SpAM

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A Method for Defining Downtown Business District Boundaries in Pre-Automobile Towns and Cities

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Abstract

This short article presents a method for illustrating the spatial delineation of downtown business districts in non-metropolitan counties. Although smaller than their urban counterparts, rural and exurban municipalities established before World War II typically contain a central business district, which is the dense colocation of commercial and civic activity comprising buildings and streetscapes that were developed before the automobile era and are thus oriented toward pedestrian traffic. The paper describes the method for distinguishing downtown business districts from postwar, automobile-oriented malls and retail development. A variety of use cases are discussed, highlighting the potential importance of this data for researchers and practitioners of economic development and planning.

Introduction

In the fallout of World War II and the emergence of the family automobile, America's central business districts—*downtowns*—gradually ceased to serve as the epicenters of civic and commercial activity throughout the country (Cohen, 1996). In the latter half of the 20th century, policymakers and researchers began paying more attention to the vitality of central business districts, guided by the idea that a regional economy is more competitive when the central city is vibrant and healthy (Hill, Wolman, and Ford, 1995; Porter, 1995). As a result, downtown redevelopment and revitalization projects have become popular approaches for policymakers seeking to inject vibrancy and economic stability into central business districts.

In such contexts, researchers and practitioners benefit from the availability of accurate spatial data. Effective administration of place-based policies and programs requires the concrete delineation of the area targeted by the policy. In many large cities, district or neighborhood boundaries, including downtown, are clearly defined by the city and are made publicly available for use in tourism, marketing, and economic development.[1] This demarcation may not be the case for smaller communities. Without dedicated GIS (geographic information systems) data, analysts, and modern online file-hosting capabilities, the task of identifying downtown district boundaries in smaller communities is neither straightforward nor practical.

This paper presents a spatial method—which the author calls "downtown district delineation" (D3)—to spatially delineate downtown business districts in smaller communities.[2] As its primary output, D3 generates a GIS data file, which represents the approximate boundaries of a community's downtown district(s). The paper also includes a detailed description of the method and a discussion of how the generated data may be appropriately used in research or practice.

Procedure

The D3 procedure involves three general steps. First, business establishments are plotted onto a map of a given municipality, and the relative density of establishments is calculated for the entire area of the jurisdiction. Second, locales with adjacent, high-density cells are identified and aggregated. Finally, a single grouping of establishments is selected—according to density, size, and centrality—and a polygon is generated. The polygon may then be saved as a new layer and used to identify the spatial boundary of the given municipality's downtown district.

[1] For example, the City of Atlanta and the City of Des Moines both provide PDF maps of city districts and neighborhoods that clearly communicate where the downtown district begins and ends (available here and here, respectively). The City of Austin, Texas, has a specific downtown webmap with GIS overlays of the planning districts within its central business district (available here). Most central cities in large metros have one of the two options available online.

[2] Although this paper's method was designed to delineate pre-automobile downtowns in rural and micropolitan areas—such as the town used as an example throughout the paper (Bradford, Pennsylvania)—the method can be used in a metropolitan context. Despite slower computer processing times because of large amounts of data, the D3 method performed well in metropolitan cities, identifying downtown districts such as that of Altoona, Pennsylvania, (the central city of a smaller metro area) and Greensburg, Pennsylvania (an outlying city in the Pittsburgh metro area). The context in which the D3 method is unlikely to work accurately—aside from automobile-era suburbs—is in central cities of large metropolitan areas (e.g., Pittsburgh) because downtown's former dominance in many larger American metros has been "eroded by the growth of suburban employment centers" (Bogart and Ferry, 1999), and the density gradient of large urban downtowns may be interrupted by the prevalence of off-street surface parking (Manville and Shoup, 2005).

Setup

Because the central business district typically coincides with historic buildings and development, attempts to identify "downtown" in a newly developed suburban area would likely yield incorrect results. As used in previous studies (Van Leuven, 2021, Forthcoming), the following heuristic is recommended for identifying municipalities that are likely to possess a pre-automobile downtown district:

- A municipality that had a 1920, 1930, or 1940 population of at least 1,000. This guideline identifies municipalities that were "largely built up before 1945" (Cervero and Gorham, 1995), before the automobile era.

- A municipality that has a present-day (or nearest decennial census year) population that exceeds 1,000 residents. This threshold is practical; it is set to avoid the analysis of "boom towns" whose populations have declined dramatically from their early-20th-century peak.

Once applicable communities are identified,[3] the analyst must collect the requisite data to be used as input for the D3 method. At a minimum, this method requires at least 1 year of business establishment data, in which every establishment is present and is paired with an industry sector code and geographic coordinates (i.e., latitude and longitude). Using additional years of data will reduce statistical noise because of the larger sample size, resulting in more robust delineations of the downtown district.

Although the following method will be described *conceptually*—in widely understood statistical terms and GIS operations—the underlying code for this method will be available in the online appendix.[4]

Step 1: Creating the Density Map

Creating the density map requires three tasks. First, municipal boundaries must be available and plotted to delineate the coverage area.[5] Second, the business establishment locations must be plotted using the latitude and longitude coordinates.[6] Third, the entire municipality must be divided into cells, sized appropriately for the area being analyzed (exhibit 1 presents two types of grid options applied to the shape of Bradford, Pennsylvania). The author recommends the hexagonal grid rather than the square grid, especially for municipalities with street networks that

[3] This heuristic is not guaranteed to identify *all* municipalities with a pre-automobile downtown business district. For example, the Town of Fremont, Indiana, has a traditional downtown but misses the threshold for consideration because of its historical population. Although its 2010 population (2,138) exceeds 750, its prewar decennial census population never rose above 1,000. An analyst specifically focusing on Fremont or Northeast Indiana would likely relax the guidelines to include Fremont; however, when focusing on the entire state, adhering to a clear set of guidelines may be more practical.

[4] Many statistical and GIS software packages are capable of implementing this method. The author used the "R" program, specifically the SpatialKDE R package (Caha, 2020) in the "RStudio" environment.

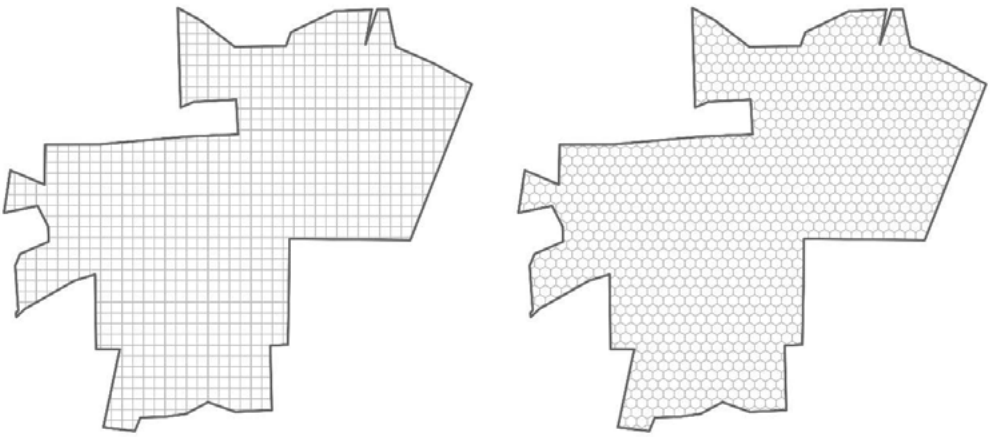
[5] A useful source of municipality boundary geospatial data files is the U.S. Census Bureau's TIGER/Line® file repository, found here.

[6] The example maps in this paper use business establishment data from the "Infogroup U.S. Historical Business Data" (Infogroup, 2020).

follow irregular features, such as rivers or railroads.[7] These three characteristics should be plotted together in a GIS for the analysis.

Exhibit 1

Comparison of Square and Hexagonal Cell Grid Tessellation of Bradford, Pennsylvania



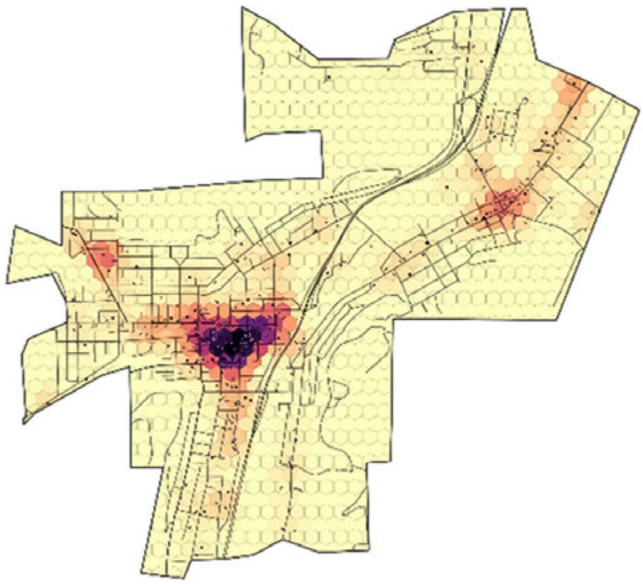
Source: U.S. Census TIGER/Line® file

Exhibit 2 displays Bradford, Pennsylvania, which is the municipality used to demonstrate applying the D3 method. A hexagonal grid is overlaid on the map, with each cell representing an area measuring 100 meters across (approximately 1/16 mile, or one-half the length of an average city block). This map is then used to calculate the business establishment density of each hexagon. Because cell placement is arbitrary—in that the hexagonal grid does not correspond to any real-world positioning and delineation of space—kernel density estimation (KDE) is used to allow each hexagon's density calculation to account for the business establishments in the *surrounding* cells. Doing so captures the spatial relationship of the businesses in the surrounding areas to show the magnitude of business density in a hexagon.

[7] The hexagonal grid, or "honeycomb," is the most efficient way to divide a surface into regions of equal area with the least total perimeter (Hales, 2001). Hexagons also combine more easily to form circles and spheres, which allow them to represent curves in the patterns of data more naturally than do square grids (Esri, 2021b). Although many downtowns are built within a rectangular gridded street pattern, such grids often do not align perfectly with a true north-south-east-west grid, instead following the shapes of rivers, railroads, and other features.

Exhibit 2

Step 1—Relative Density of Business Establishments Plotted



Source: Infogroup U.S. Historical Business Data, 2005

A defining feature of KDE is the ability to freely specify the bandwidth around cells. In other words, the user decides how large a "neighborhood" search area to use when calculating the density of nearby establishments (Esri, 2021a). For instance, a bandwidth of 150 meters (used throughout the demonstration in this article) means that a given hexagon's establishment density is calculated using establishments not only from the area represented by the cell but from an additional 150 meters outward in all directions. Neighboring establishments closer to the cell are weighted higher than those located farther away in the density calculation, resulting in a more precise density map.[8] As with many user-defined parameters of the D3 method, the user must be careful to either ensure that the chosen bandwidth reflects—or attempt to approximate—the extent to which the spatial dependence ceases between a location and its surrounding locations.

The end result of Step 1 is illustrated in exhibit 2, which shows the standardized density (z-scores) of business establishment density in Bradford, Pennsylvania. Local roads are included in the plot to demonstrate that higher density cells are mostly located along a small number of thoroughfares.

Step 2: Grouping Adjacent Cells

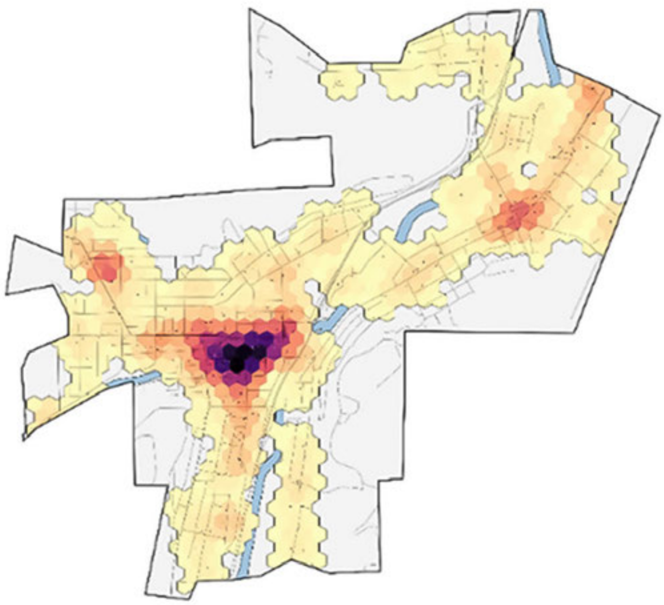
Exhibit 2 shows that a majority of cells have very low business establishment densities, so the next step of the D3 method involves eliminating non-dense cells so that the remaining cells adjacent to

[8] The demonstration in this article used a cell size of 100 meters, a bandwidth of 150 meters, and parabolic kernel function (Epanechnikov, 1969). An average city block is 100 meters long, and the bandwidth was selected to enable a "search" of 1½ blocks outward. All three parameters may easily be adjusted by the user to fit the context of the analysis. For more about kernel density estimation, refer to Silverman (2018).

each other are spatially combined. To do so, the user must first discard all hexagon polygons with a density of zero. This step dramatically lessens the right skew of the density distribution, leaving a map with only those cells that contain, or are near, business establishments (see exhibit 3).

Exhibit 3

Step 2a—Zero-Density Cells Removed



Source: Infogroup U.S. Historical Business Data, 2005

The analyst must then decide how to continue eliminating low-density cells until only the highest density cells remain. Too strict a selection criterion may result in an excessively small delineation of a downtown area that may account only for extremely dense hexagons in an otherwise moderately dense downtown district. Conversely, an overly relaxed selection may result in a downtown delineation large enough that it fails to distinguish between pre-automobile downtown development and its more sprawling automobile-era counterparts.[9] This part of the method is susceptible to the subjectivity and judgment of the user, who must keep in mind some best practices.

Among a wide variety of possible practices, two options reliably reduce all but the densest cells:

- Rank all cell density values into percentiles, keeping only the top 10 percent of cells.
- Normalize all cell density values, keeping only those cells with a z-score higher than 2.

Deciding between the two filtering approaches (or variations thereof) depends on the shape and the spread of establishment density distribution across a given community. As an example, in a

[9] The shorthand of “automobile-oriented development” refers to transportation and land use patterns that are centered around automobile use and convenience rather than pedestrian accessibility. Examples include larger city blocks, statutory parking minimums, wide streets with fast-moving traffic, and a relative absence of public space.

smaller agricultural town, very few business establishments—perhaps only a grocery store, a feed store, and a few gas stations—exist outside the town center. A larger micropolitan town may have several medium-density strip mall shopping centers and big box stores *outside* the downtown business district. Both communities are eligible for use with the D3 method, but the differences in the shape and the spread of the establishment density distribution means that the user should carefully consider which practice will best filter out low-density cells.[10]

Regardless of the chosen filtering option, after eliminating all but the highest density cells, the map should contain only a small number of hexagons. Some of the remaining cells may stand alone, but most will be contiguous with other cells to form a spatially contiguous group. Each group of contiguous cells—including stand-alone hexagons—is spatially combined into a single corresponding polygon with a dissolve operation, and the precise geometric angles of the hexagonal borders are replaced with smooth, rounded edges (see exhibit 4).

Exhibit 4

Step 2b—Highest Density Cells Only, Adjacent Cells Grouped

Source: Infogroup U.S. Historical Business Data, 2005

Step 3: Selecting the Downtown Grouping

The final step of the D3 method requires the user to determine which of the remaining cells constitute the downtown district. Step 2 generates one or more polygons from the spatially combined hexagons that represent the agglomeration of business establishments in various

[10] The author recommends that analysts performing a "batch" implementation of this technique (for example, delineating downtown for all non-metropolitan municipalities in one state) divide the operation into smaller subsets according to population and rurality.

areas throughout the community. As in Step 2, the user must consider multiple elements when determining which grouping or groupings to use for the final downtown geography delineation to save as a layer.

The first consideration is whether the community is polycentric or monocentric.[11] If the latter, then the largest grouping most likely contains downtown; however, the second consideration—the establishment density—may complicate the picture. The largest grouping may comprise mostly establishments in low-density, automobile-oriented development. The highest density grouping may also comprise establishments in automobile-oriented (i.e., not downtown) development.[12] The analyst should thus take both size and density into consideration when determining how to group the hexagons to represent a downtown district or districts. The following are two practical approaches:

- Rank groupings in descending order according to both size and establishment density. Sum both rankings, and rank the resulting sums. The highest ranked sum or sums likely contain the downtown business district.
- Omit establishments from industries with a tendency for satellite agglomeration (e.g., hospitals, doctors' offices, and other businesses in a medical campus) on the periphery of town.

If, however, the analyst is aware of a second historic business district within municipal boundaries, implementing Step 3 of the D3 method may be challenging. Such places may be difficult to identify. Although these areas possess the building density and streetscape characteristics of a traditional pre-automobile business district, they often are positioned much lower within the hierarchy of shopping districts in the community. Despite the historic character of the buildings, vacancy is common among storefronts in secondary historic business districts; thus, although building density is high, establishment density remains low, and the secondary business district may not be identified by the kernel density mapping from Step 2 because the bandwidth setting is not set to reflect that relationship. In such cases, two options may be pursued:

- If the secondary historic business district is close enough to the primary downtown district, the buffer zone around each may be increased, allowing those hexagons to be merged into a single downtown business district.
- If the secondary business district is not close enough to merge with downtown via buffering, the analyst may consider manually selecting polygons from the map generated in Step 2. Sometimes a qualitative review is needed to capture reality in ways that spatial techniques are unable.

After selecting the hexagon grouping or groupings pertaining to the community's downtown district (see exhibit 5), all other groupings and individual hexagons may be deleted from the layer (or saved

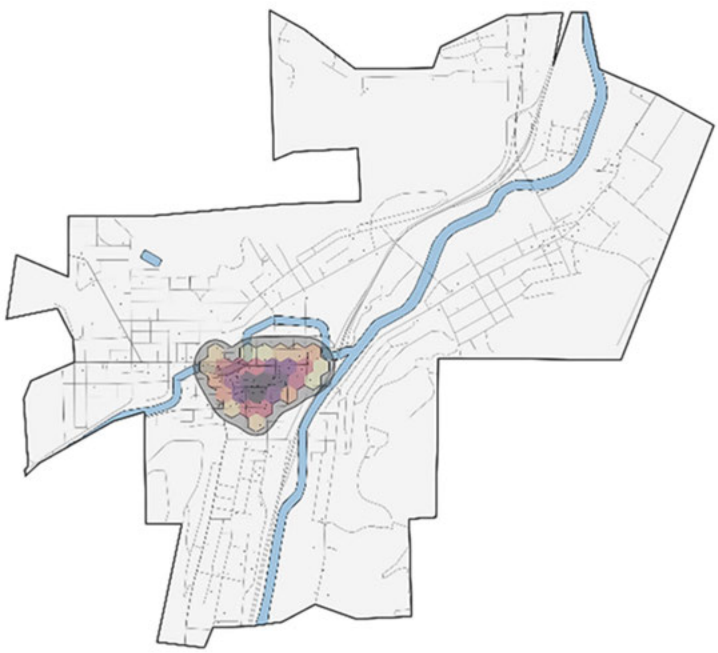
[11] As suggested by the name, *monocentric* cities and towns have only one central location; however, in some circumstances, multiple nuclei will emerge, corresponding to different sources of economic and civic activity in the community (such as a town with a courthouse square district and a separate business district adjacent to a waterfront or rail station). The latter category is referred to as *polycentric*.

[12] The latter possibility—an area that contains high establishment densities but is not located in a pre-automobile business district—is likely to be identified in areas where establishments are concentrated around a single anchor, typically a hospital or college campus.

to a new layer for later use). Because the resulting set of hexagons (or squares) does not perfectly map onto the actual location of streets and establishments in real life, the use of either cell shape introduces some degree of error into the process. A modest buffer operation may help to correct for this error, allowing the district to expand enough to encompass those parts of downtown that were narrowly uncaptured by the delineation process.[13] The final map (see exhibit 6) shows the City of Bradford, Pennsylvania, with a polygon that corresponds to its downtown district.

Exhibit 5

Step 3—Downtown Grouping Selected, Buffer Operation (50m) Applied

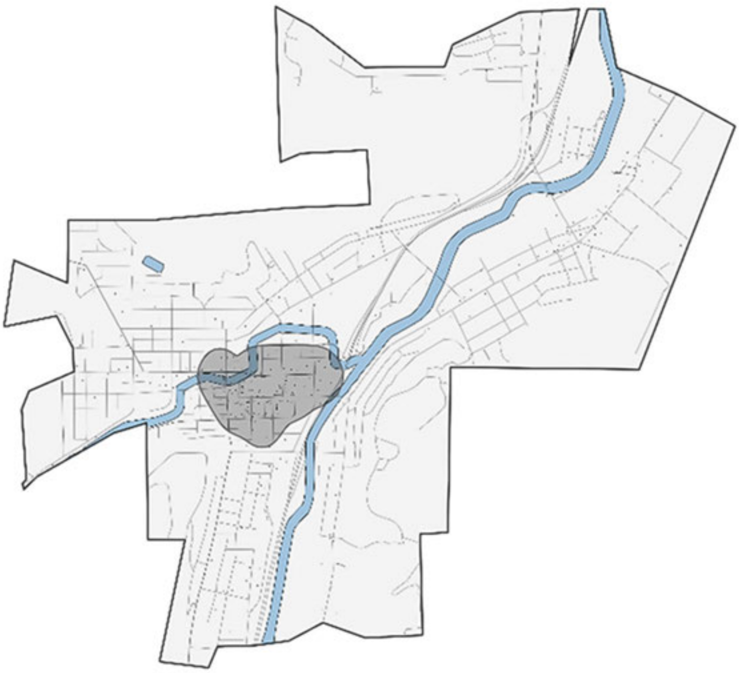


Source: Infogroup U.S. Historical Business Data, 2005

[13] In addition to performing the optional buffer operation, the user may tweak several additional parameters in the D3 method to suit the study context. Those parameters include cell size, bandwidth, density percentile threshold (if using percentiles), z-score threshold (if using z-scores), number of groupings, grouping average density threshold, grouping size threshold, and specific North American Industry Classification System industry codes to keep (or omit) from the kernel density estimation. Each of those parameters is discussed in the previous text.

Exhibit 6

Final Downtown District Delineation



Source: Infogroup U.S. Historical Business Data, 2005

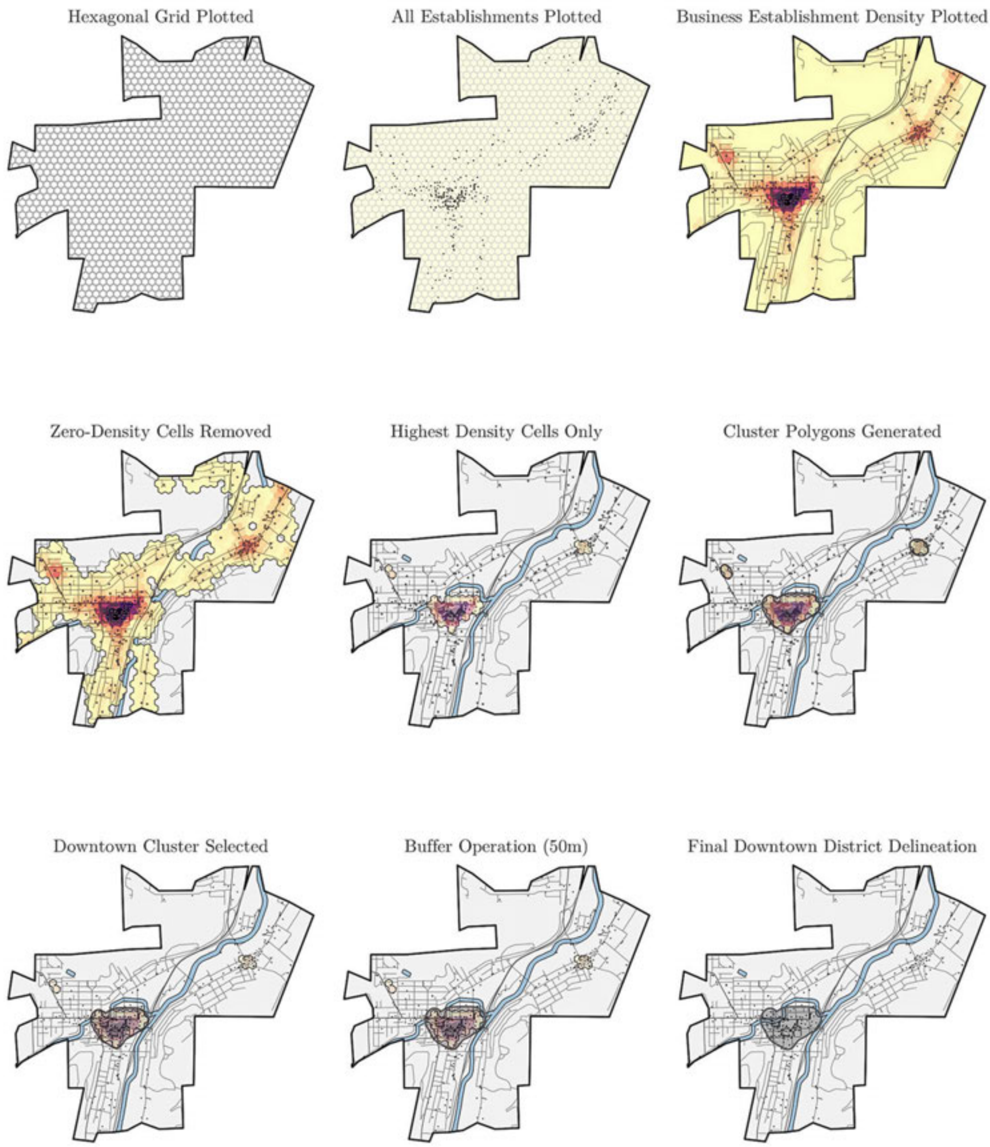
Implications and Potential Uses of the Data

The method described previously—see exhibit 7 for a step-by-step illustration of the entire method—provides practitioners and researchers with consistent, data-driven delineations of downtown district boundaries.[14] Following are three reasons why the D3 method represents an improvement over existing analytical practices involving the identification of "downtown" as a spatial unit.

[14] Although the method is data driven, many of the necessary parameters are defined according to the user's discretion.

Exhibit 7

Full Step-by-Step Illustration of D3 Method



D3 = downtown district delineation.
Source: Infogroup U.S. Historical Business Data, 2005

First, accurate downtown district delineations are crucial when evaluating downtown economic revitalization strategies. Even when fully effective, such strategies are unlikely to generate their intended outcome geography evenly throughout an entire community. Rather, the outcome geography being evaluated should, in theory, be most concentrated in and adjacent to downtown. As shown in a study of downtown revitalization in the rural Midwest (Van Leuven, 2021), communities participating in the "Main Street Program" benefited from new job growth in their downtown district.[15] When the study area was enlarged outward beyond the downtown district, however, no statistically significant increase in job creation was detected. It is imperative that researchers have a correct definition of a given community's downtown district with which to measure and evaluate the efficacy of a revitalization strategy.

Downtowns also serve as a relevant source of heterogeneity that must be accounted for in analyses of housing and real estate markets. A common empirical strategy in such studies—hedonic price modeling—estimates the implicit prices of relevant amenities and disamenities by accounting for local price heterogeneity in the housing market (Rosen, 1974). Although most hedonic price models account for property-level characteristics, such as square footage and number of bathrooms, controlling for local neighborhood characteristics is likewise necessary to gauge the true value of variables in the model. The use of a "distance from downtown" variable in hedonic price analysis is ubiquitous, appearing in studies ranging from transportation planning (Seo, Golub, and Kuby, 2014) to natural resource economics (Lansford and Jones, 1995).

The lack of a data-driven delineation of the downtown district introduces two potential weaknesses:

- *Use of the "centroid" of the downtown district.* Lacking a proper polygon to delineate where downtown begins and ends, many studies calculate the distance to the center. This method can be problematic if the downtown district is not symmetrical (e.g., a downtown that follows a single corridor) or if the central point of the municipality does not correspond with the community's dense business district.

- *Use of a predefined downtown district.* As mentioned earlier in this paper, many cities have already defined their downtown district; however, those definitions limit researchers from studying places without predefined GIS boundaries that represent the area intended to be studied. Administrative downtown boundaries may also be arbitrarily defined, based on political constituencies or colloquial perceptions of downtown, rather than a representation of the density of economic activity.

Finally, the D3 method allows for a continual recalibration of a community's downtown district, allowing it to evolve over time. Although the epicenter of a community's downtown district is not likely to shift dramatically away from its historical roots, the size and shape of a central business district may fluctuate on the basis of regional circumstances and overall macroeconomic trends. For a state or county economic development agency attempting to keep track of the economic health and trajectory of its constituent communities, a new downtown district boundary could be generated every half decade, using the geometric average of 5 years' worth of downtown delineation files.[16] Those revised boundaries would allow policymakers and analysts to stay up to date with an accurate conception of the central business district when evaluating and observing downtown economic activity.

[15] This finding was identified only for communities in the state of Iowa. For the other states in the analysis, results lacked statistical significance.

[16] Year-over-year changes in the downtown's size and shape should be regarded as statistical noise, but when aggregated over time, multiple years of data will convey a more accurate definition of downtown.

Conclusion

When used carefully, the downtown district delineation (D3) method is a useful tool for any analyst needing to differentiate between a municipality's central business district and its other commercial spaces. Whereas the parameters of D3 are highly customizable, its core function is to identify a municipality's densest (and typically most central) business district. Larger cities typically already possess a detailed spatial delineation of their downtown district, and suburban or exurban municipalities typically lack a downtown business district. This method thus targets primarily practitioners in—and researchers of—smaller non-metropolitan communities with a central business district established before the automobile era.

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References

Bogart, William T. and William C. Ferry. 1999. "Employment Centres in Greater Cleveland: Evidence of Evolution in a Formerly Monocentric City," *Urban Studies* 36 (12): 2099–2110.

Caha, Jan. 2020. "SpatialKDE: Kernel Density Estimation for Spatial Data," R package version 0.6.2. https://CRAN.R-project.org/package=SpatialKDE

Cervero, Robert, and Roger Gorham. 1995. "Commuting in Transit Versus Automobile Neighborhoods," *Journal of the American Planning Association* 61 (2): 210–225.

Cohen, Lizabeth. 1996. "From Town Center to Shopping Center: The Reconfiguration of Community Marketplaces in Postwar America," *The American Historical Review* 101 (4): 1050–1081.

Epanechnikov, Vyacheslav A. 1969. "Non-Parametric Estimation of a Multivariate Probability Density," *Theory of Probability and Its Applications* 14 (1): 153–158.

Esri. 2021a. "How Kernel Density Works." ArcMap. ArcGIS for Desktop. https://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/how-kernel-density-works.htm.

———. 2021b. "Why Hexagons?" ArcMap. ArcGIS Desktop. https://desktop.arcgis.com/en/arcmap/latest/tools/spatial-statistics-toolbox/h-whyhexagons.htm.

Hales, Thomas C. 2001. "The Honeycomb Conjecture," *Discrete & Computational Geometry* 25 (1): 1–22.

Hill, Edward W., Harold L. Wolman, and Colt Cook Ford III. 1995. "Can Suburbs Survive Without Their Central Cities? Examining the Suburban Dependence Hypothesis," *Urban Affairs Review* 31 (2): 147–174.

Infogroup. 2020. "Infogroup U.S. Historical Business Data," archive years 1997–2019. https://doi.org/10.7910/DVN/PNOFKI.

Lansford, Notie H., Jr., and Lonnie L. Jones. 1995. "Recreational and Aesthetic Value of Water Using Hedonic Price Analysis," *Journal of Agricultural and Resource Economics* 20 (2): 341–355.

Manville, Michael, and Donald Shoup. 2005. "Parking, People, and Cities," *Journal of Urban Planning and Development* 131 (4): 233–245.

Porter, Michael E. 1995. "The Competitive Advantage of the Inner City," *Harvard Business Review* 73 (3): 55–71.

Rosen, Sherwin. 1974. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition," *Journal of Political Economy* 82 (1): 34–55.

Seo, Kihwan, Aaron Golub, and Michael Kuby. 2014. "Combined Impacts of Highways and Light Rail Transit on Residential Property Values: A Spatial Hedonic Price Model for Phoenix, Arizona," *Journal of Transport Geography* 41: 53–62.

Silverman, Bernard W. 2018. *Density Estimation for Statistics and Data Analysis*. Oxfordshire, UK: Routledge.

Van Leuven, Andrew J. 2021. "The Impact of Main Street Revitalization on the Economic Vitality of Small-Town Business Districts," *Economic Development Quarterly*. https://doi.org/10.1177/08912424211038060.

———. Forthcoming. "Leveraging Main Street as a Real Estate Amenity: Retail Corridor Revitalization and Residential Property Values."