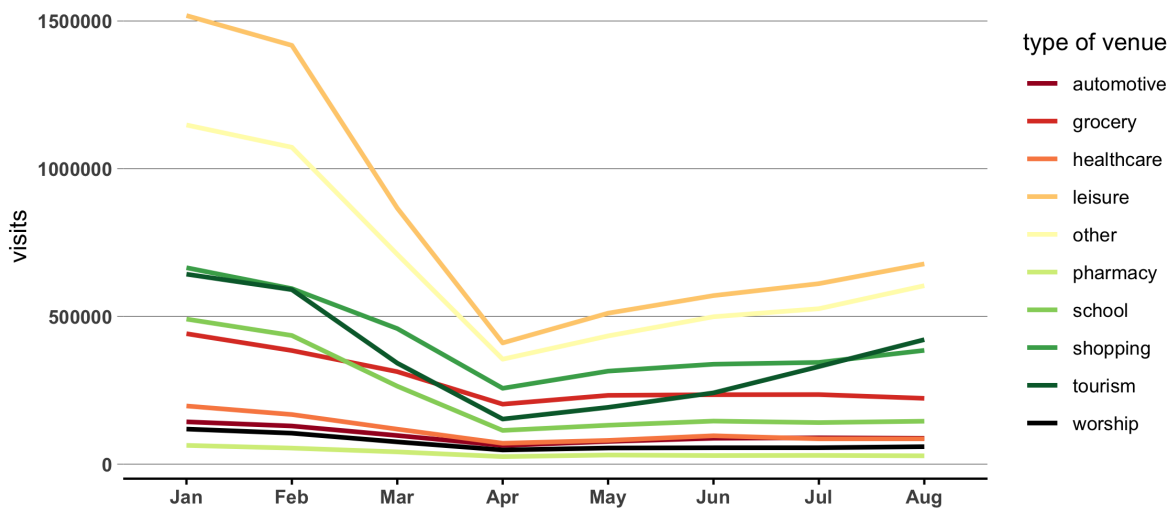
Starbucks and Wawa occupy top spots for the first several weeks of the year but when the shelter-in-place order occurs, visits fall and they are replaced in the ranks by essentials like RiteAid and ShopRite.

2.1 Comparing foot traffic by brand



In Figure 2.2 we aggregate visits by industry, grouping by classes like leisure (restaurants and bars) and tourism (museums and theaters). The pandemic has curbed visits to each class of business, but hit particularly is leisure and “other”, which includes offices. Tourism is regaining visitors while shopping and grocers are not, perhaps as many switch to digital commerce.

2.2 Industry trends by category



Next, we look at how mobility varies across smaller geographic units to determine whether or not the pandemic is impacting some parts of the city more than others. We find large disparities between the best- and worst- performing neighborhoods. Figure 2.3 explores trends across neighborhoods;
neighborhoods dominated by office work, like the Navy Yard along with Logan Square and Center City, saw precipitous declines in visits, but neighborhoods with strong amenities and residential communities have recovered. This suggests that economic activity may be shifting away from Center City.

2.3 Neighborhood trends

Best

Average Daily Visitors by Week

Highest, lowest, and most recent foot traffic in Philadelphia

neighborhood	highest	lowest	this month	% change	trend
Wissahickon Park	54	20	52	-3.703704	
Aston-Woodbridge	159	45	130	-18.238994	
Fitler Square	184	52	140	-23.913043	
East Park	223	44	167	-25.112108	
West Torresdale	81	25	60	-25.925926	
Overbrook	2329	737	1718	-26.234435	
Byberry	237	85	171	-27.848101	
Germany Hill	74	20	52	-29.729730	
Riverfront	3066	832	2144	-30.071755	
Northeast Phila Airport	1702	695	1169	-31.316099	

Data: SafeGraph | Note: Vertical lines indicate the start and end of shelter-in-place

Worst

Average Daily Visitors by Week

Highest, lowest, and most recent foot traffic in Philadelphia

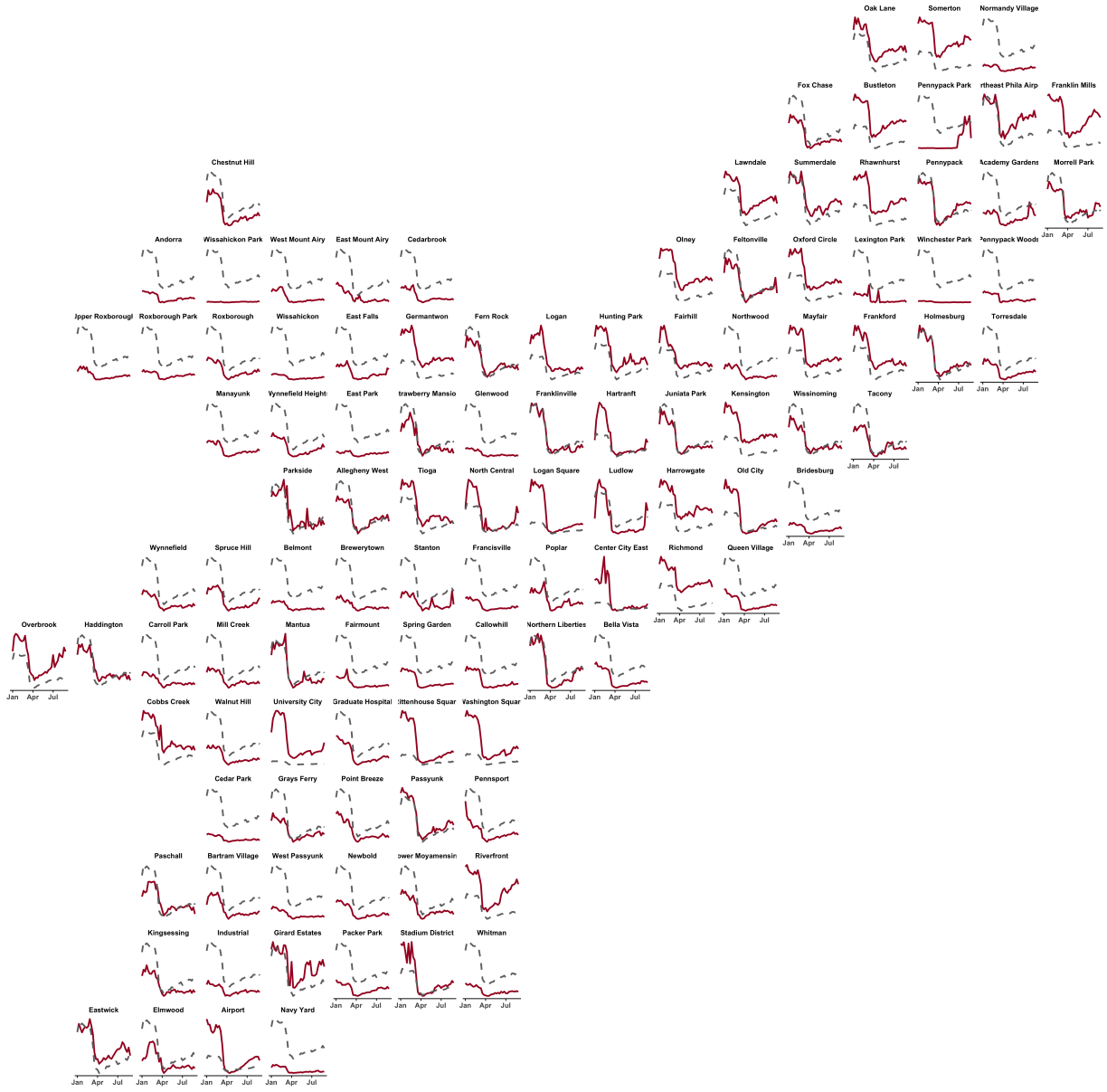
neighborhood	highest	lowest	this month	% change	trend
Center City East	7818	363	1251	-83.99847	
East Poplar	512	54	86	-83.20312	
Germantown - Penn Knox	725	132	134	-81.51724	
Modena	562	36	107	-80.96085	
Powelton	566	58	111	-80.38869	
West Powelton	1101	167	223	-79.74569	
Pennsport	934	98	212	-77.30193	
Logan Square	6161	572	1420	-76.95179	
Nicetown	702	167	167	-76.21083	
Navy Yard	289	37	77	-73.35640	

Data: SafeGraph | Note: Vertical lines indicate the start and end of shelter-in-place

Figure 2.4 presents an alternative approach for visualizing neighborhood visitations, plotting the rolling average of visits for each neighorhood (in red) compared with the citywide mean trend (dotted lines). Many

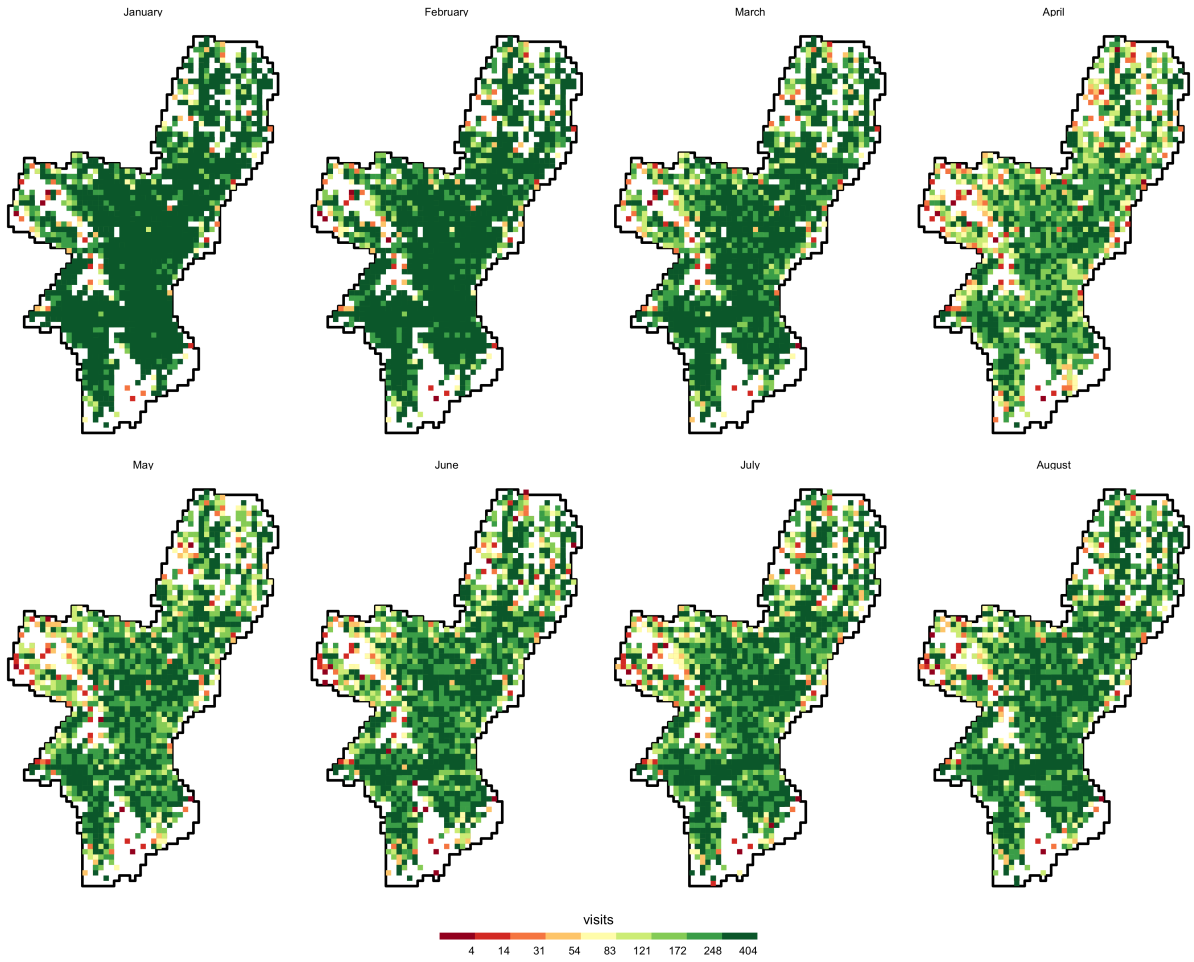
neighborhoods in the Northeast and Northwest are rebounding while University, Center and Old City are still down substantially.

2.4 Rolling averages



Because visits data are collected for each point of interest, it is possible to explore these dynamics at smaller scales. Figure 2.5 aggregates visits to 500 meter squared grid cells and visualizes them for each month between January and August. Visits fell in most cells during the worst months of the pandemic, but the business district has regained visitors each month.

2.5 Visits by month in gridded units



Businesses are not evenly distributed across the city, however, so understanding business activity requires a unit of analysis that respects **commercial corridors**—zones where businesses cluster together—of which the city has designated roughly 280. We look at visits to restaurants and bars within commercial corridors below. The largest corridors are Market West and Market East, on either side of City Hall (boxed on the map), with 1712 and 1263 restaurants and bars respectively, followed by Old City at 654 and another in University City with 493: most of the business activity is concentrated in a few locales.

2.6 Commercial corridors

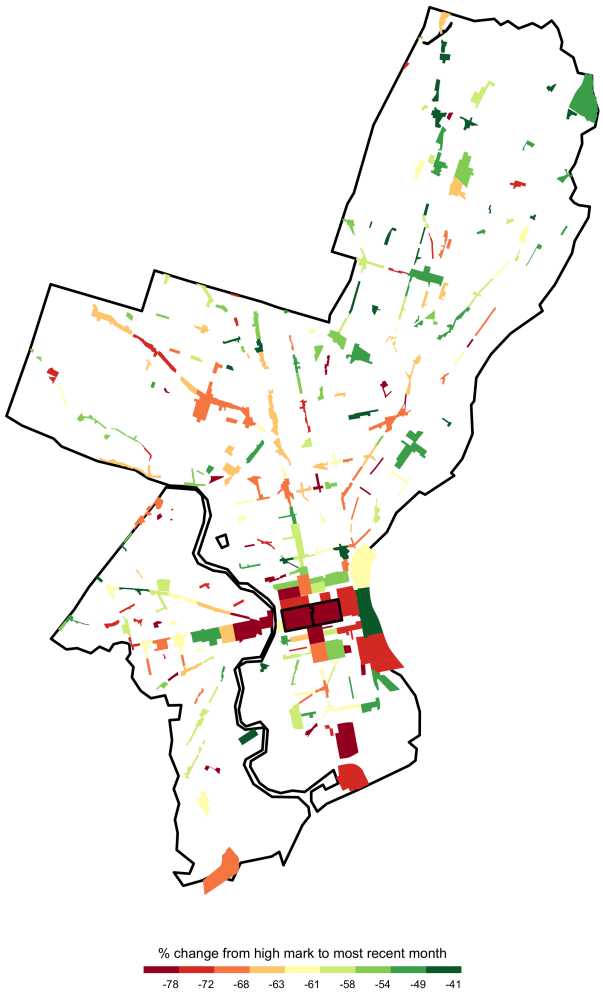


Figure 2.6 maps percent change from January to August, while Figure 2.7 plots the trend in the top and bottom 10 of these corridors over time, the greatest reduction in visitors is in Center City and at the Sports Complex. Plazas like Oxford and Levick, home to a supermarket, and City and Haverford see the smallest impact.

2.7 Corridor trends

Best	Worst

Best	Worst

Nigh Life Hubs: top ten

Weekly visits to various economic clusters

corridor	high	low	average	% change	trend
Oxford and Levick	670	307	490.4857	-54.17910	
Cheltenham & Ogontz	898	402	588.4857	-55.23385	
Aramingo Avenue	2807	1254	1941.2000	-55.32597	
Leo Mall/Lumar Center & Vicinity	1106	494	837.0286	-55.33454	
City and Haverford	724	306	491.9429	-57.73481	
Point Breeze Avenue	598	251	397.3429	-58.02676	
2nd and Lehigh	608	249	371.7714	-59.04605	
Bustleton and Red Lion	960	389	708.1143	-59.47917	
Elmwood Avenue	1191	479	782.3143	-59.78170	
Penrose Plaza and vicinity	1073	431	760.0286	-59.83225	

Data: SafeGraph | Note: Period spanning January to August 2020

Nigh Life Hubs: bottom ten

Weekly visits to various economic clusters

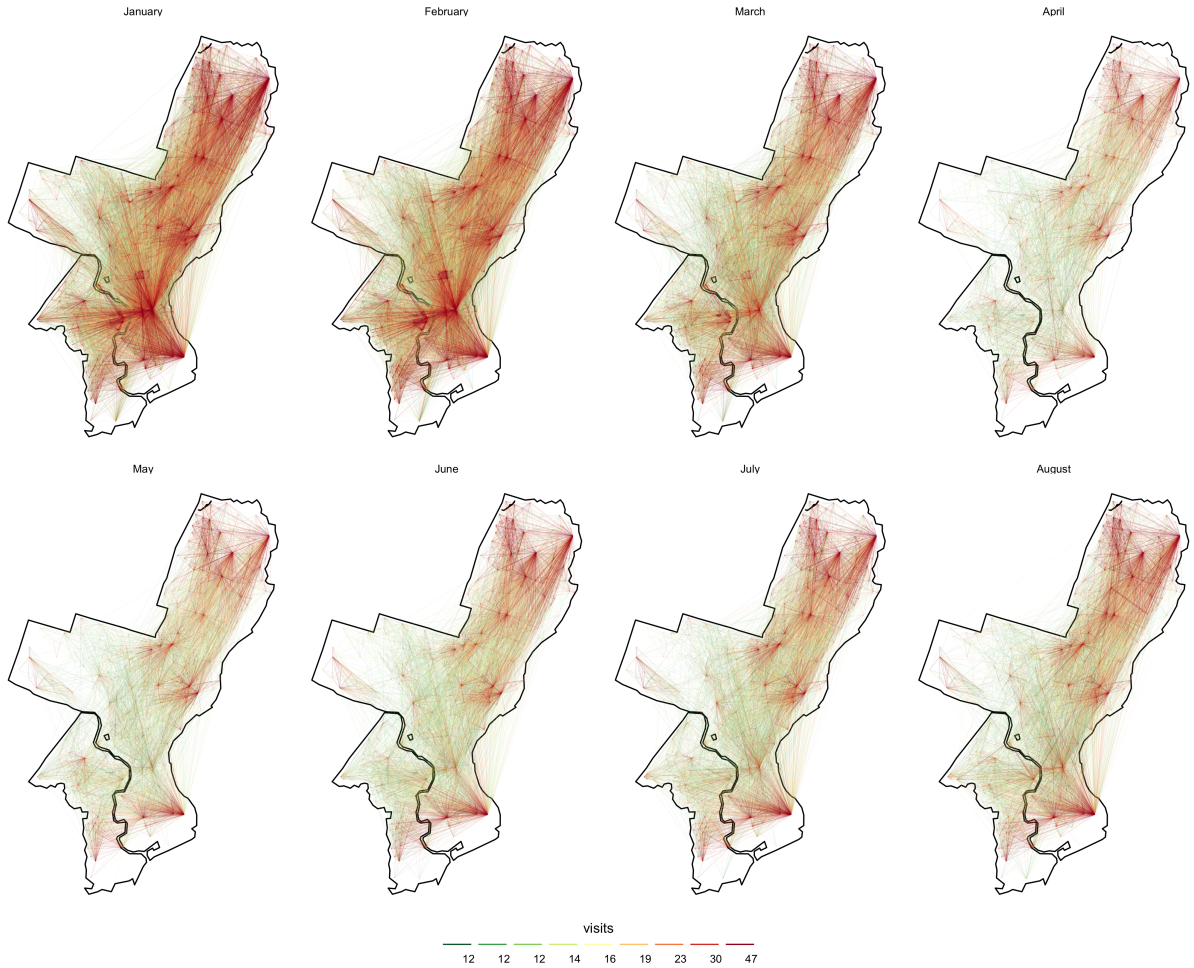
corridor	high	low	average	% change	trend
Sports Complex	2429	31	538.5143	-98.72375	
Broad and Cecil B. Moore	11687	418	3355.4857	-96.42338	
5th and Lehigh	1244	70	397.7714	-94.37299	
36th Street and vicinity	15454	873	5034.0857	-94.35098	
Rising Sun Avenue/Olney	2743	178	531.0000	-93.51075	
36th and Lancaster	2683	181	715.7429	-93.25382	
30th Street	8732	635	3027.2857	-92.72790	
Market East	41022	3091	12053.0857	-92.46502	
Market West	27629	2241	10252.2571	-91.88896	
Central Waterfront/Penns Landing	774	66	346.4857	-91.47287	

Data: SafeGraph | Note: Period spanning January to August 2020

3 How have connections change?

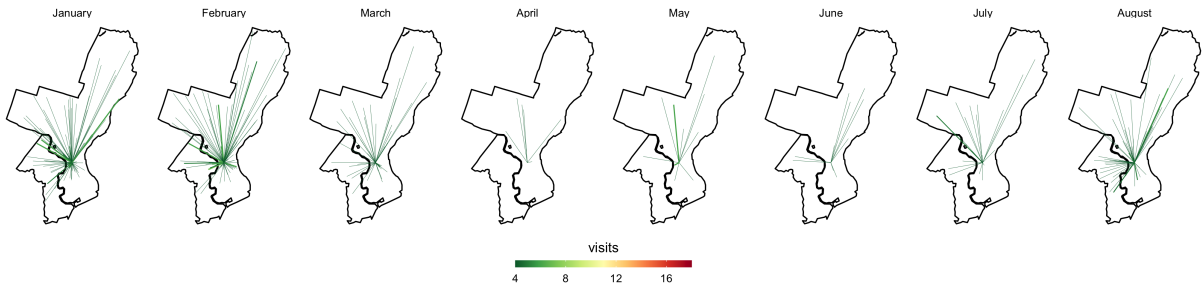
This section looks at **connections** to points of interest within the network to see how these venues are driving changes. Figure 3.1 replicates the animation from Figure 1.3 as a series of images. Again, the network changes dramatically as the pandemic sets in, but the decline in connections is most marked in the center.

3.1 Connections by month



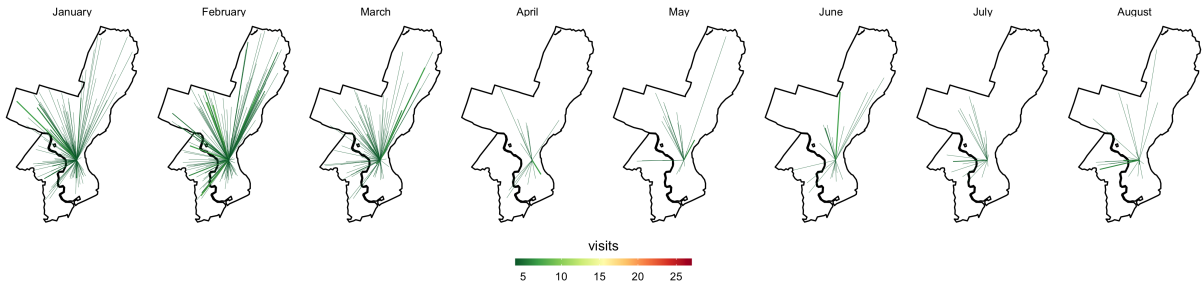
Here we take a closer look at some key network connections in Philadelphia. Figures 3.2 and 3.3 plot connections to the Comcast Center and Reading Terminal Market, respectively. Economic activity in these two key hubs declines dramatically during the worst months of the pandemic.

3.2 Comcast Center in focus



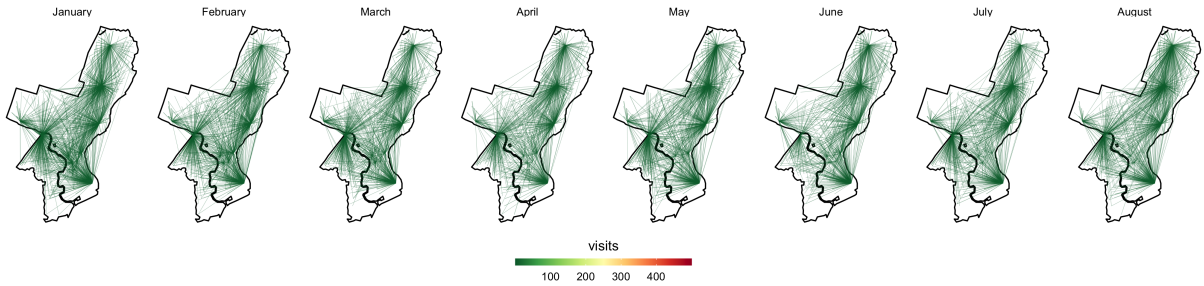
While the Comcast Center represents office work, as a signal for tourism, we can look at Reading Terminal Market; vendors on its premises saw marked declines in visits beginning in April.

3.3 Reading Terminal in focus



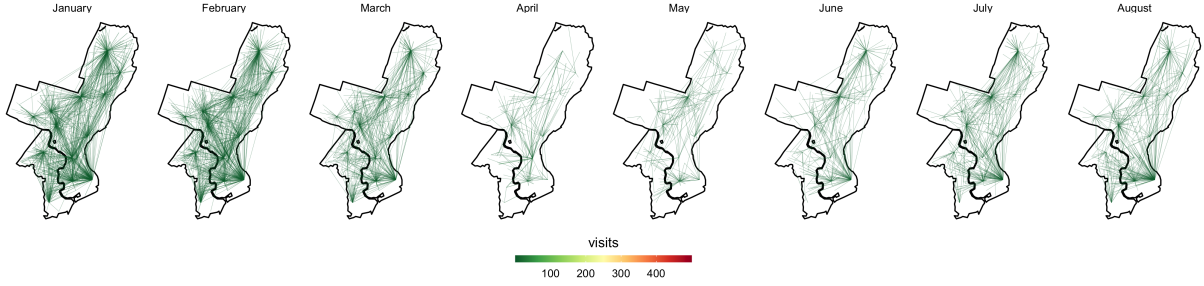
These destinations are critical to Philadelphia's office and tourist economies, but what about the brands that serve thousands on a daily basis? We can see the differential effect of the pandemic simply by looking at the change in visits to Target stores and Planet Fitness gyms. Both see similar numbers of visitors prior to the arrival of coronavirus and they have a similar number of locations—12 Targets and 14 Planet Fitnesses. Connections to Target held steady throughout the pandemic, even while—as we see above—many connections across the city broke.

3.4 Connections to Target stores



We can compare this network and its progression through the pandemic to Planet Fitness, which saw fewer connections across the city as case rates grew.

3.5 Connections to Planet Fitness gyms



We can track changing connections for all brands in the city. Figure 3.6 shows the number of connections certain brands lost between January and August selecting the top and bottom 10. It shows that brands deemed essential businesses saw comparably less of a decline than others, along with fast food restaurants. Some brands that did not see steep drops in visitors are seeing visitors from fewer neighborhoods. The map shows the locations of brands for context.

3.6 Relative brand connections

Rankings

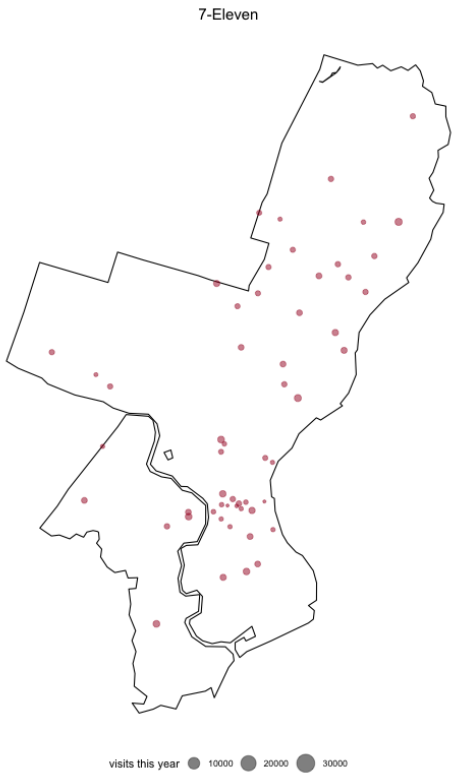
Points of Interest: best and worst

Number of unique visitor origin neighborhoods

	% change (january-august)
best	
The Home Depot	-5.350195
Target	-17.292225
Wawa	-26.031340
McDonald's	-26.162791
Wendy's	-27.915726
Walmart	-29.425953
University of Pennsylvania	-29.509559
ShopRite	-30.938416
Burger King	-35.186873
Sunoco	-35.412541
worst	
Starbucks	-61.950480
Planet Fitness	-60.937500
Acme Markets	-50.678295
Family Dollar Stores	-44.330454
7-Eleven	-44.058642
CVS	-43.862275
Chick-fil-A	-42.074364
Rite Aid	-41.500000
Dunkin'	-39.911190
Dollar Tree	-37.123596

Data: SafeGraph | Note: This is a count of unique desire lines, not total visitors

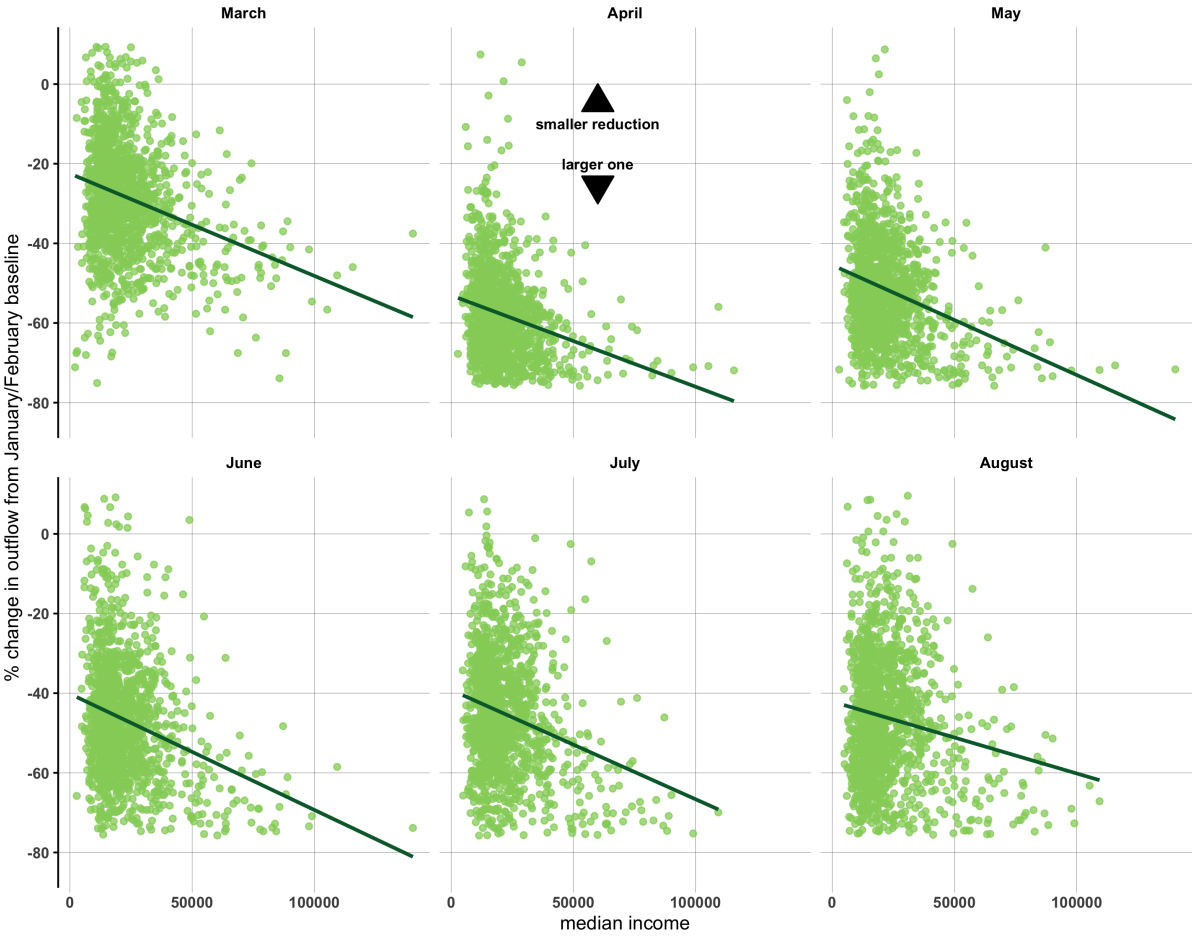
Locations



4 Possible consequences

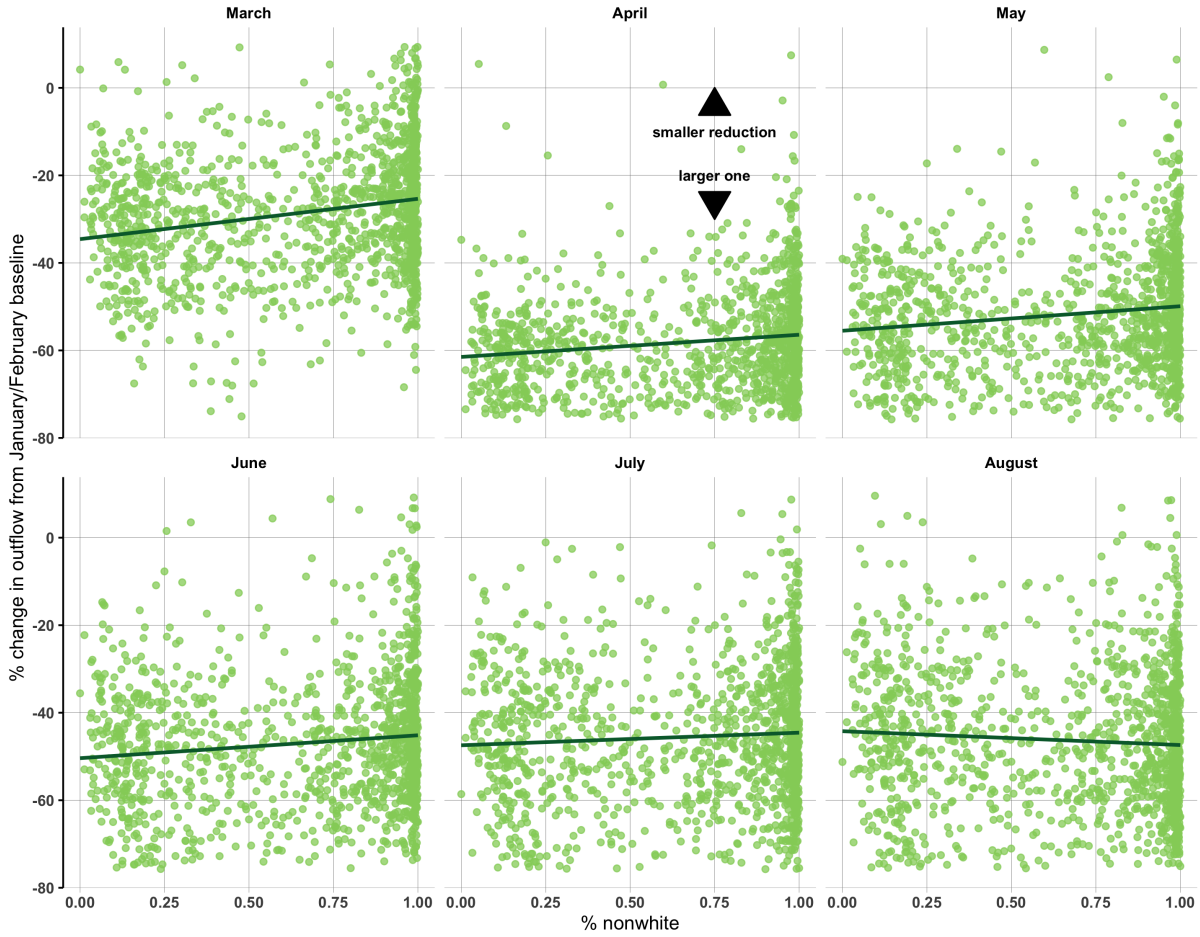
Might the pandemic further exacerbate Philadelphia's deep socio-economic divide? If communities of color and low-income communities are disproportionately comprised of essential workers who cannot work from home, then Census tracts with higher rates of non-white residents should exhibit greater rates of outflows relative to communities with fewer minorities. Figures 4.1 and 4.2 test this outflow proposition using income and race, respectively.

4.1 Did trips change with income?



In March, at the onset of the pandemic, more Philadelphians were leaving their home tracts. In April, all communties see reductions in trips. However, the higher the median income, the greater the reduction in trips, though the correlation is weak. We plot the relationship between race and mobility in Figure 4.2. There is no correlation here in any month but March.

4.2 Did trips change with race?



5 Conclusion

The purpose of this report is to examine mobility patterns in Philadelphia before and during the pandemic using cell phone mobility data provided by SafeGraph. The visualizations built from these data show large declines in mobility at the onset of the pandemic. While we cannot access economic indicators for particular neighborhoods and businesses throughout the City, as a proxy, these mobility data suggest that many industries and corridors have experienced a tremendous loss in economic activity in recent months.

The next stage of this work is to develop some interactive, web-based visualizations that can help stakeholders in Philadelphia understand and plan for a return to 'normal' mobility patterns.

[1] If that description contains "restaurant" or "bar", we classify that as leisure. Anything educational, from tutoring to public, private or charter schools to tertiary education, we call that education. Tourism includes museums and parks.