Do Irregularly Shaped School Attendance Zones Contribute to Racial Segregation or Integration?

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Abstract

This research investigates if and how much the shapes of school attendance zones contribute to racial segregation in schools. We find that the typical school attendance zone is relatively compact and resembles a square-like shape. Compact zones typically draw children from local residential areas, and since local areas are often racially homogeneous, this suggests that high levels of racial segregation in the largest school districts are largely structured by existing residential segregation. Still, this study finds that the United States contains some attendance zones with highly irregular shapes—some of which are as irregular as the most irregular Congressional District. Although relatively rare, attendance zones that are highly irregular in shape almost always contain racially diverse student populations. This racial diversity contributes to racial *integration* within school districts. These findings contradict recent theoretical and empirical scholarship arguing that irregularly shaped zones contribute to racial segregation in schools. Our findings suggest that most racial segregation in school attendance zones is driven by large-scale segregation across residential areas rather than a widespread practice among school districts to exacerbate racial segregation by delineating irregularly shaped attendance zones.

Keywords

education, racial segregation, gerrymandering, urban, school attendance zones

Although social scientists have an abiding commitment to understanding the causes of racial segregation in public schools, scholars do not know how the delineation of school attendance zones affects how much students of different racial groups are isolated from one another. Almost all of the largest school districts draw maps of school attendance zones—which are the lines that designate the "neighborhood" schools to which public school children are assigned given their residential addresses. Although the geometric shapes of these zones may ameliorate or exacerbate racial segregation in schools, researchers know very little about how compact or irregularly-shaped

zones are.[1] As a result, researchers have largely speculated about the alleged link between attendance zone shape and school racial segregation. Indeed, with the exception of a few studies (Saporito and Sohoni 2006, 2007), almost nothing is known about racial segregation across attendance zones embedded within

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large, racially diverse school districts. Only one published study uses a large-scale database to explore whether actual attendance zones are more or less segregated than hypothetical attendance zones (Richards 2014). Our contribution is to determine how often attendance zones are drawn irregularly and whether irregular zones contribute to racial integration or segregation in public schools.

A central thesis of our work is that racial segregation in public school attendance zones is driven primarily by racial segregation in local, residential areas. In this study, we show that most attendance zones are relatively compact and resemble shapes that look something like rectangles and squares. As large areas within many big city school districts are often racially homogeneous (Iceland 2009; Lee et al. 2008; Reardon and O'Sullivan 2004), we argue that compact attendance zones mimic the racial homogeneity of local residential areas.

This line of reasoning also applies to research investigating the link between the shape of U.S. Congressional Districts and the share of Democratic and Republican voters within them. In particular, Chen and Rodden (2013) show that the high geographic density of Democratic-leaning voters within cities results in "packing" them into a few Congressional Districts even when these districts are drawn randomly and compactly. In other words, the geographic concentration of partisan voters leads to some (but surely not all) political-party homogeneity within some legislative boundaries. Our argument is similar: Existing racial segregation across large residential areas structures the racial composition of school attendance zones such that compact attendance zones will often be racially homogeneous.

A closely related thesis is that irregularly shaped attendance zones often contain racially diverse populations. There are several reasons why irregularly shaped attendance zones are more likely to contain racially diverse populations compared with compact zones. As children tend to live in racially homogeneous neighborhoods, it is often necessary to draw irregular attendance zones to incorporate children who live in distant "black," "white," and "brown" neighborhoods. Moreover, the U.S.

Supreme Court has issued decisions that allow (or encourage) school districts to delineate irregular attendance zones to achieve racial diversity while prohibiting the creation of irregularly shaped and racially homogeneous zones.

Overview

This article proceeds as follows. First, we detail the legal context of school segregation in the United States as it relates to school attendance zones; this is followed by a brief review of the literature documenting how school racial composition influences the educational outcomes of students. Then we describe recent sociological literature documenting the scale of racial segregation in urban areas. This literature finds that many urban areas contain large subregions dominated by shares of a single racial group (and we depict this phenomenon with a series of maps). Based on this legal history and the large scale of racial segregation in many cities, we hypothesize that compact attendance zones are typically racially homogeneous. We make a related argument: Given the large scale of racial segregation in many school districts, they must quite literally go to extraordinary lengths to create racially diverse attendance zones that draw children from far-flung racial enclaves.

We then proceed to explore these issues empirically. We document the typical shape of attendance zones and, as a point of reference, compare the average shape of attendance zones with the average shape of U.S. Congressional Districts. In subsequent analyses, we correlate the shape of attendance zones with their racial diversity. We find that the most highly irregular attendance zones are almost always racially diverse. We conclude that the thoughtful delineation of irregular attendance zones may be one of best remaining mechanisms to achieve *modest* racial integration in racially diverse school districts.

The Legal Context of Attendance Zone Irregularity

Beginning in 1970, the U.S. Supreme Court strongly encouraged segregated school districts to delineate irregularly shaped zones as a

means of racial integration (*Swann v. Charlotte-Mecklenburg Board of Education* 1970). The case was aptly summarized in the *New York Times*:

> It is not enough for school officials to draw school attendance lines that appear to be racially neutral. Officials must foster integration by such affirmative measures as gerrymandering school boundaries to include both races, pairing "white" and "Negro" schools, and drawing school zones that combine noncontiguous areas in racially diverse neighborhoods. (Graham 1970, p. 1)

The practice of drawing irregular zones to integrate public school children is often called the "Finger Plan," and calls for the creation of multipart zones (i.e., satellite zones) for elementary schools (Davison 1995). Even now, some school districts remain under desegregation orders—and we suspect that attendance zones in some of these districts use a Finger Plan to integrate children. In other districts, desegregation orders have been lifted recently, and it may be that irregular zones are a legacy of districts' prior compulsion (or ongoing desire) to integrate students.

Indeed, drawing irregularly shaped attendance zones may be one of the few remaining ways that racially diverse school districts can voluntarily integrate students. This is evident in a 2007 Supreme Court case that largely forbids identifying the individual race of a student to assign him or her to a public school (*Parents Involved in Community Schools v. Seattle School District No. 1* 2007). The Court struck down the use of voluntary student assignment plans (e.g., magnet schools) that used an applicant's race as a school-assignment criterion. While *Parents v. Seattle* prohibited the assignment of students to schools based on race, a majority of the Court found that racial integration remained a legitimate and compelling goal achievable by drawing irregular zones: As Justice Kennedy wrote, "School boards may pursue the goal of bringing together students of diverse backgrounds and races through other means, including strategic site selection of new schools [or] drawing attendance zones with general recognition of the demographics of neighborhoods" (*Parents Involved in Community*

Schools v. Seattle School District No. 1 2007:8).

At the same time that school districts are permitted to delineate irregular zones to achieve racial integration, they are prohibited from delineating even a few irregularly shaped zones that result in racial segregation. In 1973, the U.S. Supreme Court ruled that if a school district intentionally segregated a few of its schools by manipulating its attendance zones, it could be legally assumed that all racially homogeneous schools in the district were created to maximize racial segregation (*Keyes v. School District No. 1* 1973). Under this ruling, a district that intentionally segregates a small area of the district might be compelled to racially integrate *all* of its schools. In short, the 2007 *Parents Involved in Community Schools v. Seattle School District No. 1* case suggests that it is permissible for school districts to delineate irregular zones that are racially integrated—while the 1973 *Keyes v. Denver* case provides a strong disincentivizes the use of attendance zones as a mechanism to exacerbate racial segregation. These current sociological and legal contexts entreat researchers to ask just how compact or irregular attendance zones actually are and whether "community" schools—as they are tellingly called by the petitioners in *Parents v. Seattle*—reproduce residential segregation.

Why School Attendance Zones Matter

School attendance zones largely determine the racial composition of schools (Saporito and Sohoni 2006)—and the racial composition of a school influences the academic performance of its minority students. Numerous studies show that as shares of non-white children in a school increase, academic performance declines for minority students. For example, Mickelson, Bottia, and Lambert (2013) reviewed 25 studies that examined the association between school racial composition and standardized math scores. Most of these studies found a consistent, negative association between proportions of minority students in a school and standardized math test scores a

school's students. Similarly, in their review of the literature, Reardon and Owens (2014) concluded that "Having fewer black students in a grade increases reading and math test scores for black students and does not harm whites' test scores" (p. 213). To be sure, some studies find that school racial composition has little or no effect on educational outcomes (Rumberger and Palardy 2005; Van Ewijk and Sleegers 2010), but most reviews of the literature conclude that higher concentrations of minority students have negative educational outcomes for minority children (Hanushek et al. 2009; Mickelson and Bottia 2010). Despite this negative association, racial segregation in urban schools has generally remained steady and fairly high since the early 1990s (Fiel 2013; Reardon and Owens 2014; Stroub and Richards 2013).

Literature on School Attendance Zone Racial Diversity

One of our theses is that irregularly shaped attendance zones contain diverse racial populations. Theoretically, school districts seeking racial integration—either by court order or voluntarily—must create many attendance zones that draw children from distant but racially diverse neighborhoods. Indeed, this "Finger Plan" logic appears to be legal under both the *Swann v. Mecklenburg* and *Parents v. Seattle* cases. Moreover, as school districts can no longer assign individual students to schools based on their race, this accentuates the necessity of drawing irregular zones to achieve integration.

Despite this legal history, most scholars argue that attendance zones are drawn irregularly in an effort to make them racially homogeneous (Bischoff 2008; Clotfelter 2004; Frankenberg 2009; Frankenberg and Orfield 2012; Leigh 1997; Siegel-Hawley 2013). This is also true in non-academic publications—typically anecdotal evidence published by local newspapers. A typical story suggests that newly configured attendance zones are drawn irregularly to achieve racial segregation (Andrews 2007; Shapiro 2011; Stanley 1998).

For example, an editorial in the *Dallas Morning News* (Robberson 2012) noted the irregular shape of an attendance zone served by "Mata School" (which serves children in Grades 4 and 5). The editorialist argues that Mata's zone is racially and economically "gerrymandered":

> Strange thing, public school boundaries. They seem so simple. They're anything but that, once you get up close and personal with them.
>
> If you look at the attendance boundary map for Mata . . . almost all the single family houses northeast of Grand [Avenue] are occupied by middle-class whites, until you get down to the dividing line of Cameron Avenue and Grand. At that point, the housing turns heavily Hispanic. Don't ask me why. It just does.

In addition to his perception that Mata "zones out" white children northeast of Grand Avenue while "zoning in" children of color who live on the other side of the street, the editorial also suggests that Mata attendance zone is drawn to separate lower and higher income children:

> Strangely, the school boundary for Mata excludes all those white families northeast of Grand until you get exactly to Cameron Avenue, at which point the Mata boundary takes a sharp turn. The white families send their kids to Lakewood [School]. The Hispanics and blacks . . . send their kids to Mata. If you compare real estate values on either side of this dividing line, you'll notice a stark difference as well. (Robberson 2012, front page)

Given the irregular appearance of the attendance zone served by Mata School—and the zone's (and school's) close proximity to wealthier white children—it is reasonable to speculate that the district intended to isolate wealthier white fourth and fifth graders from their lower income, Hispanic peers. Indeed, 88 percent of the children in Mata receive a subsidized meal, and 93 percent of its students are Hispanic. By contrast, well over 80 percent of the children in the school closest to Mata are white. Yet Mata is one zone among many thousands—and this raises the question of how typical or unusual it is.

Table 1. Correlations among Measures of Attendance Zone Shape (*N* = 13,169.).

	PP	CV	CH	IR
PP	1.00			
CV	0.63	1.00		
CH	0.63	0.61	1.00	
Principal component (IR)	0.87	0.87	0.86	1.00

Note. All associations are statistically significant at .01. PP = Polsby-Popper; CV = convexity; CH = convex hull; IR = irregularity.

Despite the need for systematic studies that examine a large sample of attendance zones, most existing studies draw conclusions based on inspection of a few zones (e.g., Holme and Finnigan 2013). One such study depicts two multipart attendance zones (i.e., a single zone consisting of multiple, noncontiguous polygons) in a single school district. Most of the children inside of these zones are white. Yet these zones appear to by-pass areas containing children of color (Orfield and Luce 2009:134). Such instances of multipart zones were aptly described as "skipping about as capriciously as a young child at play" (*Penick v. Columbus Board of Education* 1977:236).

While compelling, these studies are based on the observation of a few zones. What is needed is research examining a large sample of attendance zones embedded in a large number of urban school districts. A recent publication by Richards (2014) takes preliminary steps in that direction. Richards compares the racial diversity in actual attendance zones with racial diversity across hypothetical attendance zones—called Voronoi polygons—surrounding each school location. Voronoi zones are often (but not always) more compact than actual attendance zones. Once Richards creates hypothetical attendance zones, she subtracts the racial diversity in actual zones from racial diversity in the corresponding, hypothetical zones.

She finds that, on average, racial diversity in hypothetical attendance zones is slightly greater than racial diversity in actual attendance zones (Richards 2014:1126, Table 1). Specifically, she states that diversity among multiple racial groups is .003 percentage points lower in actual attendance zones than hypothetical zones. Based on this difference, Richards (2014) concludes, "By comparing the characteristics of current attendance zones to the attendance zones that would be expected in the absence of gerrymandering, I find that first grade attendance zone boundaries generally serve to segregate students by race and ethnicity" (p. 1148).

Richards's conclusions strike us as problematic given that she never directly measures the shape of actual attendance zones. As result of this omission, she does not determine the correlation between attendance zone shape and attendance zone racial diversity—a necessary step in arguing that zone irregularity is correlated with zone racial diversity. One of the contributions of the present article is to examine the correlation between attendance zone shape and attendance zone racial diversity directly; the results of our analyses lead us to different conclusions than those reached by Richards.

In contrast to scholars who argue that irregular attendance zones lead to increased segregation, others suggest that school districts often draw zones in an effort to *integrate* students (Diem 2012). The corollary is that compact attendance zones segregate students by replicating existing residential patterns (Goldring et al. 2006; Gordon 1994; Mitchell, Batie, and Mitchell 2010; Tannenbaum 2013). As in the case of arguments that districts delineate irregular attendance zones to segregate children, little scholarly literature supports the contention that many districts draw irregular zones to integrate them. Most evidence is anecdotal and derived from local newspapers (Cohee 2002; Mehta 2005; Murden 2013; Smith 2009; Solomon 2003).

How Neighborhood Segregation Structures Attendance Zone Racial Composition

Although no extant research has demonstrated that compact attendance zones lead to racially homogeneous schools, this assertion rests on convincing theoretical grounds. Seminal studies have shown that cities are racially segregated since their neighborhoods are more racially homogeneous than the cities in which they are embedded (Iceland 2009; Massey and Denton 1998).

A recent series of studies do more than show that neighborhoods (e.g., census tracts) are racially segregated. These studies show that many metropolitan areas comprise expansive areas that are typically less racially diverse than the metropolitan areas in which they are embedded (Lee et al. 2008; Reardon et al. 2008; Reardon and O'Sullivan 2004). In these studies, the concept of a "local environment" is developed and measured. Local environments are created by drawing a circle around the approximate residential location of each person in a metropolitan area. Once such circles are drawn, the researchers determine how much the racial diversity within each of these circles deviates from the racial diversity across the entire metropolitan area. Findings show that, in most metropolitan areas, a typical person's local environment is much less racially diverse than his or her metropolitan area, particularly when local environment are about the size of the typical elementary school attendance zone. In other words, the *scale* of racial segregation in most cities is at least as large as the area of the typical first-grade attendance zone.

In many cities, the scale of segregation is much larger than a typical elementary school. For example, roughly half of Atlanta School District has a high concentration of white people while the other half has a high concentration of black people. Concentrations of other racial groups in Atlanta also tend to be at least as large as typical elementary school attendance zones. In districts such as Atlanta, if a school district draws compact, square-like attendance zones, this practice will largely replicate the racial homogeneity that exists in smaller residential areas. One of our central theses is that compact attendance zones that resemble circles, squares, and other similar polygons replicate the racial homogeneity that exists in local environments.

To visualize this phenomenon, Figure 1 depicts the distribution of white, black, and other racial groups across the Atlanta, Chicago, Philadelphia, and Pittsburg School Districts. Compared with many school districts, Pittsburg has relatively small-scale racial clusters. Still, the size of these clusters is larger than the typical elementary school attendance zone (Reardon et al. 2008). By contrast, Atlanta, Chicago, and Philadelphia contain large regions that are almost completely occupied by a single racial group. In these three districts, it is difficult to draw a compact shape the size of a typical elementary school attendance zone and achieve racial diversity within it.

Given the relatively large scale of racial segregation in many large school districts— and the geographic features (e.g., lakes, rivers, multilane highways, mountains) that often present physical barriers between racial clusters—we suspect that it is usually necessary for school districts to draw irregularly shaped attendance zones to achieve racial integration. For this reason, we suspect that more compact attendance zones will be more racially homogeneous than irregularly shaped zones. To be sure, it is difficult to prove that school districts create compact zones with the intention of maintaining racial segregation. Although it is not possible to prove whether school districts draw irregular zones to integrate students, a positive correlation between attendance zone shape and attendance zone racial diversity is consistent with theoretical arguments that irregularly shaped attendance zones are drawn to integrate children.

Data and Measures

We investigate the link between attendance zone shape and attendance zone racial diversity by analyzing the School Attendance Boundary Information System (SABINS). SABINS consists of Geographic Information System (GIS) files containing many thousands
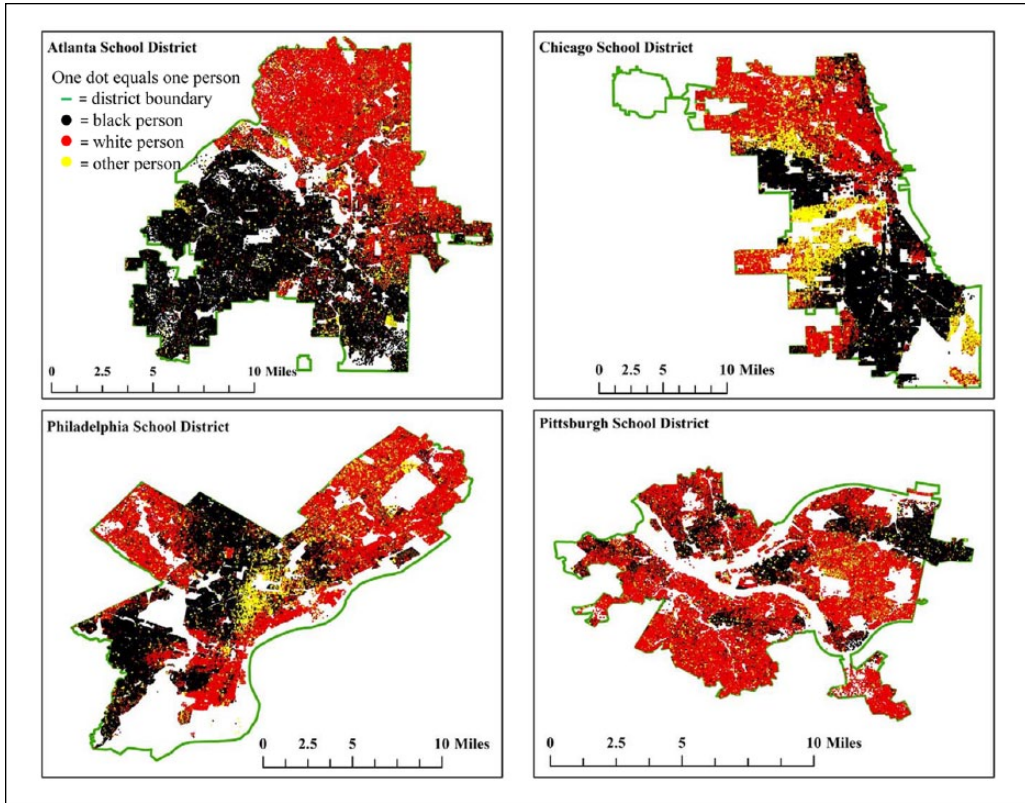
Figure 1. Distribution of racial groups within four large school districts.

of school attendance zones (Saporito, Van Riper, and Wakchaure 2013). Attendance zones in the 2009–2010 school-year SABINS database are available for over 90 percent of the largest 350 school districts in the United States. In addition to GIS files of attendance zones, SABINS data contain counts of children under 18 (by race) inside each zone. Attendance zones in SABINS are available for individual grades, from kindergarten through 12. In this article, we analyze first-grade attendance zones as they closely approximate what most people think of as an elementary zone. It is also reasonable to use a lower grade given the much larger scale of attendance zones at the higher grades. In many school districts, attendance zones for Grades 7 and higher are so large that they are coincident with the school district in which they are located.

The first phase of the SABINS project requested attendance zone maps from all the 350 largest school districts in the United States.

Of these 350 districts, 324 responded by providing data to SABINS staff—resulting in a response rate of 92.5 percent.[2] We cannot know if the zoning practices of the 7.5 percent of noncomplying districts are different from the 92.5 percent of complying districts. But, given the high response rate, we feel comfortable that SABINS data are not compromised by nonresponse bias.

Of the 324 districts that responded to a request for data, 8 did not use attendance zones as the primary mechanism for assigning students to schools.[3] Another 9 of the responding districts did not serve first graders; these were secondary school districts that typically serve students in Grade 6 or higher. The final sample consists of 307 school districts that have first-grade attendance zones. These 307 districts contain roughly a third of six-year-olds in the United States. More importantly, the geographic size and racial diversity of larger school districts make them appropriate for investigating the

relationship between attendance zone shape and racial diversity. Smaller districts are typically less racially diverse than larger districts (Bischoff 2008). There are 13,169 unique attendance zones analyzed in this study. If a school district contains first-grade attendance zones, the SABINS database includes every single zone the district delineated.

We integrate school attendances zones with 2010 block-level SF1 census data, allowing us to determine the number of children by race within in each attendance zone. As integrating 2010 census data with attendance zones entails using 2010 census block geography, we know how racial groups are distributed *within* attendance zones—a characteristic that is important to our research. As the number of blocks in most zones is reasonably high, this allows us to determine the distribution of racial groups within attendance zones.

Measures

Racial diversity within attendance zones. We conceptualize racial diversity two ways. The first is to assume that a racially balanced attendance zone has equal shares of each racial group under observation. For example, if one is observing three racial categories, a balanced attendance zone would contain a third of each group. This conceptualization of racial diversity is measured by Simpson's *absolute diversity* (AD):

$$AD = 1 - \sum_{r=1}^{K} p_r^2,$$

where p_r is the proportion of children in racial group r and K is the number of racial groups included in the index. Absolute diversity approaches one when the share of each racial group included in the index is the same; it equals zero when all children are members of the same racial group. The chief limitation of AD is that it does not compare the racial composition of an attendance zone with the school district in which it is located (see the online methodological appendix for details).

To address this limitation—and to ensure our results are robust across alternative measures—we also calculate *relative diversity*. We do this by comparing the racial diversity within an attendance zone with the racial diversity of the school district in which it is embedded. A relatively diverse attendance zone is one that has the same racial composition as its encompassing school district. It is calculated as follows:

$$RD = 1 - \left(.5 \sum_{r=1}^{K} |P_r - p_r| \right),$$

where P is the proportion of children in a school district who are in racial group r and p is the proportion of children in an attendance zone who belong to racial group r. The absolute difference between the district and attendance zone proportions is summed for each racial group, where K is the number of racial categories. Values of RD will be one when the racial composition of an attendance zone is the same as the school district in which it is located and approach zero when a zone contains only one racial group. We calculate AD and RD for three racial categories: non-Hispanic white children, non-Hispanic black children, and children from all other racial groups.[4]

Attendance zone shape. To determine the correlation between zone racial diversity and irregularity, we measure their shapes. There are dozens of ways to measure shape—most of them developed by political scientists who study U.S. Congressional Districts (Niemi et al. 1990). No one measure of shape perfectly represents irregularity as each captures one dimension while discounting others. Given this, we measure three dimensions of shape and use principal component analysis to combine them into a single measure.

The first measure of attendance zone shape is concavity (CV)—a relatively recent innovation by Chambers and Miller (2010). To describe concavity, it is helpful to first describe convexity. Perfectly convex shapes (e.g., circles, triangles, and rectangles) are those in which the residential locations of every unique pair of children within an attendance zone can be connected by a straight line that *does not* pass through the zone's boundary. In such

cases, concavity equals zero and the shape is completely compact. In contrast to convex shapes, concave shapes have at least one straight line (connecting every unique pair of children within it) passing through the boundary of an attendance zone. The higher the fraction of lines that pass through the boundary of a zone, the more concave it is. Crescents and sea stars are examples of shapes that may be highly concave (assuming the children within them are not highly concentrated in the center of such zones). See the online methodological appendix for further details.

The second measure of irregularity accounts for the children surrounding attendance zones by creating convex hulls encompassing them. A convex hull is the smallest convex shape that completely contains another polygon. To visualize a convex hull, imagine a rubber-band stretched around a crescent, sea star, or other concave shape. Once convex hulls are created for each attendance zone, we count the number of school-aged children inside the convex hull (but not inside the attendance zone). We divide that count by the number of school-aged children inside the entire convex hull. We call this measure the convex hull (CH; Hofeller and Grofman 1990). Convex attendance zones such as rectangles are coincident with their convex hulls and, in these cases, values of CH equal zero. When values of CH approach one, a zone is highly irregular. We modify Hofeller and Grofman's (1990) measure by excluding any area of a convex hull that extends beyond the school district to which an attendance zone belongs.

The last measure we use is Polsby-Popper (PP):

$$PP = 1 - \left(\frac{4\pi A}{P^2} \right),$$

where A is the area of a zone and P is its perimeter (Polsby and Popper 1991). Maximally compact zones (i.e., circles) equal zero and the most irregular zones approach values of one. An advantage of PP is that it classifies elongated shapes as irregular. For example, PP is equal to .69 for an elongated rectangle that is a half mile wide by four miles long. Elongation is an important dimension of irregularity that is not captured by CV or CH.

As there is no perfect measure of zone irregularity—and to simplify our analyses—we use principal components analysis to create a single measure of irregularity. Table 1 is a correlation matrix of the three measures. As the table shows, all correlation coefficients are at least .60. The correlations between each measure of irregularity and the principal component are above .85. We call this component "irregularity" (or IR).

Racial clustering within attendance zones. If an irregularly shaped attendance zone contains spatially distinct racial clusters within it, one can reasonably argue that the school district drew the attendance zone to create a racially diverse school. To measure clustering, we calculate *spatial segregation* among racial groups *within* each attendance zone. This allows us to determine whether racial groups are clustered together or dispersed evenly within attendance zones. Spatial indices of racial segregation determine whether members of different racial groups are interspersed with one another (as in a checkerboard pattern) or live in large, geographically distant, unique clusters (Wong 2005).

To measure spatial clustering within attendance zones, we approximate the residential locations of children. We do this by assuming that a child of a particular race lives in the center of his or her census block. On average, there are 87 blocks (populated by at least one child) per first-grade school attendance zone. After approximating the residential locations of children, we calculate multigroup spatial proximity (SP; Grannis 2002) to capture the intragroup proximities among black, white, and all others racial groups using the following formula:

$$SP = \frac{\sum_r \left(\frac{1}{X_r} \right) \left(\sum_i \sum_j x_{ir} x_{jr} c_{ij} \right)}{\sum \sum t_i t_j c_{ij} / T}.$$

SP measures the mean proximities of school-aged children of the same racial group, r, where $x_{ir} x_{jr} c_{ij}$ is the inverse distance (c) between unique pairs of children x_i and x_j who are members of the same racial group r.

Table 2. Means (and Standard Deviations) of Attendance Zone Characteristics by School District Racial Diversity and School District Desegregation Status.

Variables	All	Diverse	Homogeneous	Desegregation policy	No desegregation policy
No. of zones (and districts)	13,169 (307)	4,591 (84)	8,578 (223)	3,662 (60)	9,507 (247)
RD	0.80 (0.16)	0.74 (0.16)	0.83 (0.13)	0.77 (0.17)	0.81 (0.14)
AD	0.41 (0.17)	0.46 (0.17)	0.38 (0.16)	0.39 (0.17)	0.42 (0.17)
CV	0.15 (0.17)	0.16 (0.18)	0.14 (0.16)	0.13 (0.16)	0.16 (0.17)
CH	0.23 (0.18)	0.23 (0.18)	0.22 (0.18)	0.21 (0.18)	0.23 (0.18)
PP	0.62 (0.17)	0.63 (0.17)	0.61 (0.17)	0.59 (0.18)	0.63 (0.17)
Principal component of CV, CH, PP	0.00 (0.89)	0.06 (0.90)	−0.03 (0.86)	−0.12 (0.89)	0.05 (0.87)
(SP)	1.1 (0.10)	1.1 (0.11)	1.08 (0.08)	1.09 (0.10)	1.09 (0.09)

Note. The heading "all" refers to all school districts included in this study while "diverse" refers to those districts in which the share of each racial category is above 15 percent. The heading "desegregation order" refers to those districts that are under a court-mandated or voluntary desegregation policy. RD = relative diversity; AD = absolute diversity; CV = concavity; CH = convex hull; PP = Polsby-Popper; SP = spatial proximity.

Following White (1983), we assume that children who live in the same census block have a mean distance from each other that is a function of the block's area (A) equal to $.6*\sqrt{A}$. The sum of the intragroup distance is weighted by each racial group's fraction of the population (i.e., $1/X_r$). The denominator is the sum of the distance c_{ij} between all unique pairs of children (t_i and t_j) divided by the total number of children T.

The index measures how much children from the same racial group are closer to one another than all children are to one another generally. Values of 1 indicate that members of each racial group are, on average, no closer to each other than all children. Values higher than 1 suggest that members of each racial group are closer to same-race members than children are to each other. Racial clustering is driven by two factors. The first is the intensity of clustering. If children in each racial classification live in distinct areas (e.g., each census block consists of members of a single racial group and those mono-racial blocks are close together in space), then clustering will be greater. Similarly, the greater the distance between children of different racial groups, the greater clustering will be.

School district desegregation status. During the mid-1970s through the mid-1990s, many school districts throughout the United States were placed under a desegregation order. Many districts remain under court order. Data describing whether a school district was under a court desegregation order were collected by Logan and Oakley (2004) and augmented by Reardon et al. (2012) in August 2010, making them applicable to the 2009–2010 school year SABINS data. We further augmented these data by determining districts that reached an agreement with the U.S. Department of Education to voluntarily desegregate their schools (Qui and Hannah-Jones 2014). These data do not indicate what type of desegregation policy is used or the grades that are targeted. We use this information as school districts compelled to desegregate their schools (or do so voluntarily) may delineate irregular attendance zones to create racial diversity in their schools.

Analyses

To determine how frequently attendance zones are shaped irregularly, Table 2 presents descriptive statistics summarizing the shape, racial diversity, and internal racial clustering of attendance zones. Table 2 also summarizes this information by the racial diversity of school districts and for school districts under a court desegregation order. Our decision to focus on

racially diverse districts is straightforward: It is moot to analyze racial diversity of attendance zones that are inside school districts in which almost all of the children belong to a single racial group. If 85 percent or more of the children in a district are white, almost all of the district's attendance zones will be comprised of white children—regardless of how these zones are delineated.

To identify racially diverse school districts, we determine the share of each racial group in the district. School districts in which at least 15 percent of the children are black, 15 percent are white, and 15 percent are from other racial groups are classified as diverse. Although the cut-off point of 15 percent is arbitrary, we found that slightly lower values (of 10 and 12.5 percent) and higher values (of 17.5 and 20 percent) produced results similar to those shown throughout this article.

Values of absolute racial diversity are telling. The mean value of absolute racial diversity is fairly low across all districts (AD is .41). To put this value in context, about 75 percent of children in a zone would have to belong to one racial group to achieve an AD score of .41. Mean AD scores are fairly low even in racially diverse districts (mean AD is .46; about 70 percent of the children in a zone with an AD value of .46 would have to be members of a single racial group to achieve this value). These relatively low racial diversity values are consistent with the sociological literature that finds high levels or racial segregation across attendance zones (Saporito and Sohoni 2006).

Table 2 also shows average values of attendance zone shape. The mean value for CV is .15. This shows that, in a typical attendance zone, 85 percent of the school-aged children "can see each other" without their lines-of-sight passing through the zone's boundary (see the online methodological appendix for details). Similarly, the mean value of CH indicates that, on average, 22 percent of school-aged children reside outside the attendance zone (but inside the convex hull). In other words, only 22 percent of children are "bypassed" by the actual zone. Finally, the mean value of PP is .62, which indicates that most attendance zones do not resemble a circle,

neither are most of them highly irregular. Table 2 shows that there are small differences in the mean shape of attendance zones located in racially diverse and racially homogeneous school districts.

To obtain an overall sense of whether attendance zones are compact or shaped irregularly, we compare them with the shapes of 2010 U.S. Congressional Districts. The U.S. Supreme Court generally provides states with the power to determine how Congressional Districts are drawn and recognizes that some states will use this power to delineate districts that lead to a partisan advantage (*Vieth v. Jubelirer* 2004). Although the power to delineate Congressional Districts is not unlimited, states have considerable leeway to delineate irregularly shaped districts, and many partisan-leaning state legislatures take advantage of their power to create irregularly shaped Congressional Districts. Thus, one way to determine the extent to which attendance zones are drawn irregularly is to compare them with legislative districts (in states that have more than one seat in Congress).

We find that the average PP for U.S. Congressional Districts is .78 while it is .62 for attendance zones. The average CV and CH values for U.S. Congressional Districts are .31 and .37, respectively.[5] Values of CV and CH are .15 and .22 for attendance zones. Across all three measures, irregularity in attendance zones is about almost standard deviations lower than U.S. Congressional Districts (see Table 2). This is an indication that attendance zones are, *on average*, not highly irregular in shape. Still, some attendance zones are wildly irregular in shape, allowing us to explore the correlation between attendance zone shape and racial diversity.

Correlations among Attendance Zone Characteristics

While it appears that the average attendance zone is relatively compact and racially homogeneous, a key question is whether higher values of attendance zone irregularity are correlated with higher or lower values of attendance zone racial diversity. Table 3 shows three correlation matrices. The top matrix

Table 3. Correlation Coefficients among Attendance Zone Irregularity, Racial Diversity, and Clustering.

Variables	Zone irregularity	Relative diversity	Absolute diversity	Racial clustering
All school districts				
N zones = 13,169 and N districts = 307				
Zone irregularity	1.000			
Relative diversity	.111*	1.000		
Absolute diversity	.112*	.198*	1.000	
Racial clustering	.274*	.022	.349*	1.000
Racially diverse districts				
(N zones = 4,591 and N districts = 84)				
Zone irregularity	1.000			
Relative diversity	.265*	1.000		
Absolute diversity	.268*	.689*	1.000	
Racial clustering	.353*	.316*	.331*	1.000
Districts with a desegregation plan (N zones = 3,662, and N districts = 60)				
Zone irregularity	1.000			
Relative diversity	.188*	1.000		
Absolute diversity	.192*	.306*	1.000	
Racial clustering	.130*	.374*	.410*	1.000

*Significant at .01.

consists of all 13,169 attendance zones. The middle examines attendance zones within racially diverse school districts and the bottom panel shows correlations among attendance characteristics in districts with a racial desegregation plan.

The top matrix shows a very weak, positive correlation between attendance zone irregularity and absolute racial diversity ($r = .11$). The correlation coefficient between irregularity and relative diversity is also .11. These weak correlations are expected: It is difficult to achieve racial diversity in attendance zones when they are located in racially homogeneous school districts—no matter how irregular or compact an attendance zone is drawn. Still, the correlation is positive and contradicts prior arguments that attendance zones generally serve to segregate children (Richards 2014).

The second correlation matrix, which analyzes only those attendance zones in racially heterogeneous school districts, shows that there are modest, positive correlations between attendance zone irregularity and absolute racial diversity ($r = .27$) and between irregularity and absolute diversity ($r = .27$). On average, irregularly shaped attendance zones contain students

from racially diverse residential areas—while more compact zones are typically less racially diverse than the school districts in which they are embedded. The bottom panel in Table 3 (which examines school districts currently operating under a desegregation order) also shows a positive correlation between irregularity and relative/absolute diversity. Both values of r equal .19.

These results are consistent with the argument that irregular attendance zones are more racially diverse than compact zones. We reasoned that the law prohibits districts from delineating irregular attendance zones that lead to racial segregation. We also argued that racial integration policies such as the "Finger Plan" were encouraged by the U.S. Supreme Court during the 1970s and may persist among some school districts that remain under a court desegregation order. Finally, as the scale of segregation is larger than the area of a typical, compact first-grade attendance zone (Lee et al. 2008; Reardon et al. 2008), school districts attempting to integrate students through zoning practices would have to create some highly irregular shapes to achieve this goal. The results are consistent with this reasoning.
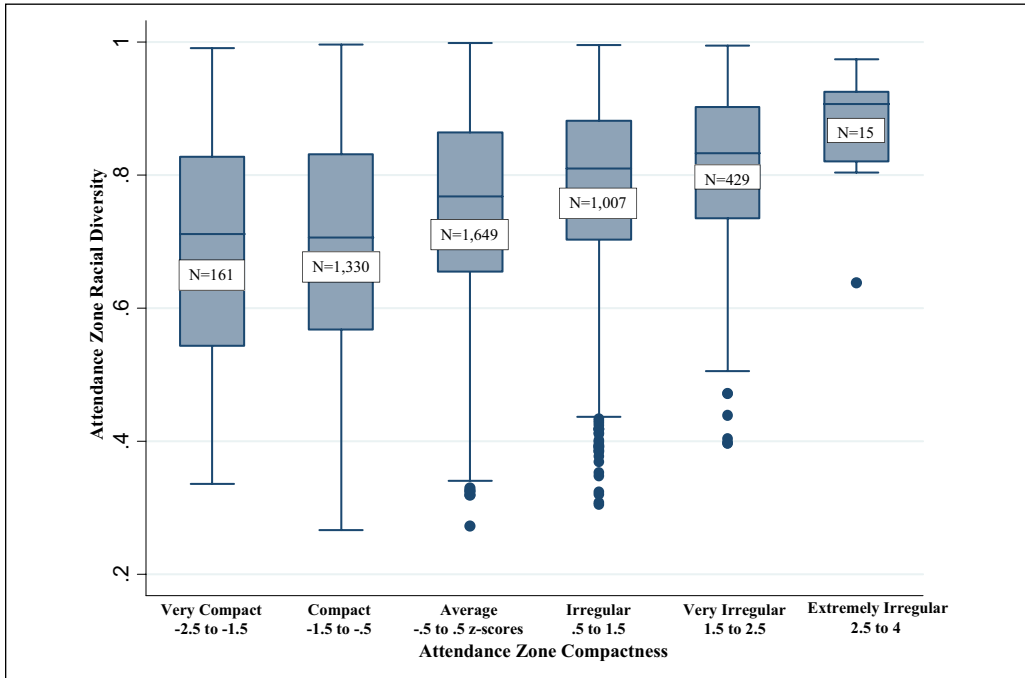
Figure 2. Relationship between attendance zone racial composition and compactness within racially diverse school districts, 2009–2010 school year.

The evidence is also consistent with the theory that racial homogeneity within compact attendance zones is structured by the relatively large scale of racial segregation that exists in many school districts. Our findings show that first-grade attendance zones are a standard deviation more compact than the average U.S. Congressional. Zones also typically lack racial diversity. This evidence suggests that much racial segregation in public elementary schools is driven by residential segregation coupled with compact zoning practices. While the evidence does not show that school district personnel draw compact attendance zones to intentionally segregate students by race, compact zones often contribute to that result.

Are the Most Irregular Zones Always Racially Diverse?

Although the correlations shown in Table 3 are modest, they fail to show an important detail: It turns out that virtually all of the most bizarrely shaped attendance zones are racially

diverse. This is best illustrated by the box and whisker plot shown in Figure 2, which shows the *distribution* of racial diversity scores by categories of attendance zone irregularity. Here, scores for irregularity are classified into discrete groups by their *z* scores (and the analysis is restricted to school districts with racially diverse populations). The line in the middle of each box is the median. The top of the box is the 75th percentile while the bottom of the box is the 25th percentile. The top of the box to the top of the whisker (i.e., the horizontal line of the "T") is the upper 25 percent of cases excluding any outliers (marked with a circle).

The plot to the far right shows the distribution of relative racial diversity among extremely irregularly shaped attendance zones. Fully half of these zones have racial diversity scores above .90, and all but one zone has a racial diversity score above .80. These findings indicate that the most egregious cases of zone irregularity are racially heterogeneous.[6] To put the distribution of racial diversity scores in context, it is helpful to recall that the mean

relative racial diversity score in racially diverse school districts is .75 (and the standard deviation is 0.16). It is also useful to know that in a school district in which the share of each racial category is .33, the share of students in any one racial group would also be reasonably close to about a third for the zone to be racially diverse. If zoning practices were typically aimed at segregating students, we would expect the most highly irregular zones to be racially homogeneous. We find the opposite.

As the most irregular zones are 2.5 or more standard deviations above the mean, they represent a very small fraction of all cases. Still, even zones with z scores between 1.5 and 2.5 above the mean are apt to contain racially diverse populations. Well over half of all such zones have racial diversity scores above .80, and over 75 percent of them have diversity scores above about .75. The distribution of scores is somewhat greater for zones that are .50 to 1.5 z scores above the mean—but even in these somewhat irregular zones, over three quarters of the racial diversity scores are above .70. The three right-most box and whisker plots suggest that the distribution of racial diversity scores among the most irregularly shaped attendance zones is limited and typically contain racially diverse or somewhat racially diverse student populations.

To be sure, some highly irregular attendance zones are also racially homogeneous. These racially homogeneous zones are indicated by the "dots" shown at the bottom of the whiskers on the three right-most plots. These dots indicate that racially homogeneous zones are statistical outliers; although relatively rare, at least some irregularly shaped zones contribute to racial segregation. It is possible—perhaps likely—that a few school districts engage in racial segregation by delineating irregular attendance zones. Still, the evidence suggests that this practice is limited. If delineating bizarre zones was a widespread practice that school districts used to exacerbate existing residential segregation, one would expect highly irregular zones to typically contain racially homogeneous students. This is not the case.

In contrast to irregular zones, the most compact zones depicted in Figure 2 contain the full range of possible racial diversity scores and indicate that the distribution is normal. More than a quarter of "very compact" and "compact" zones are racially homogeneous as their racial diversity scores are below about .55, and half are below .70. To put this in context, in a school district in which the share of each racial category is about one third of the children, about 78 percent of the students would have to be members of a single racial group to achieve a relative racial diversity score below .55. About 64 percent of the children would have to be members of one group to achieve a diversity score below .70. So, about half of the most compact attendance zones lack racial diversity (even though they are located in racially diverse school districts). However, more than a quarter of compact zones have racial diversity scores above .80, indicating that such zones are racially diverse.

Overall, the box and whisker plots show that the relationship between attendance zone shape and racial diversity is heteroskedastic; that is, there is far less variation in racial diversity among highly irregular zones and the overwhelming majority of the most irregularly shaped zones are racially diverse. By contrast, compact zones are, on average, less racially diverse than irregular zones. But compact zones also contain the full range of diversity scores. This heteroskedasticity accounts for the low to modest correlations between zone shape and zone racial diversity shown in Table 3.

Irregularly Shaped Attendance Zones and Internal Racial Clustering

What other evidence might suggest that zone irregularity could be associated with racial diversity? We argue that if an irregularly shaped school attendance zone contains spatially distinct racial clusters within it, it may be that the school district drew the attendance zone to create racial diversity. This speculation is consistent with our overall arguments that racial segregation in most districts exists at a large scale and districts must enact a "Finger Plan" for an attendance zone to draw children from these distant and racially distinct clusters.

The positive correlations between zone irregularity and racial clustering—as shown in the Table 3—are consistent with this argument. If we examine all zones, the correlation between attendance zone irregularity and internal racial clustering is .27. This correlation is .35 in racially diverse districts and .13 in districts with an integration plan. As attendance zones become more irregular, it is more likely that children from different racial groups within them live in more spatially and racially distinct clumps. By contrast, compact zones are more likely to contain students of different racial groups who are interspersed in somewhat of a checkboard fashion.

Although these correlations are not powerful, they clearly run in the opposite direction of those who argue that irregularly shaped attendance zones contribute to racial segregation. Our evidence shows that the more irregular in shape a zone is, the more likely it is to contain a racially diverse population—and that irregular zones often achieve this segregation by drawing children from distinct racial enclaves. Moreover, the most egregious examples of zone irregularity contain racially diverse populations. These facts are important for two reasons: First, zones that have irregularity scores 1.5 standard deviations above the mean are so peculiar that they were almost certainly drawn that way intentionally. It is highly possible that someone drew them that way to integrate children by race (or perhaps by social class). Second, if someone had the intent to integrate children, it may have been necessary to create a highly irregular zone to obtain that result.

Limitations and Future Research

Our analyses show that irregularly shaped attendance zones are positively and modestly correlated with their racial diversity. They also show that most highly irregular zones are almost always racially diverse. This is new information that contradicts the hypothesis that school districts try to maximize racial isolation by "gerrymandering" attendance zones. Yet our correlational study has its limitations. It is not possible to determine the intent of local school

district administrators when they delineate their zones—*especially when those zones are compact*. Compact attendance zones may be drawn to minimize transportation costs, respect local topography, please local constituencies, or segregate students by socioeconomic status. Compact zones may also be drawn to replicate racial segregation across residential areas. All of these factors may influence the shape and racial composition of attendance zones. Our research (and previous literature) does not address these possibilities empirically.

Our study does not examine segregation across entire school districts. Our unit of analysis is a first-grade attendance zone.[7] A school district may contain one or two highly irregular attendance zones that are racially diverse but, overall, most of its zones could be compact and racially homogeneous. If a school district contains one or two zones that are irregular and are racially diverse, it does not mean the district is attempting wholesale racial integration. It may be that the large majority of the school district's zones are compact and racially homogeneous— thereby reproducing segregation. Future analyses can address this limitation.

Other issues arise when examining the contours of a single attendance zone. It may be that once a zone is established, it remains that way for many years, but children of one race or another move in or out. These demographic shifts would upset what was previously a racially balanced attendance zone. The lack of temporal data for school attendance zones limits the ability to make strong causal inferences.

Finally, an exclusive focus on attendance zone shape does not allow for a more nuanced understanding of why they are segregated. Determining how much attendance zone shape contributes to racial segregation is an immensely complicated analytical issue that has bedeviled statisticians, geographers, and political scientists for decades. It is not possible to truly determine whether a school district has "maximized" racial integration or segregation across attendance zones. It is not even possible to determine if, for example, racial segregation in actual zones is greater than one would expect by chance. This would require generating a large set of randomly drawn,
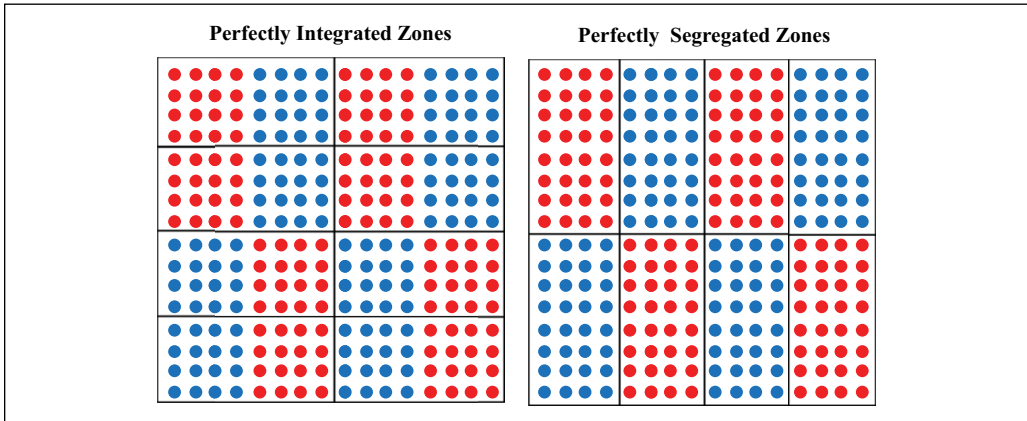
Figure 3. Two sets of stylized attendance zones.
Note. Zones to the left and right have the exact same shape and population. Yet, zones to the left minimize segregation and zones to the right maximize segregation.

equi-populous and compact zones for every school district.[8]

This challenge is illustrated by Figure 3, which is a stylized map in which children of two different racial groups are residentially clustered. The figure also shows two sets of attendance zones. The zones on the left achieve perfect integration as all of them have an equal proportion of children from each racial group. The zones on the right achieve perfect segregation. Yet both sets of zones are compact, have the same shape, and contain the same number of children. It is conceivable—perhaps even likely—that at least some school districts delineate compact zones with the goal of minimizing or maximizing racial segregation. Identifying such districts is challenging.

Conclusion

Since the mid-1990s, there has been a steady decrease in the number of school districts that remain under a court desegregation order (Reardon et al. 2012). Moreover, school districts can no longer assign students to schools based on their individual race. This new context limits the ability of school districts to minimize segregation. As a result, the thoughtful delineation of school attendance zones may be one of best remaining mechanisms to achieve *modest* racial integration within large, racially

diverse school districts. We use the word modest because the scale of racial segregation across residential areas in many of the largest U.S. school districts limits their ability to make small changes to their attendance zones and realize large gains in racial integration. Moreover, Table 2 of this article shows that many school districts are racially homogeneous and, other than consolidating with adjacent school districts, there is little they can do to create racial balance within their schools. Certainly one implication of our findings is that racially diverse school districts that want to delineate irregular zones to achieve racial integration must go to extraordinary lengths to achieve this end.

Our findings bear this out in several ways. First, the average shape of school attendance zones within the largest school districts is more compact than the average U.S. Congressional District. This would suggest that prevailing racial segregation within large school districts is not driven by a widespread practice of creating irregularly shaped attendance zones. Evidence shows that irregular, bizarre, or peculiar attendance zones consisting of sprawling, multipart polygons stretching hither, thither, and yon are almost always racially diverse. Our second finding is that the most highly irregular zones are almost always racially diverse; to be sure, some irregularly

shaped zones have low racial diversity but such cases are statistical outliers. Finally, we show that irregularly shaped zones are more likely than compact zones to contain racially distinct residential areas in which black, white, and all other children are likely to live in discrete neighborhoods. All of this evidence runs contrary to arguments that school districts engage in the widespread practice of drawing truly irregularly attendance zones as a way to exacerbate racial segregation. Indeed, most irregularly shaped zones contribute to racial integration.

Although many people would find good news in these findings, they should not detract from the fact that schools *are* racially segregated. Our findings suggest that racial segregation is driven primarily by residential segregation. Compact attendance zones replicate the racial composition of local areas. As most local environmentsare racially homogeneous, so are school attendance zones. Indeed, our findings are consistent with the literature on Congressional District gerrymandering (Chen and Rodden 2013); this literature argues that some political-party imbalance emerges even when compact legislative districts are delineated. Similarly, our findings show that many compact attendance zones are racially homogeneous. This suggests that residential segregation limits racial integration in schools, particularly in school districts that prioritize compact zoning practices. Most racially diverse school districts would have to quite literally go to extraordinary lengths to minimize racial segregation—a proposition that is costly and politically unpopular.

This empirical reality is consistent with Justice Kennedy's argument—and our findings—that school boards pursuing the goal of racial integration must often draw irregular attendance zones that recognize the demographics of racially disparate and geographically distance neighborhoods. The challenge of drawing irregular attendance zones to reduce racial segregation is that many of them must be drawn so bizarrely that they will likely increase transportation costs, upset parents, be complicated to produce, and, perhaps, exacerbate white flight to private schools.

Authors' Note

We are responsible for all errors and omissions.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Notes

1. Throughout this article, the term *irregular* designates any attendance zone that deviates substantially from a circle or square (or in which students are scattered in far-flung residential areas). Compact attendance zones resemble circles and squares and contain students that live in close proximity to one another. See the online methodological appendix for a more complete description.
2. The School Attendance Boundary Information System database also includes a non-random sample of school districts that were smaller than the largest 350. We did not include these smaller districts as they were not sampled randomly. Nevertheless, we conducted analyses

that include attendance zones in both larger and smaller school districts. Results are strikingly similar to those shown throughout the remainder of this article and are available on request.

3. The districts that do not have attendance zones are Boston, Buffalo, Hartford, Providence, San Francisco, Springfield, St. Lucie, and Yonkers.

4. We also calculated and analyzed diversity indices between white and non-white children. Results for two-group diversity are shown in the online methodological appendix.

5. Estimates for Congressional zone concavity are based on tables from Hodge, Marshall, and Patterson (2010).

6. Figures A1, A3, and A4 in the methodical appendix show highly irregularly shaped attendance zones.

7. It is conceivable that our results apply only to attendance zones serving the lower grades. On average, zones for the lower grades are geographically smaller than those for the higher grades. In the context of segregated residential areas, this suggests that it is easier to create integrated zones for students in higher than the lower grades. A smaller, compact polygon randomly overlain on a segregated school district is more likely to be racially homogeneous than a larger, equally compact polygon overlain in the same school district. This suggests that efforts to create diverse elementary schools might require irregularly shaped attendance zones—while the opposite might be true for middle and high schools. With the larger attendance areas associated with middle/high schools, irregularly shaped zones might be more likely to reflect efforts to create or maintain segregated schools as a random (or indifferent) zoning strategy has a greater chance of creating diversity in the higher than the lower grades.

8. To our knowledge, it is not possible to know if the distribution of segregation scores in a large set of randomly generated zones within a school district represents the distribution of racial segregation across all possible zones within a school district. Hence, it is not possible to determine if segregation in an actual set of zones is "greater than one would expect by chance." Still, work by Chen and Rodden (2013) has made considerable progress in this direction.

Supplemental Material

The online appendix is available at http://scu.sagepub.com/supplemental.

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