Six Scooter Companies, Six Maps: Spatial Coverage and Regulation of Micromobility in Vienna, Austria

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Abstract:
Like other large European cities, Vienna has a mix of transportation modes including personal cars, buses, trams, an underground, commuter rail, and more recently bikeshare and dockless scooters. The latter entrants to the transportation sector pose new challenges for municipal regulation, such as how many vehicles should each operator be allowed to deploy, where may vehicles be ridden, and where may they be parked in terms of already-crowded roadways and sidewalks. In addition, a crucial aspect of the accessibility and reach of these systems is the size and position of their geographic service area, or 'geofence', within which users can locate vehicles to begin a ride and park them to conclude one. Although Vienna recently clarified its regulations to permit dockless scooters (by treating them equivalently to bicycles) there are few requirements for or instructions regarding geofences, which leaves most of the spatial decision-making up to private operators. Spatial analysis of the six scooter geofences available during summer 2019 indicate that operators differ sharply in their coverage of Vienna, as well as where scooter parking is prohibited (via visually-communicated 'no parking zones'). Categorization of no parking zones across operators indicate that the bulk are located around parks, pedestrianized corridors, and cultural institutions (such as palaces and museums). Moreover, all six operators modified their geofences during the course of this study (adding neighborhoods and removing others), which took place absent any type of municipal approval or disclosure to users. These observations combine to establish a dockless-mobility profile of Vienna (including regulations and outcomes) that can serve as a model for future comparison cases worldwide. It indicates that there is likely a role for the public sector to provide oversight over dockless-scooter operations *spatially*, such as by creating incentives for geofences to better serve outlying neighborhoods.

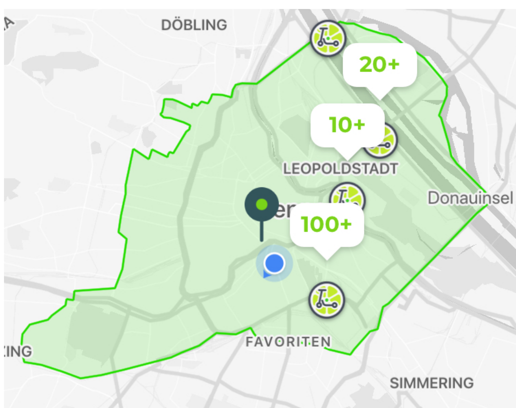
Introduction:

Vienna, the capital of Austria, is a large, dense city in Central Europe (population 1.89 M), that has a robust public transit system and commuting behavior that is less reliant on the personal automobile than most American cities. Indeed, cycling makes up a significant portion of travel – 7% citywide (Wiener Linien, 2018) – and upwards of 13% in the inner-city districts (MA 18, 2015), which feature separated bike lanes, bike-specific signage and signaling, and ample bike racks (see **Figure 1**). The city has had a bikeshare system since 2003 (which changed management several years ago), and is now comprised of 120 stations and approximately 1,500 bikes ("CityBike Wien," 2019). The transit network consists of U-Bahn and S-Bahn networks, streetcar and bus lines, as well as several large train stations for intercity and international travel. In 2017, a number of dockless bikesharing companies launched in the city, but several of the largest (Ofo and O-bike) concluded operation following the city's passing of a more-stringent bikeshare regulation (Laa and Emberger, 2019). Specifically, these new rules held operators responsible for removing bicycles that were either obstructing pedestrian walkways or damaged/vandalized, with fines levied for those not removed within four hours after a complaint was filed.

Figure 1: (clockwise from top left) Active transportation facilities in Vienna including large bike racks, bike signaling, separated bike lanes, as well as dockless scooters and bikesharing. All photos were taken by the author.

At nearly the same time dockless bikes pulled out of Vienna (September, 2018), dockless scooters were deployed, led by American companies Bird and Lime ("Lime Europe," 2018, Leitner, 2018). These systems allow anyone who has downloaded the relevant mobile application to rent scooters in an on-demand basis, generally charging €1 for the vehicle to be unlocked, and a charge for every minute of the ride thereafter (e.g. 15 cents/minute). At first, dockless scooters were operating in something of a regulatory gray zone, given that the existing vehicle code had no mention of such vehicles. However, Vienna recently clarified its regulations so that it now treats electric scooters effectively as bicycles, which includes rules on where they may or may not be ridden and parked (§ 88b. StVO). This outcome falls on a spectrum of how municipalities have so far dealt with dockless scooters, from little to no policies preventing operation (San Diego, CA) to tight regulations on the number of operators, overnight scooter curfews (Atlanta, GA), and outright bans (Ventura, CA). With this context, Vienna's policy is largely welcoming to scooters (albeit with some regulations).

Indeed, there is little guidance in terms of how scooter companies should dictate the geographic coverage of their service; put another way, how geofences are drawn and communicated to their riders indicating where scooter trips may begin and end. Generally, there are two ways that dockless mobility companies (offering bikes and scooters for short-term rentals) establish spatial boundaries on trips: a geofence polygon and 'no parking zones.' Users of a mobile application are generally presented with both of these features simultaneously, often with the no parking zones colored red, and the geofences as color-filled polygons, or simply as outlines (See **Figure 2**).



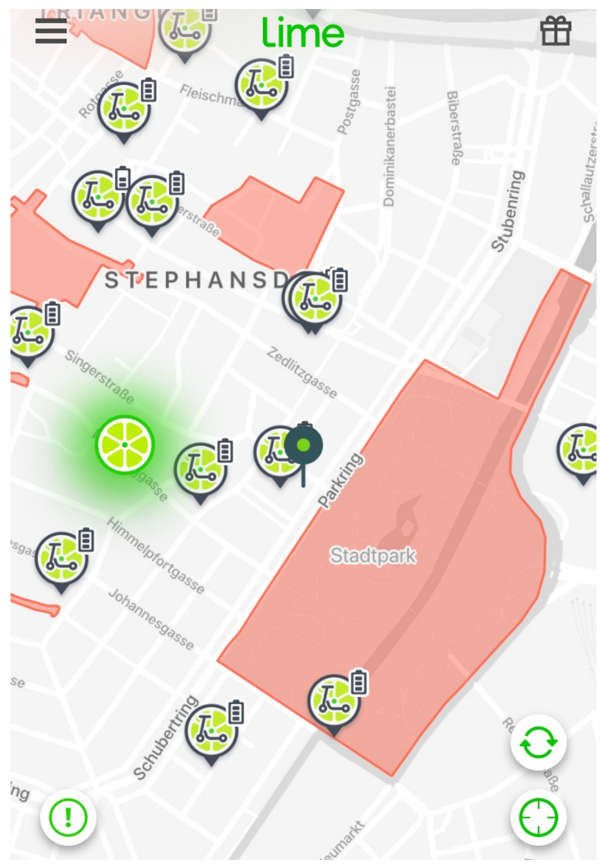


Figure 2: Screenshot from Lime's smartphone application (iOS version) displaying scooter availability in Vienna within the larger geofence (green polygon, left), and designated no parking zones in red, such as Stadtpark (right) visible when more zoomed in. The circular icons displaying a scooter logo surrounded by a black outline indicate approximate locations of scooters available for rent, as well as their battery level.

In most cases, there is a financial penalty for ending a scooter ride either outside of the geofence entirely, or within a no parking zone. As of August, 2019, fees for such conduct in Vienna are set at €25, which operators warn riders of via smartphone applications and emails (see **Figure 3**). This is dramatically higher than the cost of a 1-3 kilometer scooter ride, which generally costs under €5. In addition to fees, some operators will simply not let riders end a ride (via the smartphone application) if they are currently within a no parking zone. This option forces the rider to move the scooter out of the no parking zone in order to end the trip (and to cease being charged).

Please note that the use of our e-scooter is permitted only in the shared area, which is marked in green in the app on the map. Zoom the map all the way in so you can see the red areas to avoid. If a ride in a red zone are completed, we will have to deduct a penalty of 25 € from your account to cover the additional costs for the return transport.

For questions about the fee, you can contact the customer service number +43720778499.

Your Lime Team

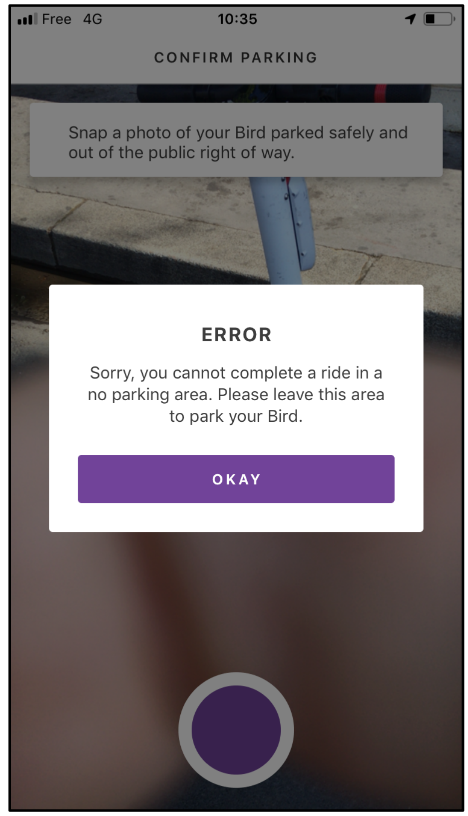


Figure 3: Body of an email message from Lime (left) warning riders of fees incurred if rides are ended in no parking zones (or as they call it, a 'red zone/area'), and a mobile application screenshot from Bird (right) indicating that a ride cannot be ended because the scooter is in a no parking area.

Vienna's hands off approach to scooter geofences stands in contrast to other cities regarding this features of dockless systems, including San Francisco. The home to many scooter company headquarters (including Lime, Spin, and Skip) and at times a bellwether for technology adoption, San Francisco mandated that potential scooter geofences be included in all permit applications, and that all changes to geofences of licensed companies be submitted to the city's transit agency (SFMTA) before being implemented. Critically, nothing in the Vienna guidelines on dockless scooters mandates geofences (initial or subsequent iterations) ever be shared with the city administration.

From June through August, 2019, six scooter companies operated in Vienna (Bird, Circ, Hive, Lime, Tier, and Wind).[1] Under Vienna's bikesharing regulation (Magistrat der Stadt Wien, 2018) which now applies to scooters, each company was allowed to deploy up to 1,500 vehicles. In terms of overall scooter-fleet size, Vienna possibly had as many as 9,000 vehicles on its streets over the study period, assuming each of the six operators deployed its allotted 1,500 scooters. For comparison, Paris reached nearly 20,000 around the same time, which prompted calls for regulatory reform from officials (Crellin, 2019).

On top of that, the other requirements concern business management (maintaining an office in Vienna, obtaining a license), handling data according to local laws, and displaying an official emblem on vehicles. The only spatial component of the city's regulations for operations is ensuring that vehicles be parked off of public greens, and not on sidewalks in front of buildings with cultural significance (except at available racks). Indeed, nothing in these regulations touch on the overall spatial availability of scooters in Vienna, and a straightforward interpretation of this policy is that operators may set their scooter geofences wherever they would like, including the setting of no parking zones. Moreover, there is no data sharing described between operators and the city administration, which has taken place in a number of other municipalities with dockless scooters. For example, Austin, Texas releases aggregate figures on scooter rides to the public via an online data dashboard.

It is important to note that while Vienna maintained a station-based system throughout this time period (CityBike Wien), there are a number of features of dockless scooters that may make them more attractive to potential riders. First, CityBike Wien is in some ways antiquated compared to other station-based systems around the world, including the inability for users to unlock bikes with their smartphones, as well as substandard equipment (Laa and Emberger, 2018). In comparison, dockless scooters can be reserved and unlocked via a number of mobile applications, and trips can end anywhere within a geofence, rather than at specified stations. This allows for many more trips to be accomplished in a true door to door fashion, as opposed to trips that require more walking on each end of bikeshare travel. In addition, scooters require little to no physical effort to ride (compared to a bike), which make them more desirable for occasions when a rider does not want to sweat, or is wearing clothing that would make it difficult to bike. That said, scooter trips are more expensive than CityBike Wien, which effectively is free (for the first hour) following a rider making a deposit of just €1.

The omission of geofence-specific regulations is evident following even cursory use of dockless scooters in Vienna; geofences vary by brand, as do no parking zones. Geofences are not rigid, but appear to change over time (although not at any regular cadence). Some operators slow

[1] Over the course of Summer 2019, Circ changed its name from "Flash." At the end of August, 2019, Wind ceased operations in Vienna, and Kiwiride launched its own scooter-sharing service. One dockless bikeshare company also operated during this period, named Donkey Republic, although it is not included in this analysis.

scooter speeds to a halt in no parking zones, whereas others do little to prevent you from parking there (fees are not always imposed). Given this, the purpose of this study is to understand how this variance in scooter geofences relates to Vienna's layout, built form, and its existing regulations for dockless mobility. In addition, it is hoped that Vienna may serve as a case for the benefit of cities around the world – many now facing similar situations. Following a literature review of the spatial arrangement and regulation of shared-mobility systems (of which scooters are a part), methods for geofence (and no parking zone) spatial analysis are provided, as well as results regarding Vienna's six scooter operators, a discussion of challenges of overseeing such dynamic service models, and proposals for public policy that could improve access and equity outcomes. This paper closes with open questions on dockless mobility and transportation planning, study limitations, directions for future research, and a summary conclusion.

Literature Review:

Personal mobility being met through devices in shared systems is not new; the very first bikesharing system debuted in the Netherlands in 1965 (known as 'white bikes'), which were free and could be left outside any building within the city (Shaheen et al., 2010). Shared systems advanced through different technological phases (such as versions that were coin-operated, or those which accepted credit and debit cards at kiosks, and now via mobile phones), as well as formats. Over the last decade, station-based bikesharing systems have operated in North America, South America, Asia, and Europe, which entail riders pick-up and drop-off bikes into secured stations (or docks), located on sidewalks or city streets ("The Bikeshare Planning Guide," 2018). Bikeshare is intended to obviate the need of owning one's own bicycle, dealing with repairs, and theft, as well as encouraging active transportation in urban areas and as a means of filling gaps in transit systems.

Studies on the spatial layout of bikeshare stations have produced intriguing findings, including using demand forecasting to optimize station layout (Garcia-Palomares et al., 2012), choosing locations in a manner that reduces the need for bike rebalancing (Liu et al., 2015), and increasing the amount of bikeshare to transit/rail connections (Griffin and Sener, 2016). Relevant work also involve examining how bike lanes and other features of urban form contribute to bikeshare usage (Buck and Buehler, 2012), how the location of firms can be integrated into models of trip forecasting (Wang et al., 2016), and using open data (rather than surveys) to determine dock siting (Chen et al., 2015).

In addition to this, scholarship from a number of disciplines has analyzed how the roll out of bikeshare systems interact with wealth, gentrification, and underserved neighborhoods. In "Bike Lanes are White Lanes" (2016), Hoffman argues that cycling infrastructure's (such as new bike lanes) reception varies by block because of the bicycle's status as a "rolling signifier," in that it signals different things to different communities. For example, to certain segments of the population (such as young, white, highly-educated persons) a bicycle can convey a sense of sustainability, self-reliance, and athleticism, whereas to others (including communities of color) it may indicate simply that someone does not earn enough income to own a car. Adonia Lugo, in "Bicycle/Race" notes that even the terminology around the same transportation choice can vary: some cyclists see themselves as "carfree," whereas others in the exact same position are considered "transit dependent" (2018).

This supposition can be extended to bikeshare; some minority and low-income communities in San Francisco have resisted the installation of bikesharing stations in the Mission neighborhood, in part because it is viewed as the herald of gentrification (Swan, 2018). Bikeshare networks have at times contributed to this belief via the sequencing of station roll-out. For example, San Francisco began its bikeshare operation largely in high-income neighborhoods, after which they then attempted to expand them to poorer areas (similar issues have surfaced in Minneapolis). An obvious response to these episodes are to ensure that the way mobility systems begin include consideration as to the socio-economic coverage.

In the last four years, dockless or 'floating' bikeshare systems grew dramatically, originating in Chinese cities, with large companies such as Ofo and Mobike also venturing into international markets in 2017. Much of that expansion was reversed following significant financial trouble on the part of Chinese operators (Huang, 2018), although dockless bikesharing has operated successfully in a number of cities, including in the U.S. and Europe (Lloyd, 2018; Field, 2019; Dickey, 2019b). Dockless systems present a number of different spatial questions than docked ones; what are the boundaries of use? Where should bikes be able to be parked at the end of rides? How many bikes should be allowed within an established geofence to ensure adequate availability but avoid crowding? The newest entrant to urban mobility – dockless scooters – generally operate analogously to dockless bikes, and thus raise the very same questions. Bird launched the first dockless scooter system in Santa Monica in the fall of 2017 (Hall, 2017), and since then has expanded to over 100 cities, as has Lime (formerly known as LimeBike). Bird and Lime are far from the only operators in multiple cities; the ridehailing giant Uber also operates scooters as part of its JUMP product line (Dickey, 2019a), as does American ridehailing company Lyft (Hawkins, 2018). Moreover, a number of scooter operators with large European footprints have emerged, including Tier, Circ, and Wind, which have raised large sums of venture capital (O'Hear, 2019). Ridership figures so far also illustrate the popularity of dockless scooters; NACTO reported that there were 38.5 million scooter trips in 2018 in the U.S., which exceeded total station-based bikesharing trips (36.5 million) ("Shared Micromobility," 2019).

Given dockless scooters are barely two years old, scholarship on their operations – and their implications for urban mobility – is more limited. Though, early contributions have considered whether or not dockless scooters are being parked correctly (Fang et al., 2018), how scooter systems could fill in the gaps of existing fixed-line transit (Smith and Schwieterman, 2018), and Americans' perceptions on the devices ("The Micromobility Revolution," 2018). Furthermore, in Chicago, initial analysis of the city's dockless scooters indicates that the morning commute peak represents the period of highest scooter usage, trips average roughly two miles, and that the eastern edge of the city's scooter geofence is perhaps constraining a number of riders (Smith and Schwieterman, 2019). In San Francisco, the transportation agency's evaluation of the two permitted scooter operators indicated that both had failed to meet expectations in terms of outreach to lower-income neighborhoods, and that ridership was predominantly male and white ("Powered Scooter Share," 2019). In Portland, Oregon, a report on the city's scooter pilot revealed that such vehicles were not siphoning riders away from bikeshare. Indeed, a survey of scooter users found that 38% of respondents had never ridden bicycles in the city, and 78% had never used the local bikeshare system ("E-Scooter Findings Report," 2019).

So far little academic scrutiny has been paid to mobility geofences specifically, perhaps in part because they change so frequently, or because they are not visible features on the street (only virtual), and do not cause as obvious or immediate problems as a scooter parked in front of an access ramp. Moreover, comparisons of geofences across brands or across time for a single brand are difficult to do without taking time for smartphone-application monitoring and manual conversion (described below). However, geofences at times have made it into the media, including expansions, and an episode in San Francisco in which Scoot erected scooter no parking zones in two low-income neighborhoods, seemingly undermining its permit application (Bhuiyan, 2019). In the aftermath of an LA Times' article on this issue (which was shared widely online), Scoot removed one of the no-parking-zones, and released a letter which showed they had in fact been asked by the Chinatown Transportation Research and Improvement Project to keep scooter trips from being ended within Chinatown, the other affected neighborhood (Fitzgerald Rodriguez, 2019).

Methods:

The primary method of analysis for this study was capturing the current extent of each of the six scooter company geofences in Vienna (Bird, Lime, Circ, Tier, Hive, and Wind), including both the area in which scooter trips may begin and end, and the no parking zones in which scooters cannot be parked. While this information is available to potential riders via each company's application (see **Figure 2**), it is not available for download from the operators or Vienna, which prevents cross-brand comparisons. For this reason, I manually converted each geofence and no parking zone into a digital mapping file (or layer) using the GIS web platform Carto (See **Figure 4**). This entails the construction of polygons which match the mobile-application geofences on a street-by-street and feature-by-feature (e.g. river, park, palace) basis. In effect, a traced-copy of each geofence and no parking zone was established in Carto every time any geofence changed.

Starting from a single known geofence point, I used the polygon-construction tool to ensure each new subsequent vertex of the geofence was marked on Carto, resulting in a facsimile of the geofence. The level of difficulty in constructing geofence copies varied by operator, in part because some do not display geofence boundaries as prominently, and also because others cloud the geofence edges with icons representing scooters, landmarks, or charging stations. Visual inspection following construction of a new geofence copy was essential for error detection (discussed further in the limitations section).

Figure 4: Conversion of scooter geofence from smartphone application (left) to digital mapping shapefile on Carto platform (right).

This conversion step allows for several types of spatial analyses. The first is a comprehensive comparison of geofences (operator to operator) which can demonstrate how each extends access to scooters among different Vienna neighborhoods (or excludes them). In addition, comparisons of no parking zones can also take place across operators, which were converted using the same technique on the Carto platform (point-by-point recreation). Given no parking zones were significantly smaller than geofences, this process was generally faster and entails less chances for spatial errors.

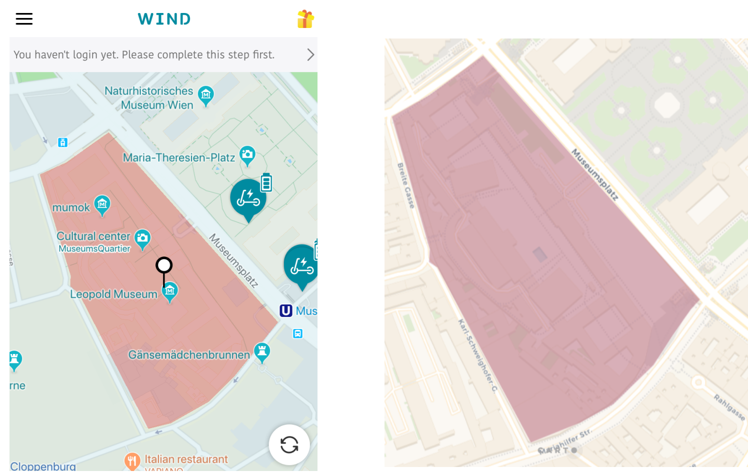


Figure 5: Conversion of scooter-geofence no parking zones from smartphone application (left) to digital mapping shapefile (right) on Carto platform.

A second benefit of tracking scooter geofences for a single city is that it is possible to observe how geofences change longitudinally. Indeed, while scooter companies sometimes contact customers when they their geofence changes (via email or in-app notifications), it can also take place without any notice at all. Moreover, cities do not often keep records (public or otherwise) of the temporal changes in mobility geofences, raising the value for researchers to build a timeline of geographic change. This data-collection method seeks to create a record of the spatial distribution of dockless scooters in a way that is otherwise impossible from existing public sources. Bike and scooter sharing companies do not necessarily have a strong interest in sharing how their coverage of cities change (particularly when they *pull out* of neighborhoods) and making real-time records of geofences is a low-tech, low-cost mechanism of solving this information gap.

In terms of timing, geofences of each of the six scooter companies were checked on a weekly basis for changes, between the beginning of June and the end of August, 2019. Geofences were checked each Monday, and all changes were recorded by manually constructing new polygons in Carto. No parking zones were analysed during July, 2019 for each operator, and not checked in the same longitudinal fashion. Part of the reason for this is that anecdotal use of scooter systems did not indicate that no parking zones were changing at the same speed or the degree to which geofences were changing. For the purposes of no parking zone categorization, inspection of each site where a zone was located on Google Maps (satellite and street view). That allowed for the identity and category of the site to be ascertained (e.g. park, palace, hospital).

Results:

The results for this study are broken down into three sections: comparison of overall scooter geofences in Vienna, comparison and categorization of scooter no parking zones, and analysis of operator-specific changes across time. While scooter geofences are normally presented to riders as multi-component maps within mobile applications (including approved areas, no parking zones, as well as bike lanes, landmarks, etc.) these analysis steps deliberately separate those features for comparison. This type of cartographic simplification is beneficial because it allows for comparison of one aspect of geofences at a time. How these features (geofences and no parking zones) and their modifications change over the study period relate to municipal regulation and user experience are addressed in the discussion section.

I. Overall Scooter Geofences

Capturing the six scooter geofences in Vienna for June, July, and August 2019 illustrate significant patterns and variations in coverage, which relate to the city's layout, density, transportation network, demographics, and built form. Every single geofence tracked (across brands and months) includes Vienna's first through ninth districts, which feature major tourist destinations, shopping, a large number of employers, and cultural institutions (such as art museums and palaces). Outside of these districts, geofence coverage varies; **Figure 6** displays which districts were covered by each (as of August, 2019). From this perspective, there is a clear preference among operators for districts 1-9, and 20, compared to districts 11, 13-14, 19, which varied from 5 to 3 operators, and district 23, which had zero scooter geofences.

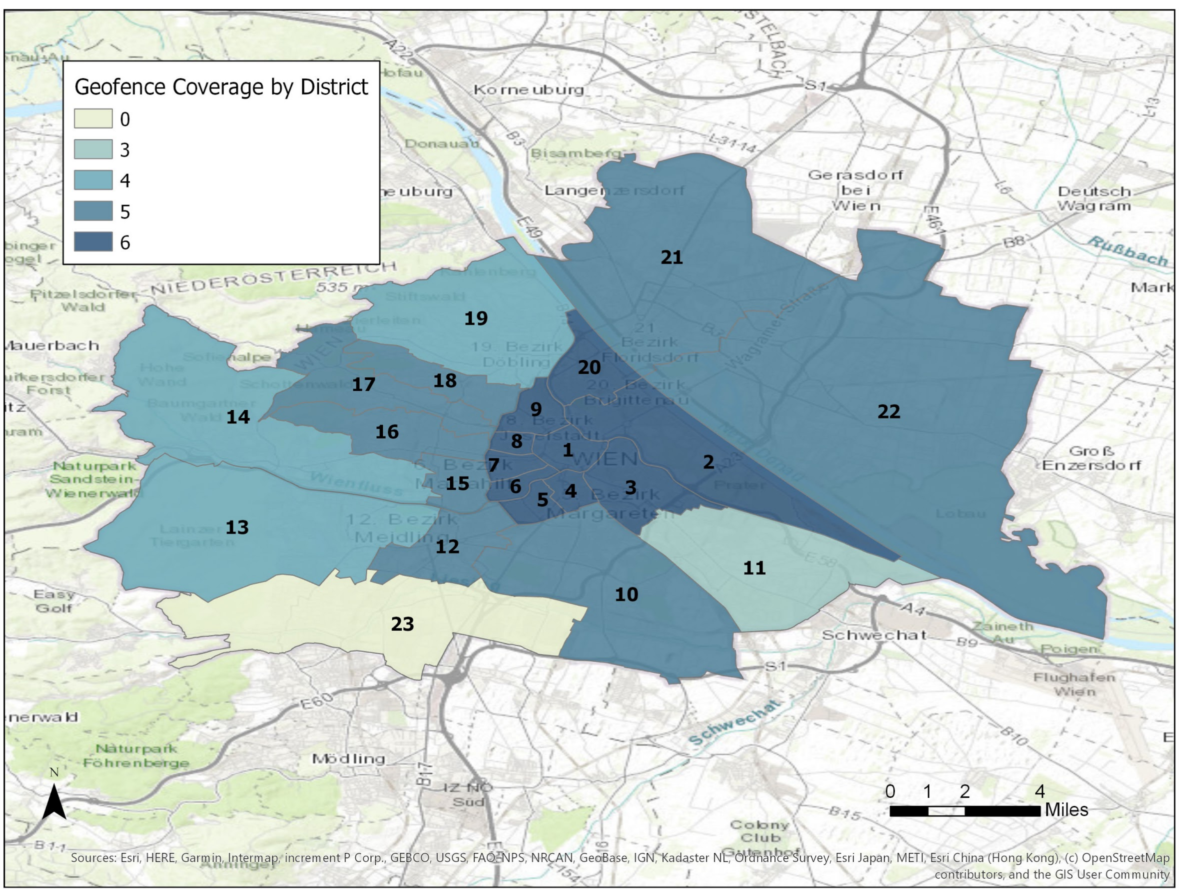


Figure 6: Map of Vienna Districts (1-23), color-coded by the number of scooter geofences (as of August, 2019) present in each district.

Districts covered by all six scooter operators are located in the center of Vienna, with less coverage in nearly all directions moving outward. Importantly, what counts as a district "including" a geofence does not mean that scooters are available throughout it. For the purposes of the above analysis, a district was counted as containing a given scooter service even if the geofence for that operator only touched a small portion of the district (see **Figure 7**). For this reason, a district-level analysis of scooter geofences – while presenting a rough view of coverage variation – omits some of the nuances of how districts are covered.

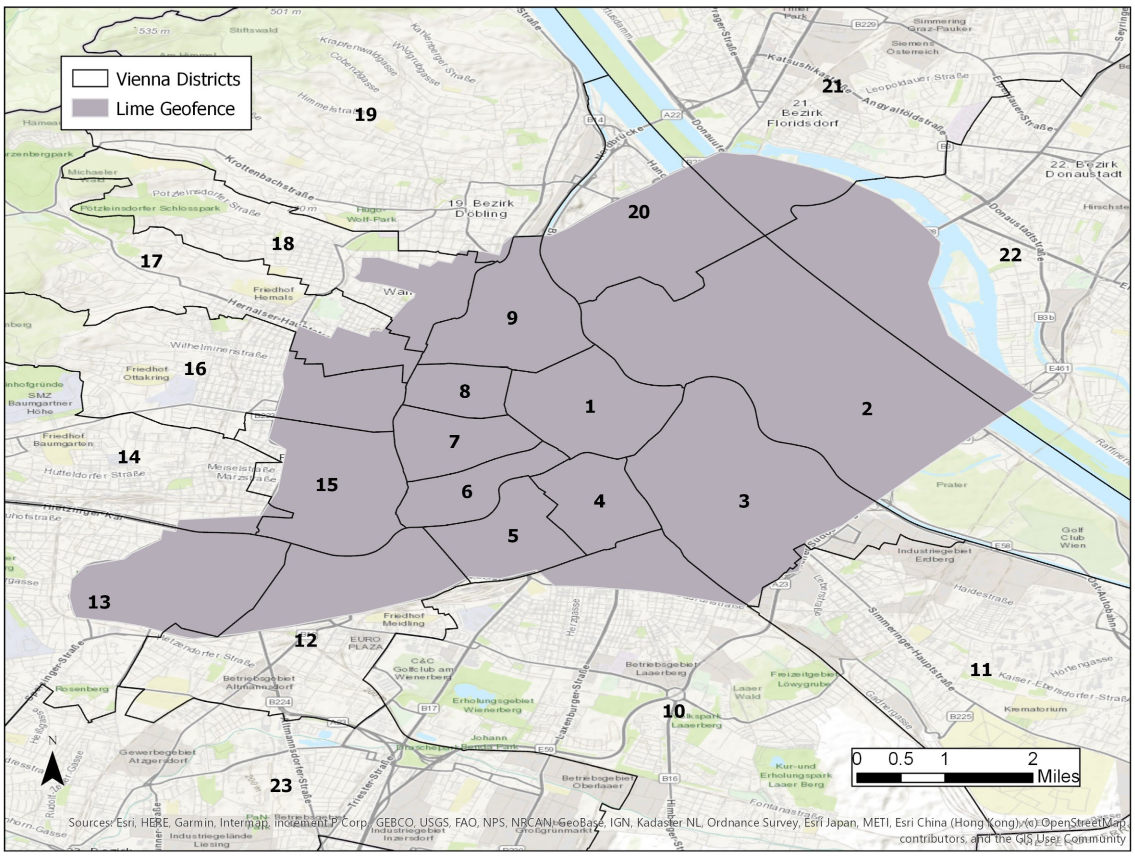


Figure 7: Example of the district-level analysis of the Lime scooter geofence in Vienna, which indicates that how much of a district a geofence includes varies significantly. For example, all of Districts 7 and 8 are included in Lime's geofence, whereas only a small slices of District 16 is covered.

Aside from district coverage, it is also revealing to examine how scooter geofences vary more directly compared to each other. In **Figure 8**, the outlines of all six of the geofences are displayed (as of August, 2019).

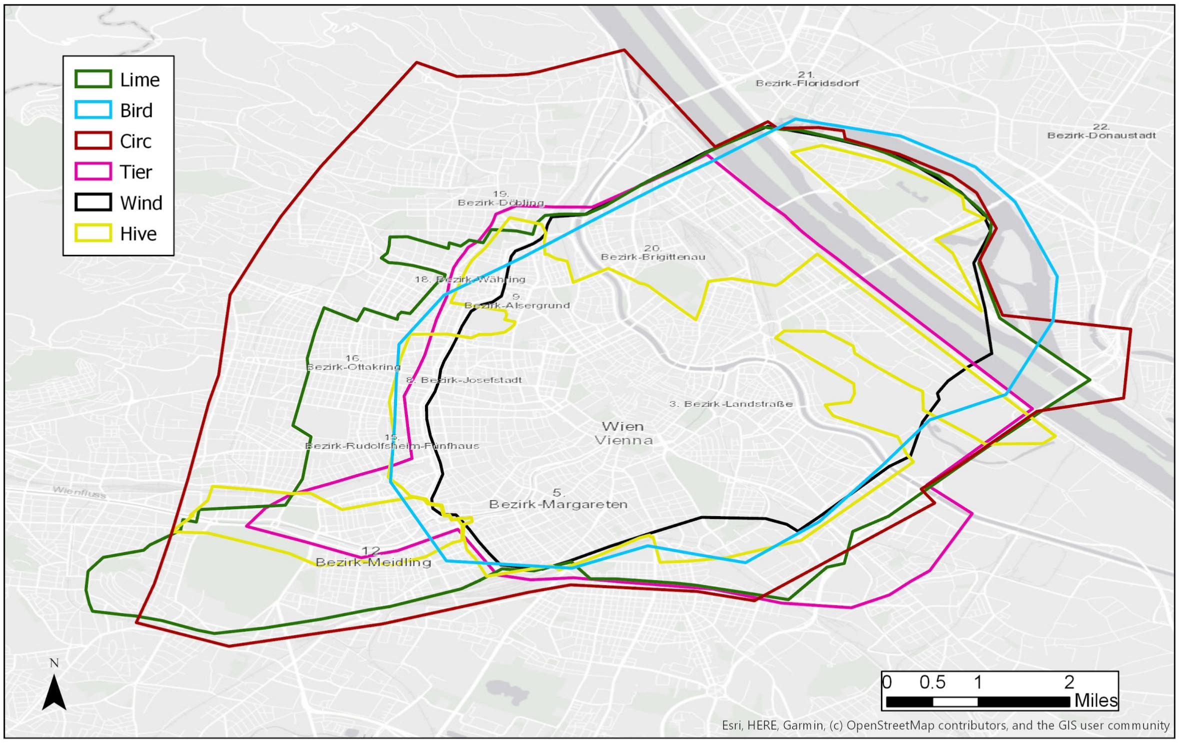


Figure 8: Outlines of all six scooter geofences in Vienna, as of August, 2019.

This combined map illustrates several important features of geofence coverage in Vienna. First, coverage on the eastern side of the Danube (the large river in the northwestern quadrant) is almost entirely limited to Kaisermühlen, which is surrounded by water, and includes swimming destinations, a large park, and more recently-developed residential neighborhoods (compared to the city center). Second, several geofences stretch to the far western edge of Vienna in order to include Schloß Schönbrunn, which is a large palace and grounds that draws many tourists. Third, there is very little overlap in terms of geofence outlines at their edges; although many parts of the city are included within more than one geofence, each geofence ends at different places throughout the city.

The distinct spatial layouts of the scooter operators in Vienna entail that riders cannot consider these systems equivalent. Indeed, if riders hope to avoid any type of fee from ending their scooter trip outside of a given geofence, they must consider which scooter brand they will choose for each specific trip. This map also indicates that riders will be limited in terms of which scooters are available to start their rides based on their origin.

II. Scooter No Parking Zones

In addition to scooter geofences, no parking zones vary significantly by scooter operator as well. Prater provides a useful example of how different companies chose to geographically constrain scooter use (See **Figure 9**). Indeed, Tier has blocked out nearly all of Prater, whereas Hive has only designated a very minor portion of the park as off limits. This heterogeneity in terms of no parking zone shape holds across a number of different sites around Vienna, including Vienna General Hospital.

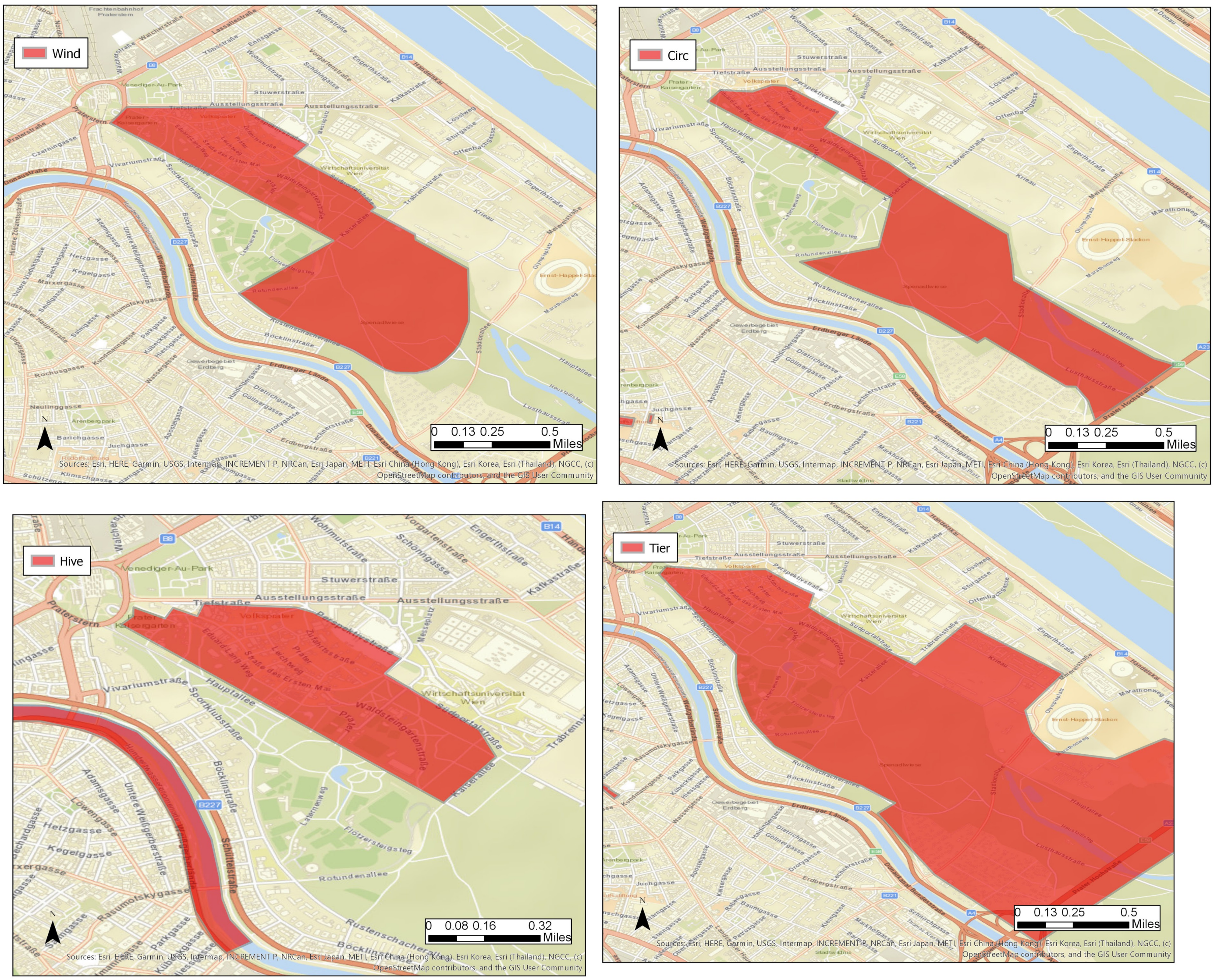


Figure 9: Comparison of how four different scooter companies (clockwise from top left: Wind, Circ, Tier, and Hive) designate no parking zones in Vienna's Prater.

Beyond covering a given area with unique no parking zones, operators also vary purely in terms of no parking zone siting overall. Indeed, this aggregation clearly demonstrates that scooter operators in Vienna determine on their own where no parking zones should and should not occur, as opposed to following a set list provided by the city administration. In **Figure 10,** all of the tracked no parking zones are displayed, with zone overlap represented with darker red shading.

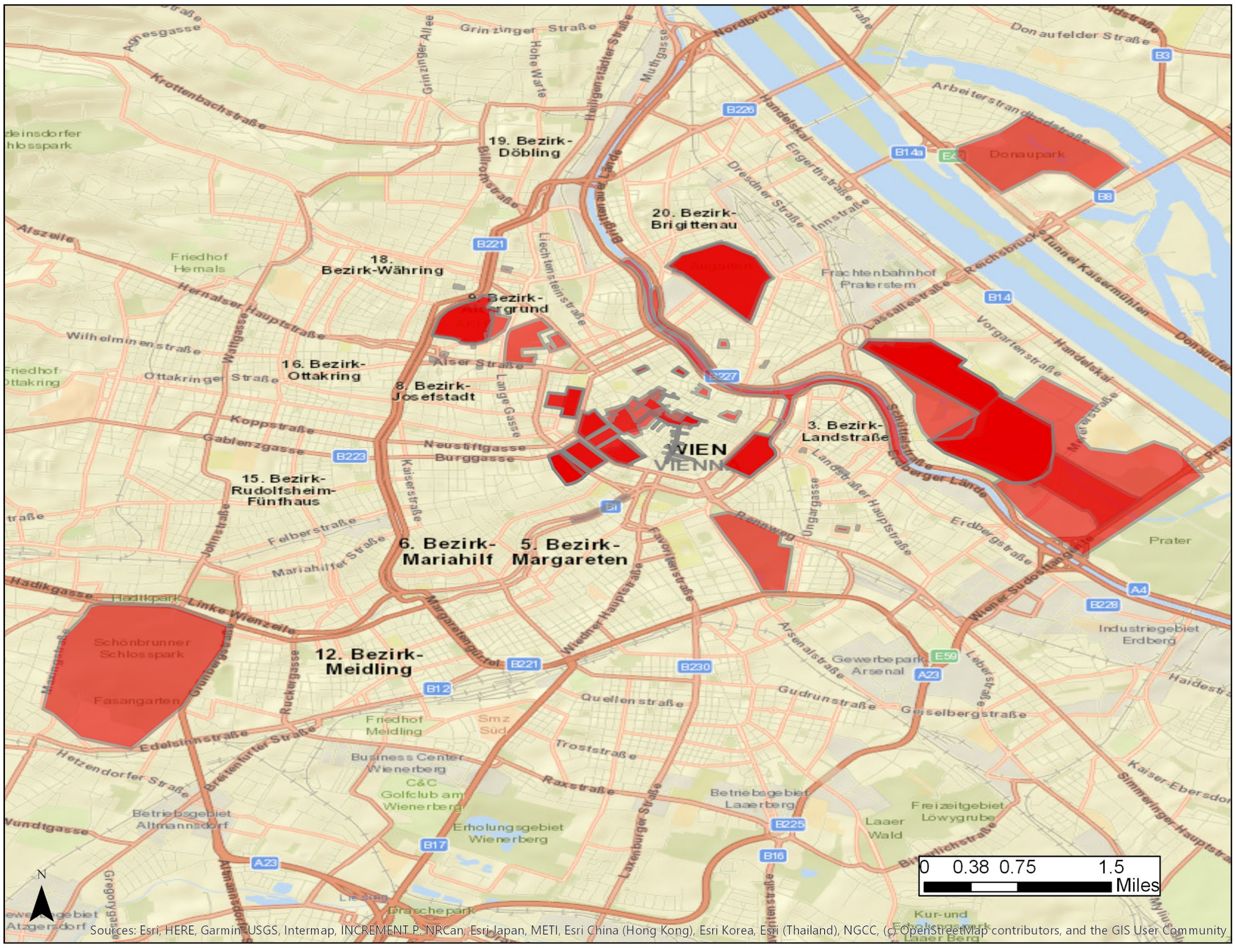


Figure 10: Scooter no parking zones in Vienna across six operators.

From this perspective, no parking zones vary dramatically in size (from single blocks to entire parks and neighborhoods), and appear in nearly all parts of Vienna. It is also evident that the highest concentration of no parking zones occurs in the city center, including the pedestrianized area surrounding Stephanplatz, shopping corridors, Maria-Theresien-Platz, and MuseumsQuartier.

Beyond inter-brand comparisons, tracking all no parking zones in Vienna provides a chance to categorize these areas by function or purpose, in terms of what sorts of spaces are being made off limits for scooter trips to end. No parking zones were sorted into the following types: parks, pedestrianized zones, cultural institutions (palaces, museums, churches), hospitals, and water. **Table 1** summarizes these no parking zones by type, and sub-divides them by operator.

Table 1: Scooter No Parking Zone Categorization

Operator	Park	Cultural Inst.	Hospital	Pedestrianized Zone	Water	Total
Circ	2	4	2	7	-	15
Wind	3	1	-	-	-	4
Hive	2	5	-	1	1	9
Lime	3	6	1	2	-	12
Bird	2	1	1	-	-	4
Tier	7	4	1	7	-	19
Total	19	21	5	17	1	**63**

Of the 63 total no parking zones, 21 were established around cultural institutions, followed by parks, and pedestrianized zones. Whereas Bird and Wind each only established four no parking zones, Tier at this point had 19 and Circ 15 no parking zones. Without question, this analysis clarifies that operators were independently deciding where to place no parking zones based on the city administration's vague guidelines. Though, some no parking zones were identical (such as over Stadtpark). Overall and similarly to geofences, riders must be wary of which scooter brands they are choosing for which destinations. For example, Schloß Schönbrunn is a no parking zone in some systems, which riders may not be aware of until they seek to end their trip in that area.

III. Intra-Operator Geofence Changes over Time

Lastly, during the course of this study (June to August, 2019) all six of the scooter operators modified their geofences (some multiple times), both via geofence expansion and retraction (see **Figure 11**). Scooter operators Bird, Hive, Wind, and Tier ended the summer with larger geofences than they began with, and Circ and Lime ended with smaller geofences.

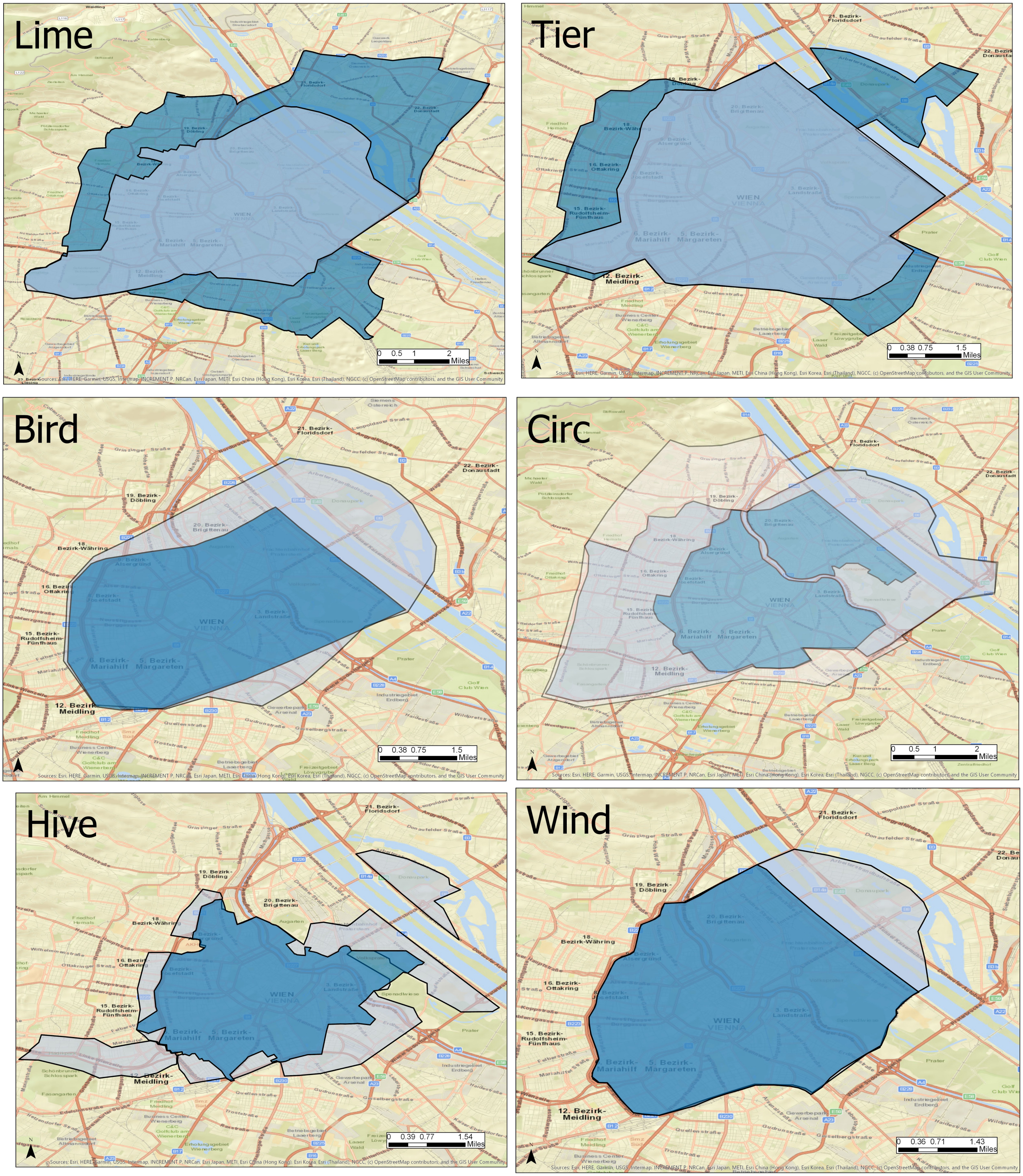

Lime
Tier
Bird
Circ
Hive
Wind

Figure 11: Comparison of scooter geofence changes over the course of Summer 2019. The darkest blue indicates the oldest geofence, and newer geofences are colored lighter and lighter shades of blue.

These changes demonstrate that over the course of just three months, scooter availability varied significantly across Vienna. Neighborhoods were both added and removed from different operators' geofences. Four of the companies (Wind, Hive, Bird, and Circ) all extended across the Danube river in their latter geofences, although Lime and Tier both reduced their coverage in that region of Vienna. Beyond that, the change in size of geofences (within brands) also was dramatic; Circ grew nearly three-fold in size from June to August, while Lime's geofence was nearly cut in half (in terms of area). These geofences also do not follow a similar pattern in terms of shape, but exhibit unique and at times curious forms, such as the distinct pieces of the Hive geofence (including a disconnected zone across the Danube river).

Discussion:

By reviewing all dockless scooter geofences in Vienna over a three-month period, several important observations can be made, relating to both city-specific coverage and municipal regulation of shared mobility writ large. First, spatial analysis demonstrates that each scooter company maintains unique geofences covering Vienna in overlapping but non-identical ways. Geofence coverage is most robust (meaning covered by all operators) in the city's inner-most districts (1-9 and 20), with lessening coverage in more-outlying areas (including none in District 23). Discretion is also evident in the setting and shape of scooter no-parking-zones, which vary by operator, even though all were working from one set of basic municipal guidelines. The cataloging of scooter no parking zones (the first known account of such a technique) illustrates that cultural institutions were the most common reasons for such a designation, followed by parks, and pedestrianized areas. The third major finding was that each company modified its scooter geofence over the course of the three-month study period (some more than once), with four expanding their coverage and two contracting it. Outside of this work, there is no public record of geofences changing in real time across operators in such a relatively short period (one season). Geofence changes were not minor; neighborhoods were both included and excluded over the course of the study, and geofences grew to three times their original size in one case, and were cut nearly in half in another.

In terms of Vienna, there are three public-policy recommendations to make based on the documented spread of and changes to scooter geofences. The first is that coverage is generally inconsistent outside of the inner-most districts, which limits the neighborhoods and residents that have access to a more sustainable alternative to driving. This is particularly significant in Vienna's case because transit provision also declines in the outermost districts, which raises the value of scooter sharing in such places. Indeed, car ownership per household tends to increase as the distance from the city center grows, which means that the very individuals you would want to shift their mode from car to scooter will often be out of range of most to all geofences. Given this, rather than mandate scooter companies cover a given percentage of the city (or specific areas) for a license, Vienna could experiment with offering incentives to operators that choose to expand their geofences to neighborhoods with lower transit provision. For example, the city currently allows each permitted operator up to 1,500 scooters; perhaps that cap could be lifted to 2,000 if a given geofence is expanded to a handful of neighborhoods in question. Overall, regulators must take into account that operators set geofences based on existing market constraints (like vehicle caps), and so attempts to encourage coverage expansions overall should offer some form of concession (or carrots) that will be attractive to such companies.

Another incentive-based approach involves scooter parking. Currently, operators use their mobile applications to communicate no parking zones to riders. One addition to this could be zones where vehicle parking is *encouraged*, and where riders could be provided with a financial incentive such as a discount on their current fare or on their next ride. Such parking incentive zones could be designated at locations that serve broader municipal goals for micromobility, such as at transit stations. If a widespread hope for dockless scooters is that they operate in a first-mile/last-mile fashion, then geofencing strategies should be broadened to incorporate such spatially-specific incentives.

Second, Vienna should clarify and standardize information-sharing practices for scooter companies regarding communication of changes in geofences to registered users. Losing coverage of a given neighborhood (as has taken place) may significantly limit a user's mobility options, and outside of the geofence tracking documented here, it is all but impossible to see how geofences change from one iteration to the next. Mandating that scooter operators submit all geofences modifications to the city (or at least, published to an online clearinghouse) would enable officials to appraise how scooter coverage varies. In addition, the disclosure of such geofences could allow for their integration into other mapping programs, such as Google Maps, or transit aggregators like CityMapper.

In regards to Vienna, there is the chance to create a profile of the city's scooter ecosystem that may be fruitful for future comparisons as these services expand across the globe. The characteristics of this profile include number of scooter operators, and the municipal regulations in place regarding geofences and no parking zones (See **Table 2**).

City	Vienna, Austria	San Francisco, CA
Number of Scooter Operators*	6	2

Number of Shared Scooters*	7,000	1,500
Municipal Conditions for Initial Operation	Yes	Yes
Geofences Submitted prior to Operation	No	Yes
City-Designated No Parking Zones	No	Yes
Approval for geofence changes needed	No	Yes
Geofences Published Online	No	No

* As of August, 2019

Important work going forward will be fleshing out how Vienna's experience with scooters compares to its peers. For example, this table is useful to distinguish how Vienna's scooter situation varies from San Francisco, CA. As noted above, in that city, there are only two permitted scooter operators, planned geofences must be submitted as part of municipal permit applications, geofences cannot change without city approval, and a large city plaza has been designated as a no parking zone for all operators. Indeed, that regulatory environment has created a far different experience for dockless mobility, in which geofences change very little over the course of an entire year, as opposed to several times over just a three-month period. It is not obvious that San Francisco's cadence is more optimal than Vienna's, but the comparison sheds light on how municipal regulations influence the stability in scooter services from a spatial standpoint.

Building off of Vienna's scooter profile (and comparisons), this study relates to how cities around the world can consider influencing mobility geofences via policy. For those municipalities that mandate operators obtain permits, there are a number of spatial-specific decisions to make. The first is to require that all permit applicants submit maps of the geofences they intend to operate. This stipulation provides cities with the ability to appraise geofences *before* they launch, and adds weight to any geofence recommendations provided to permit applicants, such as avoiding service duplication with other modes, or including underserved areas). Indeed, this could raise the salience of municipal goals regarding dockless scooters at the outset of the planning process, and convey that the permitting agency will be appraising the spatial layout of applicants proposals.
The next question for cities to address is what the process will be for allowing scooter operators to modify geofences once their services are already live. Vienna's experience thus far with an

open-ended process (no approval or notice is required) represents one end of the spectrum of options. Alternative approaches include city approval of desired geofence changes, and/or disclosure of such changes to the agency, registered users, or the public via some form of clearinghouse website. There is likely the chance that too burdensome a process for modifying geofences does not benefit cities or users (e.g. no more than once per year), but it is in the public interest for changes to be made available for users, transportation planners, and those developing mobile applications that aggregate mobility services. Some form of expedited approval of geofences — such as decisions being made in one week's time — would provide the chance to avoid any sort of significant cut in geofences that would limit access. Of course, spatial regulation of new mobility services is but one aspect of regulatory oversight, to say nothing of pricing, vehicle speeds, managing sidewalk clutter, and discount programs, among others.

Limitations

There are several important limitations to raise in the context of this work. First, manually converting geofences from scooter mobile applications to layers with desktop mapping software can introduce errors. While the accuracy of this method is adequate for the purposes of the appraisals made here (inclusion or exclusion of neighborhoods, large changes over time, etc.), there are likely to be small inaccuracies in the resulting polygons. This could be avoided if scooter operators or permitting municipalities provided geofences as files for download either on their own websites or some form of centralized clearinghouse. As noted above, mandating that geofences be provided each and every time they change would create an accurate visual timeline that could offer insights as to how scooter access is distributed and changes temporally, as well as if there is need to change how such services are regulated to expand access. In addition, employing Vienna's districts as a means of appraising scooter coverage must be provided with the context that population is not uniform across these administrative units. Vienna's inner districts are far more dense than the outlying districts, many of which includes large parks or open space.

A second limitation is that I cannot be certain I captured every change to a geofence that took place in Vienna over the three-month study period. Geofences for each of the six scooter operators were checked on a weekly basis, but there is the possibility that this cadence missed some geofence modifications. A final, more nuanced limitation has to do with the functioning of geofences themselves in scooter systems. Use and study of different operators indicate that – for lack of a better phrase – not all geofences are created equally. By this I mean that some operators levy penalty fees each and every time a user ends a ride outside of a geofence (or in a no parking zone), while others do not. Still, others do not even let users end trips in such places (see **Figure 3**). For those brands which let riders end rides outside of a geofence or in a no parking zone without penalty, the geofence effectively does not exist, or has no real spatial meaning. Given this, tracking geofences across brands in the same way may ignore these subtle differences in how riders actually think about each differently. For example, if Wind does not charge penalties for parking outside of its geofence, riders may not care as much how the geofence changes from month to month.

Directions for Future Research

With these limitations in mind, there are a number of directions subsequent research can take regarding dockless mobility and its regulation by municipalities. To begin, transportation planners must better understand how users perceive and modify their travel behavior based on geofences — for both bikes and scooters. Indeed, is not obvious how aware scooter riders are of geofences when they select a given service (mobile applications vary in how prominently they display such areas), and this may also vary significantly based on if the rider is a tourist, commuter, or resident. Spatial analysis alone cannot inform us on this topic, which is ripe for surveys. Specifically, scooter users and residents generally should be surveyed on what they understand geofences to mean, how their travel decisions relate to differing geofences across brands, and whether or not they have been penalized for ending trips outside of geofences or within no parking zones. On the last question, this line of inquiry would provide evidence regarding one of the limitations noted above – that not all micromobility companies enforce geofences to the same extent. It is likely difficult to discern these differences anecdotally (via a researcher's observations), and more amenable to a broader survey sample.

Beyond general awareness of geofences or related trip making, it is unknown how riders handle the level of geofence "volatility" evident in Vienna, and if that deters micromobility use overall. One hypothesis is that fast-changing geofences could confuse or annoy daily/weekly riders (particularly if their origins or destinations are affected), leading them either to switch to an operator with a more consistent geofence, or find another means of transport for the trip in question, including by purchasing their own scooter. These types of questions should be included in any kind of survey undertaken in Vienna, as well as other cities whose geofence cadences are different.

There are also a number of questions regarding system management and civic "order" that flow from geofence and no parking zone research. These topics interrelate; it is of benefit to cities that vehicles within dockless systems stay within their boundaries, and it is important for operators that they reduce the amount of vehicle vandalism and damage. How this relates to geofences is highly salient, and one straightforward hypothesis is that scooter operators that more-clearly display their geofences are likely to have a higher percentage of trips comply with those boundaries. The same holds true for no parking zones; cities are generally intent on keeping certain areas free of dockless scooters (such as high-volume pedestrian plazas). There are now, in effect, experiments taking place across a wide range of operators as to what type of mobile-application sequence (geofence display, app notification, etc.) correlates with the least amount of problematic parking. This line of questions indicates why some cities have been intent on having micromobility companies share their data as a condition of operation, which allows transportation agencies to run such analyses and determine which method leads to the best outcome on its streets.

Finally, there are a number of other questions regarding scooter use that are untethered from geofences, but deserve significant scrutiny. These include riders' sensitivity to scooter pricing and hardware differences, as well as interactions with public transit. Indeed, researchers in Vienna have conducted work on possible mode-shift from transit to the CityBike Wien system (Leth et al., 2017), and there is clear room for an adaptation of those methods to dockless systems, and in particular scooters.

Conclusion:

Spatial analysis of the six scooter sharing companies in Vienna over summer 2019 indicate significant differences in the spatial layout of vehicle availability and possible trip destinations. Each company operates a unique scooter geofence, as well as distinct no parking zones. Geofences all covered Vienna's innermost districts, but were less present in all outlying areas of the city. Both of these geographic area types (geofences and no parking zones) changed over the three-month study period, and some operators changed their geofences multiple times. Without manually converting these geofences into digital mapping files, there would otherwise be no record of such rapid turnover. In aggregate, these geofences and their modifications reflect a looser approach to municipal regulation on the part of the Vienna city administration, which does not mandate geofences be reported publicly, or appraise them in any way before they are implemented. Geofences both expanded and contracted between June and August, which affects which neighborhoods may take part in this innovative mobility solution. No parking zones were set at the discretion of each operator (with minor municipal guidance), and generally were designated around parks, sites of cultural importance, and pedestrianized corridors. Vienna represents an ideal case study for understanding modern and dynamic micromobility services, which raise a number of questions for both users and public agencies charged with oversight.

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