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Context Classification of Roadways Using Nationally Available GIS Data

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CONTEXT CLASSIFICATION OF ROADWAYS USING NATIONALLY AVAILABLE GIS DATA

THESIS

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Civil Engineering in the College of Engineering at the University of Kentucky

By

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ABSTRACT OF THESIS

CONTEXT CLASSIFICATION OF ROADWAYS USING NATIONALLY AVAILABLE GIS DATA

A Context Classification System based on context attributes of the area surrounding a roadway provides detailed information about the environment of a roadway corridor, while enabling practitioners to cater roadway projects to the community they are within. This study sought to create a system that would automatically classify roadway segments into the correct context, using data sources that are available nationwide. The proposed approach was tested by classifying the roadways in Highway District 7 of the Kentucky Transportation Cabinet. This process would make context classification approachable to more organizations, as it would reduce the amount of time required to apply a classification to a large network and would increase the consistency within a district- or state-wide classification. Measures evaluated include population density, employment density, building density, intersection density, street density, and block length.

KEYWORDS: Context classification, Expanded Functional Classification, Highway Engineering, Transportation Network

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CHAPTER 1. INTRODUCTION

Functional Classification has been used nationwide for categorizing roadways for over 30 years. It was originally designed to be a tool for allowing planners and designers to have a common language and understanding of roadway classes and establishing a framework for classifying roadways based on mobility and access. Over the years, Functional Classification has been integrated into guidance documents and state agencies have incorporated Functional Classification in their design manuals and used it as a surrogate for roadway design. More recently, NCHRP Report 855 (Stamatiadis, et. al 2018) introduced the Expanded Functional Classification System (Expanded FCS) that utilized context as the basis for the classification, envisioning it as a supplement to Functional Classification. This system was based on density, land use, and building setbacks, and sought to identify the different mobility/access demands, operating speeds, and user groups of roads. The Expanded FCS was later adopted into the Policy on Geometric Design for Highways and Streets 7th Edition, also known as the Green Book (GB7; AASHTO 2019).

The Expanded FCS is useful to designers and planners alike as it provides a deeper understanding of the area surrounding the roadway. Its flexible continuum expands the context information given through the traditional rural/urban classification, providing a deeper understanding of how the community interacts with the roadway and what user groups are prevalent. In this manner, it also provides guidance of each user group's priority along a corridor, which aids practitioners in making critical project decisions. It allows planners to focus on the present and future context of the community and provides designers with a better starting point for their design solutions that would allow for improved safety, multimodal options, and functionality of the road.

The Expanded FCS also initiates conversation about the needs of the roadway and its users before the design process ever begins. Without an expanded classification system, roadway design tends to be formulaic, failing to feature critical thinking about what would best serve the community surrounding the corridor considered. By stimulating a critical thinking process about the needs of the roadway, the Expanded FCS switches the mindset of designers away from strict tables and formulas to a more customized approach. This has the potential to result in roadway designs that are safer and better suited for the environment they are in.

Even though the Expanded FCS provides much more detailed and useful information than the traditional Functional Classification, a survey sent to all state Departments of Transportation (DOTs) by the NCHRP Project 15-72 team suggested that only 11 out of the 50 states have initiated the implementation of a context-based classification in their system, and 15 have no plans of implementing it (Stamatiadis, et. al 2021). Figure 1 shows the state of practice regarding the implementation of the Expanded FCS nationally. The state representatives who responded to the survey suggested that lack of guidance in implementation resulted in their hesitation in adopting the Expanded FCS and that agencies need better resources and guidance before they would be able to implement such a policy.

Other representatives suggested that their state does not yet see that the benefit of the system outweighs the cost of making such a change, or that the state simply does not have the resources to do so.

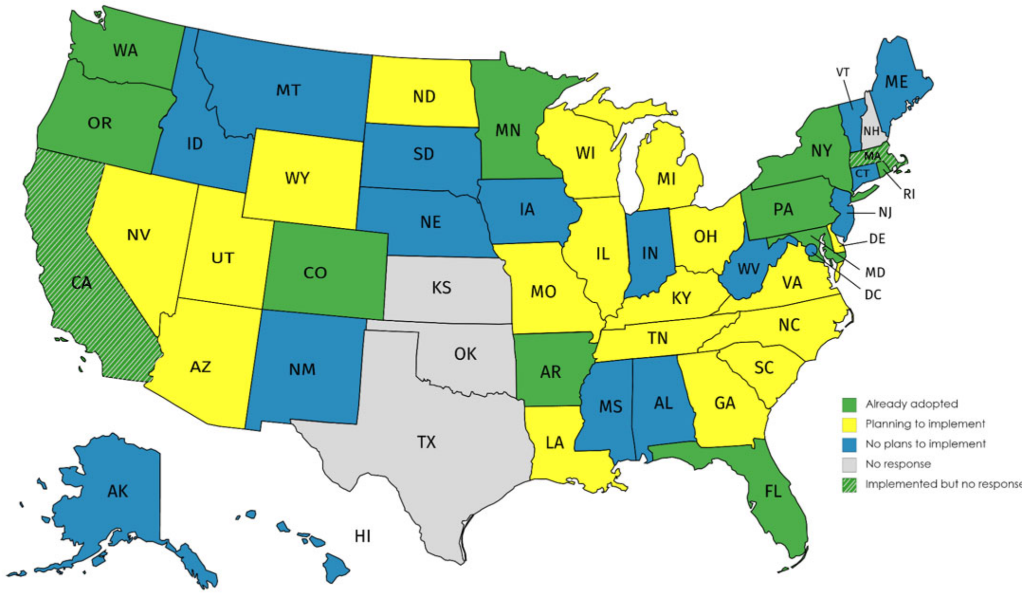


Figure 1. States planning to implement an Expanded FCS.

NCHRP Project 15-72 is developing this required guidance and making the Expanded FCS more approachable for state DOTs. One of the issues hindering implementation is that the classification is on a continuum, making it difficult to determine where one context ends and another begins. Another issue is that the traditional rural/urban classification was done on an area-wide basis, whereas the Expanded FCS works better and gives more information when classified on a roadway level. Both issues can be addressed through resolution of a third issue; the Expanded FCS described in GB7 does not include a well-defined approach to perform the classification, nor does it provide quantitative measures to be used for determining the context of a roadway. In response, NCHRP Project 15-72 has identified a set of quantitative measures to use as surrogates for more subjective context identifiers. The purpose of this study is to evaluate these measures using GIS data readily available to all states, and to create an automated process of classifying roadways.

An automated process would apply the data-driven approach of NCHRP Project 15-72 to give states a first cut of the classification, taking out the initial cost of having to classify the road network manually. This would be helpful because it would eliminate the initial struggle of identifying areas of different contexts, giving agencies an advantage in terms of familiarity of the contexts. It could also help in statewide classification of the entire road network, saving time and money. An automated process would only require a calibration and review of the results to determine boundary areas and improperly classified segments, i.e., false positives, greatly reducing the time needed to perform the classification. Using the data driven approach also helps to keep classification consistent, avoiding differences between context definitions that may occur with visual inspection. Through reducing the cost and increasing the consistency of classification, an automated process would make the Expanded FCS much more approachable to all states.

CHAPTER 2. LITERATURE REVIEW

2.1 CONTEXT CLASSIFICATION DEFINITIONS

The traditional urban/rural context designation fails to give a practitioner insight into the characteristics and user needs of a roadway, as it only identifies large areas of urbanization, is not refined enough to identify the role of the roadway in the community and lacks understanding of multimodal designs. The expanded context designations defined in NCHRP Report 855 and GB7 seek to mitigate this issue. This new concept includes two designations for rural areas (rural and rural town) and three designations for urban areas (suburban, urban, and urban core). These designations are as follows:

> *Rural* – This context consists of very low land density where there is no developed community present. Features of this context include large building setbacks, mainly agricultural and resource extraction land use, and few houses or structures.
>
> *Rural Town* – This context represents more developed rural areas; the intention of this context is to recognize the changes a rural road undergoes when it enters a community area. These areas still have low development densities but feature a variety of land uses, often including schools, commercial and city-related development, and residential areas. The characteristics of this context include on-street parking, small building setbacks, and sidewalks in some locations.
>
> *Suburban* – This context generally applies to areas on the outskirts of an urban area and feature mixed land uses, which may include residential neighborhoods, big-box commercial development, and government/municipal facilities. Characteristics of this context include low density development, mixed building setbacks, and off-street parking. Roads in this context generally have higher speed designs than other urban contexts.
>
> *Urban* – This context consists of mixed-use, high-density development. Predominantly an area of multi-story and medium-rise structures, these areas feature conference centers, gathering areas, and other entertainment facilities, as well as residential and other commercial uses. The users of Urban areas are different from other contexts discussed so far, with higher numbers of transit and pedestrian/bicycle users and lower speed expectations for drivers. Most Urban areas feature sidewalks and small to medium building setbacks.
>
> *Urban Core* – This context features the central business district of medium to large cities. These areas consist of mostly high-rise structures, high development density with mixed uses, small building setbacks, and off-street garage parking. This area features the highest pedestrian/bicycle needs, which call for nearly continuous sidewalks, pedestrian gathering areas, and shared-use paths. Land use is predominantly restricted to commercial and government use.

2.2 EXPANDED FCS IMPLEMENTATIONS

Several states have already adopted some form of the Expanded FCS and most have customized it based on their local needs. Among the state DOTs that have adopted the Expanded FCS, those of Pennsylvania/New Jersey, Washington, Florida, Minnesota, Maryland, and Oregon are leading its implementation and developing designs consistent with the Expanded FCS. A summary of these efforts is presented here.

Pennsylvania and New Jersey DOTs were among the first to adopt an Expanded FCS in 2008. The *Smart Transportation Guidebook* (PDOT, NJDOT 2008) considers a similar classification idea to that presented in GB7. They have classified roadways on a context continuum ranging from rural to urban core, primarily based on development and land use. This continuum is shown in Figure 2. The measures used in this classification are density units, building coverage, lot size, block size, building height, and building setback.

Figure 4.3 Defining Contexts

	RURAL	SUBURBAN			URBAN		
	Rural	Suburban Neighborhood	Suburban Corridor	Suburban Center	Town/Village Neighborhood	Town Center	Urban Core
Density Units	1 DU/20 ac	1 DU/ac - 8DU/ac	2 - 30 DU/ac	3 - 20 DU/ac	4 - 30 DU/ac	8 - 50 DU/ac	16 - 75 DU/ac
Building Coverage	NA	< 20%	20% - 35%	35% - 45%	35% - 50%	50% - 70%	70% - 100%
Lot Size/Area	20 acres	5,000 - 80,000 sf	20,000 - 200,000 sf	25,000 - 100,000 sf	2,000 - 12,000 sf	2,000 - 20,000 sf	25,000 - 100,000 sf
Lot Frontage	NA	50 to 200 feet	100 to 500 feet	100 to 300 feet	18 to 50 feet	25 to 200 feet	100 to 300 feet
Block Dimensions	NA	400 wide x varies	200 wide x varies	300 wide by varies	200 by 400 ft	200 by 400 ft	200 by 400 ft
Max. Height	1 to 3 stories	1.5 to 3 stories	retail -1 story; office 3-5 stories	2 to 5 stories	2 to 5 stories	1 to 3 stories	3 to 60 stories
Min./Max. Setback	Varies	20 to 80 feet	20 to 80 ft	20 to 80 ft	10 to 20 ft	0 to 20 ft	0 to 20 ft

Figure 2. Pennsylvania and New Jersey DOTs context thresholds

Washington and Florida DOTs context classification guides were both released while the draft version of NCHRP Report 855 was being published and were developed to mirror the contexts in that report. The Context and Modal Accommodation Report Learner's Guide of Washington DOT most closely parallels NCHRP Report 855, with the only difference being that it excludes the rural town context (WSDOT 2017). Measures used to define context in this classification include land use, housing density, job density, intersection density, building height, building setback, and parking location.

The Florida DOT Context Classification Guide (FDOT 2017) revised the original five classifications to better fit their local conditions. They split the suburban class into residential and commercial suburban contexts and included a natural class to identify areas where land is being preserved and is consequently uninhabited (Figure 3). This guide also includes overlays for industrial, warehouse, and port areas, and includes a special district context to accommodate areas that might not fit directly into a single context. For the main classes, Florida used land use, building height, orientation and setback, parking location, block size, intersection density, and residential/office density to classify roadways into its context categories.

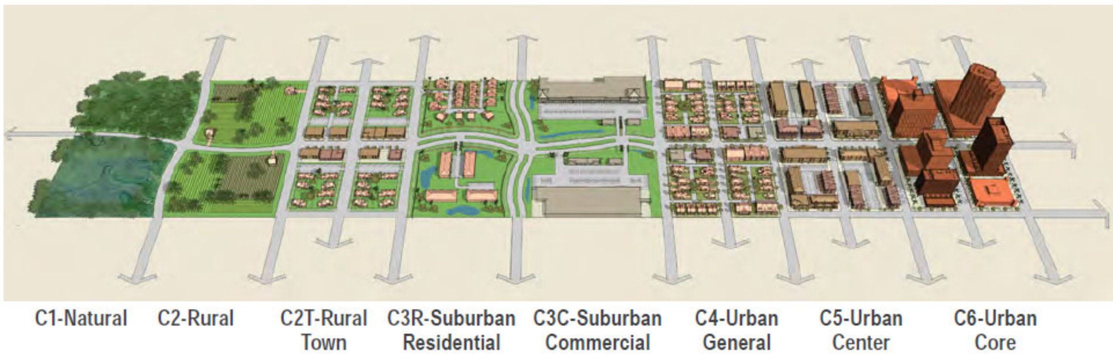


Figure 3. Florida DOT context classification continuum

Minnesota DOT released their context-sensitive design guidance shortly after NCHRP Report 855 was published. The Technical Memorandum on MnDOT Land Use Contexts, Types, Identification, and Use (MnDOT n.d.) approaches the classification in the same manner as Florida DOT, adding a natural context and expanding the suburban context to best fit the roadway system in Minnesota. In addition, Minnesota DOT also added a separate context for industrial/warehouse/port uses, rather than just an overlay. Minnesota DOT used measures such as land use, building height, orientation, setback, and density, and parking location to define its contexts.

Maryland DOT recently published their new context classification system guide, Context Driven Access and Mobility for all Users (MDSHA 2019). This guide takes the same approach for suburban areas as Florida DOT and Minnesota DOT, splitting the suburban context into two. Maryland DOT has targeted the larger of these contexts, the suburban activity center, as an area with the greatest potential for context-driven roadway enhancements. Different from most other context classifications, design components in this context and urban contexts are based on the presence of Short Trip Opportunity Areas (STOAs), which identify areas where better bike, pedestrian, and transit facilities may be needed.

Oregon DOT recently released their context-based design guide, Blueprint for Urban Design (ODOT 2019), as well. The classification system in this guide focuses more on land use than other characteristics. These contexts are similar to those in NCHRP Report 855 but overlap them slightly because of their land use focus. These contexts include rural community, suburban fringe, residential corridor, commercial corridor, urban mix, and traditional downtown/Central Business District. While land use is the primary metric for this classification, ODOT also considers parking location and block size, as well as building orientation, setback, and density, to classify its roadways.

2.3 FLORIDA DOT AUTOMATED PROCESS

In the process of implementing their Expanded FCS, Florida DOT also performed a GIS process to automate the initial classification (Kent, et. al 2021). The methodology for this process consisted of four parts: segmentation of the Florida network, calculation of segment measures (e.g., intersection density) using density rasters, assignment of a network connectivity score to each segment, and context determination using a series of "if-then" logic scripts. The segmentation process relied on established city boundaries and intersection densities instead of utilizing a segment length to classify. The "if-then" logic scripts that were used are outlined in Figure 4. Six measures were taken from the original context classification guidance released by Florida DOT; these were land use, intersection density, block perimeter/length, and population/employment density.

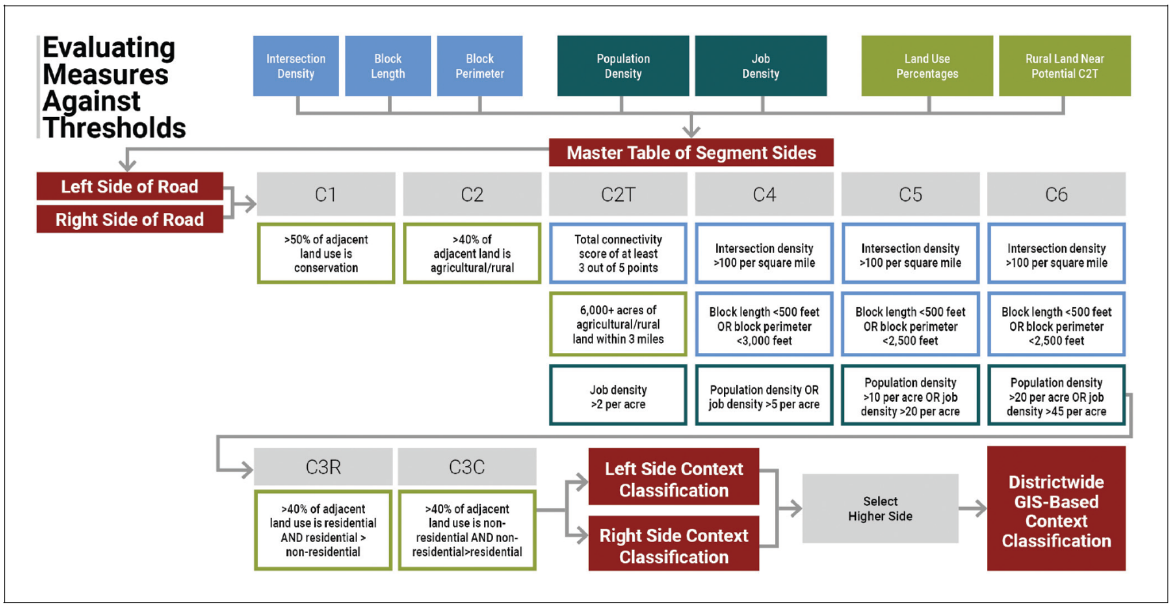


Figure 4. Florida DOT Automation Process (Source: Kent, et. al 2021)

The sensitivity analysis performed on this process showed that all segments were classified within one context level of the original classification, which was based on all 12 measures. The automation process still calls for a visual inspection but makes the classification process much faster. The biggest limitation to this approach is that the analysis relies on land use data sets, which are not readily available on a statewide basis. The segmentation process could also be subjective, making segmentation decisions vary between practitioners, which could result in some inconsistencies. However, this process is quite successful in simulating the judgement of the human eye through a data-driven approach.

2.4 CONTEXT CLASSIFICATION MEASURES

To create an automated process similar to the one Florida DOT utilizes that could be used nationwide, a method of measuring roadway characteristics needed to be determined. Many of the characteristics other states use are qualitative in nature, making them complex and difficult to measure and compare. Thus, quantifiable surrogate measures needed to be established. NCHRP Project 15-72 completed a review of the Expanded FCS implementations and determined which measures were most often used as an identifier of context. Table 1 shows the measures used in the reviewed context classification guides, and Table 2 shows the measures survey respondents identified (Stamatiadis, et. al 2021).

Table 1. Measures used in context classification guides

Measures	Responses
Land use	6
Building height	4
Building orientation	4
Setback	6
Parking	4
Block size	3
Traffic volume	3
Intersection density	4
Population density	1
Employment density	2
Building density	4
Allowed residential density	1
Allowed office/retail density	1
Short Trip Opportunity Area (STOA)	1

Table 2. Measures reported in NCHRP Project 15-72 survey

Metrics Used - Already Adopted	Responses
Pedestrian patterns	7
Bicyclist patterns	7
Land Use	6
Parking presence	6
Housing units	6
Building setback	6
Intersection density	6
Parking location	6
Housing units/area	5
Block size	5
Employment density	5
Presence of fronting uses	5
Roadway Network	5
Building height	4
Building coverage	4
Crash Data	4
Other vulnerable user patterns	3
Other (please specify)	3
Building orientation	0

For the automation approach to be developed, metrics that could be reasonably attained by all states were preferred. As such, the following measures were chosen based on the availability of U.S. Census data, roadway centerline data, and Bing Maps building polygon data. Some of these were chosen directly from the list of previously used measures, and others were chosen to represent those measures while using more accessible data.

Population density – Represented as people per square mile, this is a quantitative measure that can be used as a surrogate for trip generation and corresponding activity level. This can be calculated from U.S. Census population data.

Employment density – Represented as employees per square mile, this is a quantitative measure that can be used as a surrogate for trip attraction and corresponding activity level. This may be paired with population density to represent overall activity levels. This can be calculated using U.S. Census employment data.

Building density – This measure can be represented as building count per square mile or building area with unit of square feet per square mile. The building area density is measured as the square footage of the building footprint, as this is the only data readily accessible through the Bing Maps database. This quantitative measure can be used as a surrogate for activity levels in an area and as pedestrian accessibility/activity. It can also suggest the movement of vehicles in an area and the permeability of pedestrians through the area, which would give an indication of possible limits for the vehicular operating speed of the area.

Intersection density – This measure is represented as intersections per square mile and can be derived and calculated using roadway centerline data in a GIS processing program. It can give an indication of the network form (e.g., whether there is a structured grid network), which can suggest the movement of vehicles and the permeability of pedestrians through the corridor. This also indicates the prevalence of user groups and the possible influence of vehicular operating speed of the area.

Street density – Represented as number of streets per square mile, this quantitative measure can be derived using roadway centerline data in a GIS processing program. Similar to intersection density, street density provides an indication of the roadway network as well as the user groups, permeability of pedestrians, and movement of vehicles along the roadway, which could also be indicative of the possible influence of vehicular operating speed.

Average block length – This measure is expressed in feet and measures the average length of a street block. This can be derived in a GIS processing program using the intersection points derived for the intersection density calculation and roadway centerline data. This measure provides similar indications as the street and intersection densities, acting as a surrogate for network layout, user group priority, vehicle movement, pedestrian permeability, and vehicular operating speed.

CHAPTER 3. METHODOLOGY

The study area chosen for this project was Highway District 7 of the Kentucky Transportation Cabinet (KYTC), centered around Lexington, KY. This area includes the counties of Anderson, Bourbon, Boyle, Clark, Fayette, Garrard, Jessamine, Madison, Mercer, Montgomery, Scott, and Woodford. The overall approach for the project includes four steps: 1) manual classification of the study area, 2) creation of routes segmented at even intervals with buffers surrounding them, 3) ArcMap processing that includes a rural/urban determination based on U.S. Census Urbanized Areas and a calculation of each measure, and 4) sensitivity analysis to determine the measures that could be used in separating contexts. The sensitivity analysis was completed in two steps. The first step was performed in Microsoft Excel and determined what percentage of segments were classified correctly using defined optimum thresholds of each measure, while the second step was performed in ArcMap and determined how many false positive rural town clusters were identified when an optimum threshold of each measure was chosen. Four different combinations of segment length and buffer width were used to examine their effect on correctly classifying the road network.

3.1 DATA AND GIS PROCESSING

The project started by retrieving a shapefile of the state and local roadways in District 7. These were obtained from KYTC's Road Centerline and Highway Information System Data webpage (KYTC, n.d.). In ArcMap, these road segments were joined together by route using the Create Routes tool and were then segmented at equal interval lengths. Since the length of segment could greatly affect the results of the analysis, two copies of the shapefile were made to test different lengths. The segment lengths tested were 0.25 miles and 0.50 miles.

A context designation was then manually assigned to each segment in each roadway shapefile using ArcMap. This assignment started with a separation of traditionally classified rural and urban segments using the U.S. Census Urbanized Area boundaries. The U.S. Census defines an urbanized area as a location with a population of 2,500 persons or greater. If the segment was within one of these boundaries it was considered urban, otherwise it was considered rural. To determine whether the segment was urban or rural, the Spatial Join tool was first run with the roadway segments as the target features and the urban area polygons as the join features. The join operation JOIN_ONE_TO_ONE was selected, and the match option was set to within; this matched each segment with the urban area it was within, if any. Once this process was completed, a new field was created in the output attribute table for the rural/urban classification. In the Field Calculator an "if" statement was coded, with the rule that if a segment's urban area identifier field was null then the segment was in a rural area, and otherwise the segment was in an urban area.

Rural segments were then separated from urban segments by creating one new layer containing only rural segments and a second rural layer only containing urban segments. All segments in these layers were then manually assigned a context. This context was visually determined through aerial and street view photos, and was based on elements such as building setback, building density, building height, street density, and multimodal facility presence as defined in the context classification definitions (AASHTO 2018; Stamatiadis et al. 2018). Table 3 displays how many miles of each context were considered, while Figure 5a shows the classification of the district and Figure 5b shows a close-up of the Fayette County classification. The classification layer was then exported as a separate shapefile.

Table 3. Length of roadway manually classified in each context

Context	Total miles
Rural	4342.0
Rural Town	72.9
Suburban	2436.6
Urban	332.1
Urban Core	50.8

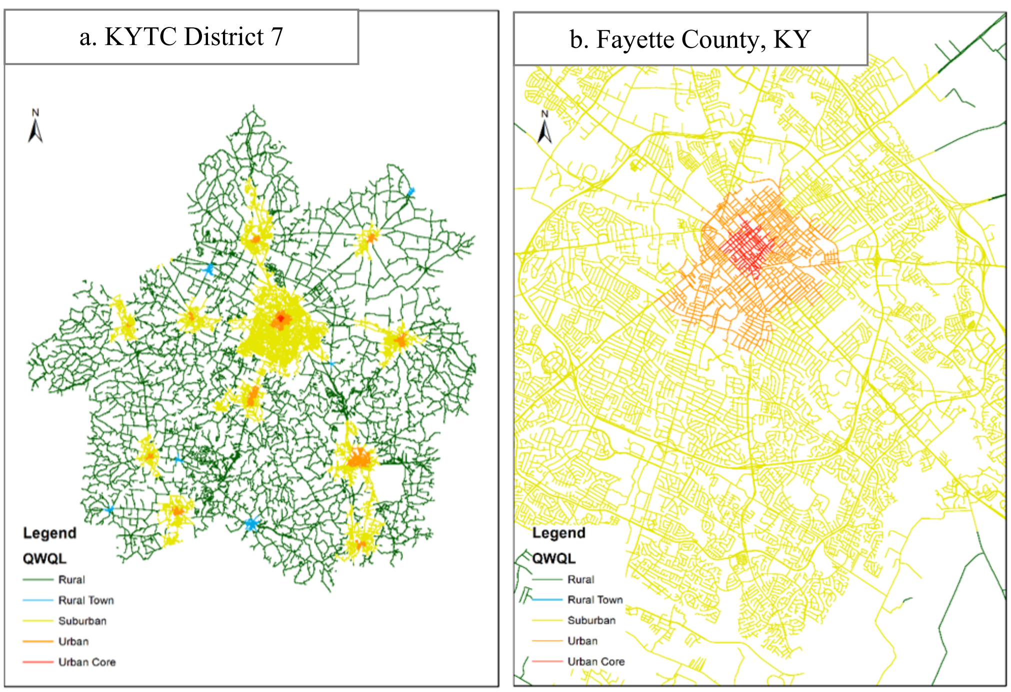


Figure 5. Manual classification of roadway network

Once the evenly split segments were classified by both the rural/urban differentiation and the manual classification, a buffer was created around each segment. This was done so that the measures identified above could be computed for the influence area (i.e., buffer) surrounding each road segment. Once again, different buffer widths were tested to ensure that the size of the influence area did not affect the results of the analysis. For each length variation, a buffer width of 0.25 miles and 0.125 miles was tested. These two buffer widths combined with the two segment lengths resulted in a set of four scenarios that were used in the sensitivity analysis of the measures to be used. Context measures were then calculated for each scenario.

The following metrics were calculated for each dataset: building density (buildings/square mile), building area density (square feet/square mile), intersection density (intersection count/square mile), population density (residents/square mile), employment density (jobs/square mile), street density (streets/square mile), and average block length (feet). Building footprint data for this was obtained from the Microsoft Bing Maps U.S. Building Footprint database (Microsoft n.d.), intersection data was derived from the KYTC roadway centerline shapefiles, U.S. Census demographic data was obtained from the Census Transportation Planning Products (CTPP) database (AASHTO, n.d.), and block length was derived from the KYTC roadway shapefile.

All the datasets were imported into ArcMap, where a series of spatial joins were performed between the buffered roadway file and the datasets. The areas of the buffers were also computed so densities could be calculated. Each of the metrics were calculated as follows.

> Building area density – The attribute table of the building dataset was opened, a new column was created, and the Calculate Geometry tool was used to calculate the area of each building polygon feature. A spatial join was then performed on the roadway buffer file, joining it to the building file and summarizing the attributes by sum. Through this process, the area of all buildings within the buffer were summed to estimate the total building footprint within the buffer. A new field was then created, and the Field Calculator was used to divide the total building area by the buffer area, resulting in the building area density for each segment.
>
> Building density – When the spatial join for the building area density was performed, one of the tool outputs was a count of how many join features (buildings) were joined to each target feature (buffer). This count was divided by the buffer area in a new field via the Field Calculator to calculate building density for each segment.
>
> Intersection density – Similar to the building file spatial join, a spatial join was performed on the latest output file, joining it with the intersection point file. For this join, attributes were only summarized by join count. This count was representative of the number of intersections found within each buffer. The count was then divided by the buffer area in a new field via the Field Calculator to find intersection density for each segment.
>
> Population and employment density – The attribute table of the U.S. Census data was opened and three new fields were created: tract area, population density, and employment density. The tract area was found using the Calculate Geometry tool. The Field Calculator was then used to divide the population count by the tract area.

This was repeated for the employment count. A spatial join was then performed between the latest output buffer file and the U.S. Census polygon data, summarizing the attributes by average. This resulted in average population and employment density fields, representative of the average population and employment density for each buffer.

Street density – A spatial join was performed between the latest output buffer file and the continuous route file. This resulted in a count of the number of streets within each buffer. A new field was created for street density, which was computed by dividing the street count by the buffer area in the Field Calculator.

Block length – First, the segments in the continuous route file were divided at points of intersections using the Split Line at Point tool. Within this split file, a new field was created for segment length, which was calculated using the Calculate Geometry tool. A spatial join was then performed between the latest output buffer file and the newly split segment file, with the attributes summarized by average. The result was an average length of the segments within each buffer, which was representative of the average block length.

Once all the metrics were calculated, the Table to Excel tool was then used to export the data to Microsoft Excel for analysis.

3.2 SENSITIVITY ANALYSIS

3.2.1 Segment Analysis

Processing began by separating rural and urban segments according to the U.S. Census Urbanized Area distinction. In an Excel file for each length and width scenario, three spreadsheets were created: 1. Rural segments; 2. All urban segments; and 3. Suburban and Urban only segments. In this way, thresholds could be found to separate two contexts at a time; the first sheet separated Rural and Rural Town, the second sheet separated Urban Core from the other urban segments, and the third sheet separated Suburban and Urban segments.

The next step was to find the possible threshold that would best distinguish between the segments for evaluating each metric. A graph was created for each measure showing the percent of correct segments identified in each context based on the threshold chosen. Figure 6 shows an example of this approach. These graphs can be viewed as supply-demand curves; as the threshold value increases, the number of correctly classified segments of one context increases while the number of correctly classified segments of the other context decreases. The optimum value, i.e., the value that maximizes the percentage of correctly classified segments while still providing some balance between the percentages for both contexts, is generally found somewhere near the intersection of the two curves. To find the range that the optimum value fell under for each measure, the measure value that gave the maximum average percentage was treated as the upper bound of the threshold and the measure value at the intersection point (also the point where the percentages were close to being identical) was treated as the threshold lower bound. All measures that performed well had very small ranges, so the maximum average percentage was used as the optimum threshold for simplicity.

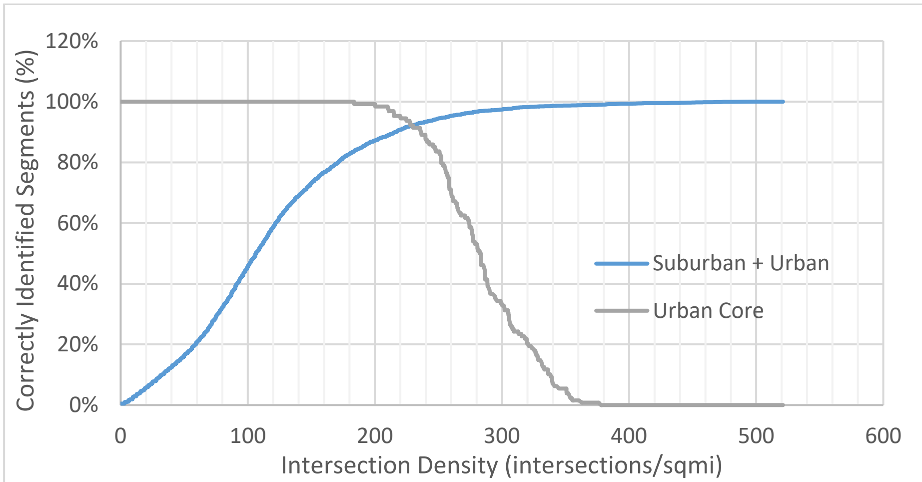


Figure 6. Urban segmentation based on intersection density

Once these thresholds were determined, additional evaluation was undertaken to determine whether two combined measures would increase correct classification of segments and improve the predictive ability of single measures used alone. This was accomplished in Excel and several combinations were considered to determine whether any combinations would improve correct segment classification. Predictor and correctness columns were created for each threshold combination to be tested. The predictor columns contained formulas that dictated what context a segment would be, based on the thresholds of the metrics being tested. For example, in the Suburban/Urban evaluation, if the intersection density and building density of a segment were both higher than the assigned thresholds, the segment would be classified as Urban. Likewise, if one of those measures was lower than the assigned threshold then the segment would be classified as Suburban. The correctness columns then compared the assumed context to the manually assigned context and assigned a binary value: 1 if they were the same and 0 otherwise. The percentage of correct segment classifications for each metric was then calculated to determine whether any combination of metrics improved the separation of contexts.

3.2.2 Cluster Analysis

The segment approach did not ensure that all Rural Towns were identified, so another approach was utilized for separating the rural segments. This approach used a cluster analysis to determine which thresholds would correctly identify all Rural Town clusters while minimizing falsely labeled Rural Towns. The buffers previously created in ArcMap were used for this process. The manually classified Rural Town clusters were depicted with a bright red color for easy identification. A copy of the buffer was then overlaid based on the quantity of the measure being evaluated; if a segment fell above the threshold it was depicted as a Rural Town, and if it fell below the threshold it was depicted as a Rural segment. Rural segments for both the manual and automatic classification were removed from the map so that Rural Town segments could easily be identified. The chosen threshold was adjusted until the lowest value that identified at least one segment in each rural town was found. An example of one of the final measure maps is shown in Figure 7.

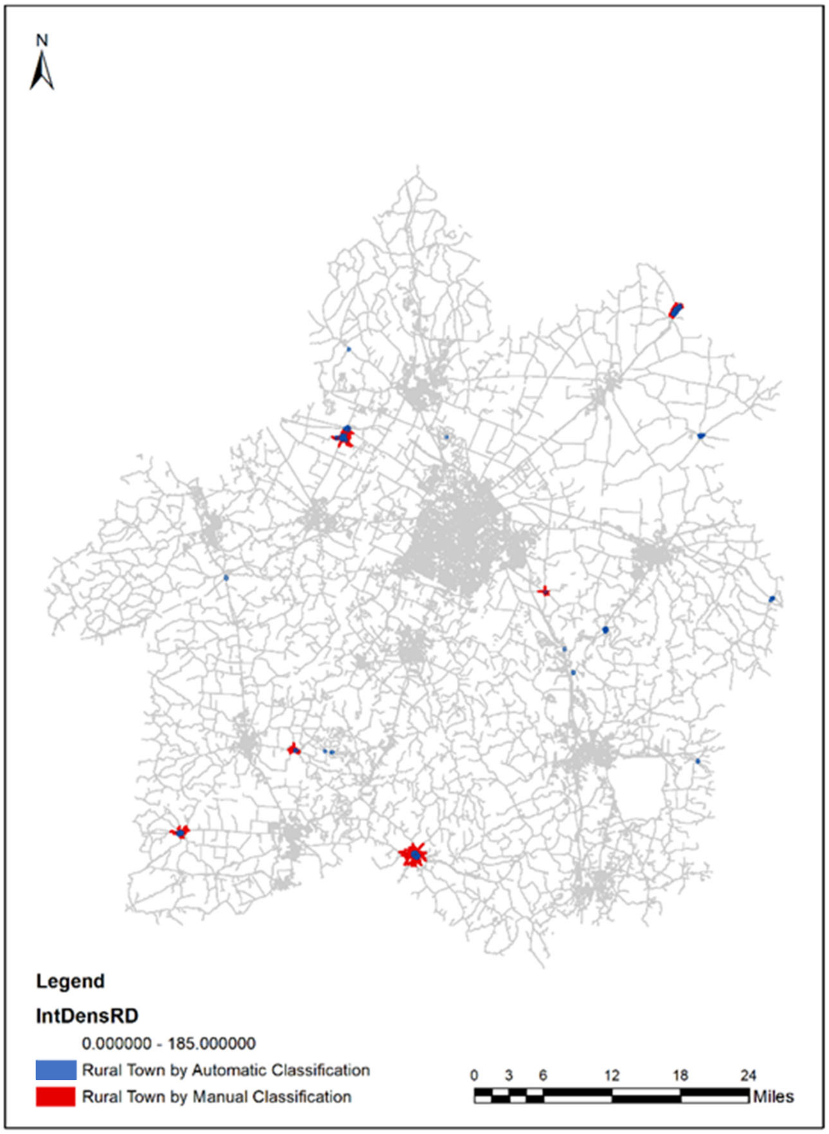


Figure 7. Rural Town intersection density cluster analysis

Once the threshold was determined, the number of false positive clusters was counted and recorded. The corresponding percentage of correct segments was also calculated for each cluster analysis threshold. Each measure was then compared based on these metrics.

CHAPTER 4. RESULTS

The results of both the cluster analysis and the segment analysis were compared for the four scenarios used: 0.25-mile segments with 0.125-mile buffers, 0.25-mile segments with 0.25-mile buffers, 0.50-mile segments with 0.125-mile buffers, and 0.50-mile segments with 0.25-mile buffers. For each of these conditions, thresholds were identified that divided two contexts at a time. For example, first the urban segments were analyzed, first dividing the Urban Core sections from the rest of the urban segments using the optimum threshold for each measure, and then dividing the Suburban segments from the Urban segments using a different threshold for each measure. The rural segments were then analyzed similarly, dividing Rural Town segments from Rural segments using the optimum threshold for each measure. Finally, the rural segments were analyzed once again, this time on a cluster basis rather than a segment basis. The best performing thresholds for the three separations were then used to classify all segments of KYTC District 7.

4.1 SENSITIVITY ANALYSIS RESULTS

Tables 4 through 7 show the results of both the segment analysis and the cluster analysis. The optimum thresholds for each of these context divisions are listed in the Threshold column of the tables. Tables 4, 5, and 6 show the segment analysis, where each threshold was determined by finding the value that maximized the sum of the percentage of correctly classified segments. For example, in the Suburban/Urban analysis (Table 5), the percentage of correctly classified Urban segments and percentage of correctly classified Suburban segments are averaged together to calculate the average percentage of correctly classified segments. These results are displayed for each of the four segmentation and buffer conditions. The highlighted cells are those considered as the best predictors of context classification for each split.

Table 4. Suburban-Urban / Urban Core Segment Analysis Thresholds

Measure	Threshold	Suburban-Urban Correct	Urban Core Correct	Average Correct	Threshold	Suburban-Urban Correct	Urban Core Correct	Average Correct
	0.25-Mile Length and 0.125-Mile Buffer				0.25-Mile Length and 0.25-Mile Buffer			
Population Density	5900	96%	100%	**98%**	5800	96%	98%	**97%**
Employment Density	2800	95%	92%	**94%**	2800	95%	97%	**96%**
Building Density	680	37%	95%	**66%**	1000	51%	98%	**75%**
Building Area Density	5,200,000	86%	96%	**91%**	5,200,000	93%	98%	**96%**
Street Density	180	90%	87%	**89%**	140	96%	97%	**97%**
Intersection Density	210	91%	92%	**92%**	210	97%	98%	**98%**
Block Length	380	76%	94%	**85%**	360	86%	97%	**92%**
	0.5 Mile-Length and 0.125-Mile Buffer				0.5 Mile-Length and 0.25-Mile Buffer			
Population Density	6000	96%	93%	**95%**	5900	97%	100%	**99%**
Employment Density	2800	95%	97%	**96%**	2800	95%	95%	**95%**
Building Density	680	36%	96%	**66%**	1000	52%	97%	**75%**
Building Area Density	5,900,000	92%	92%	**92%**	5,600,000	96%	96%	**96%**
Street Density	170	86%	95%	**91%**	140	96%	93%	**95%**
Intersection Density	200	89%	91%	**90%**	200	95%	99%	**97%**
Block Length	380	73%	90%	**82%**	360	80%	94%	**87%**

Table 5. Suburban / Urban Segment Analysis Thresholds

Measure	Threshold	Suburban Correct	Urban Correct	Average Correct	Threshold	Suburban Correct	Urban Correct	Average Correct
	0.25-Mile Length and 0.125-Mile Buffer				0.25-Mile Length and 0.25-Mile Buffer			
Population Density	500	35%	90%	**63%**	600	31%	80%	**56%**
Employment Density	200	35%	90%	**63%**	200	29%	93%	**61%**
Building Density	1000	51%	73%	**62%**	1000	52%	66%	**59%**
Building Area Density	2,800,000	45%	82%	**64%**	2,900,000	50%	69%	**60%**
Street Density	120	68%	70%	**69%**	90	70%	51%	**61%**
Intersection Density	130	75%	66%	**71%**	100	68%	53%	**61%**
Block Length	500	61%	77%	**69%**	480	66%	50%	**58%**
	0.5 Mile-Length and 0.125-Mile Buffer				0.5 Mile-Length and 0.25-Mile Buffer			
Population Density	500	35%	90%	**63%**	500	33%	93%	**63%**
Employment Density	250	38%	84%	**61%**	250	35%	87%	**61%**
Building Density	1000	50%	70%	**60%**	900	51%	75%	**63%**
Building Area Density	2,700,000	42%	79%	**61%**	2,100,000	37%	90%	**64%**
Street Density	120	67%	66%	**67%**	90	75%	66%	**71%**
Intersection Density	120	69%	69%	**69%**	110	77%	69%	**73%**
Block Length	480	60%	74%	**67%**	490	61%	81%	**71%**

The 0.50-mile segmentation with 0.25-mile buffer scenario performed the best in both urban segment analyses. For the Suburban-Urban / Urban Core analysis, population density was the best predictor of context, with a maximum average percentage of 98.5%.; this was due to correctly classifying 97% of the Suburban-Urban segments and 100% of the Urban Core segments. Other measures performed equally well, including intersection density with an average percentage of 97% and building area density with an average percentage of 96%.

Separating Urban segments from Suburban segments was more difficult because of the similar characteristics of the two contexts. Similarities such as building densities, block sizes, and building sizes are the reason for this lack of clear separation. Nonetheless, intersection density was most successful at separating the contexts; an intersection density of 110 intersections per square mile classified 61% of Suburban segments and 81% of Urban segments correctly, resulting in an average correct percentage of 73%. Street density was also an adequate separator, classifying 75% of Suburban segments and 66% of Urban segments correctly. Employment density performed the worst in this case, only classifying 35% of Suburban segments and 87% of Urban segments correctly.

A combination of measures was also examined for both steps of the urban classification to determine whether combinations of measures would perform better than a single measure alone. The best performing measures from Tables 4 and 5 were chosen and different combinations were tested. The results of these combinations are shown in Table 6. When separating Urban Core segments from other urban segments, a combination of intersection density and population density brought the average percentage of correct segments up to 99.3%, classifying nearly all segments correctly for this division. However, combining the two highest performing measures in the suburban/urban split did not improve the classification precision. The best result from this effort was that of combining intersection density and street density resulting in an average percentage of 72%, which did not exceed the 73% correctly classified segments that intersection density alone already achieved.

Table 6. Urban segment analysis using combined thresholds

Measures	Threshold 1	Threshold 2	Context 1 Correct	Context 2 Correct	Average Correct
Urban Core / Other urban segments					
1. Intersection Density 2. Building Area Density	200	5,600,000	100%	95%	**97.5%**
1. Intersection Density 2. Population Density	200	5900	100%	99%	**99.3%**
1. Building Area Density 2. Population Density	5,600,000	5900	99%	96%	**97.7%**
Suburban / Urban					
1. Intersection Density 2. Street Density	110	90	86%	58%	**71.7%**

For the Rural-Rural Town segment analysis (Table 7) the condition with 0.25-mile segmentation and 0.25-mile buffers performed the best. Of the measures within this condition, building density, building area density, and street density were all successful in separating Rural segments from Rural Town segments. A building density of 240 buildings per square mile resulted in an average percentage of 92.5%, a building area density of 590,000 square feet per square mile resulted in an average percentage of 92.5%, and a street density of 25 streets per square mile resulted in an average percentage of 93.5%. These are all adequate separators for the rural segment analysis.

Table 7. Rural / Rural Town Segment Analysis Thresholds

Measure	Threshold	Rural Correct	Rural Town Correct	Average Correct	Threshold	Rural Correct	Rural Town Correct	Average Correct
	0.25-Mile Length and 0.125-Mile Buffer				0.25-Mile Length and 0.25-Mile Buffer			
Population Density	60	48%	58%	**53%**	60	49%	60%	**55%**
Employment Density	25	45%	58%	**52%**	40	62%	56%	**59%**
Building Density	400	94%	85%	**90%**	240	93%	92%	**93%**
Building Area Density	950,000	92%	85%	**89%**	590,000	92%	93%	**93%**
Street Density	60	94%	86%	**90%**	25	94%	93%	**94%**
Intersection Density	40	85%	85%	**85%**	30	92%	91%	**92%**
Block Length	980	85%	84%	**85%**	960	91%	91%	**91%**
	0.5 Mile-Length and 0.125-Mile Buffer				0.5 Mile-Length and 0.25-Mile Buffer			
Population Density	60	45%	62%	**54%**	60	44%	65%	**55%**
Employment Density	20	24%	87%	**56%**	40	56%	59%	**58%**
Building Density	360	91%	83%	**87%**	250	91%	88%	**90%**
Building Area Density	1,000,000	91%	80%	**86%**	690,000	90%	85%	**88%**
Street Density	60	93%	85%	**89%**	30	94%	90%	**92%**
Intersection Density	40	81%	86%	**84%**	30	87%	90%	**89%**
Block Length	980	79%	84%	**82%**	940	82%	90%	**86%**

Even though the segment analysis percentages seem adequate, a review of the classified map showed that this process did not detect all manually classified Rural Town areas. It also classified other areas as Rural Towns that did not fit the Rural Town definition of having a street network. For this reason, a cluster analysis was performed to ensure all rural towns were detected from a given threshold. The 0.25-mile segmentation and 0.125-mile buffer condition performed best for most metrics, namely intersection density, building density, and building area density, but the 0.50-mile segmentation and 0.125-mile buffer condition performed better with street density and block density. The results of the cluster analysis are shown in Table 8. In this analysis, intersection density outperformed the other measures, resulting in only 10 false positive clusters.

Table 8. Rural / Rural Town Cluster Analysis Thresholds

Measure	Threshold	False Positive Rural Town Clusters	Threshold	False Positive Rural Town Clusters
	0.25-Mile Length and 0.125-Mile Buffer		0.25-Mile Length and 0.25-Mile Buffer	
Population Density	35	**Most of map**	35	**Most of map**
Employment Density	15	**Most of map**	15	**Most of map**
Building Density	710	**25**	290	**55**
Building Area Density	1,400,000	**60**	750,000	**55**
Street Density	65	**120**	15	**200**
Intersection Density	185	**10**	50	**35**
Block Length	1150	**250**	2090	**300**
	0.5 Mile-Length and 0.125-Mile Buffer		0.5 Mile-Length and 0.25-Mile Buffer	
Population Density	35	**Most of map**	35	**Most of map**
Employment Density	15	**Most of map**	15	**Most of map**
Building Density	500	**65**	340	**40**
Building Area Density	1,100,000	**80**	860,000	**40**
Street Density	80	**50**	20	**130**
Intersection Density	135	**30**	60	**25**
Block Length	1030	**150**	2090	**300**

Similar to the urban segments, different combinations of the best performing measures were tested to determine whether the classification could be improved. These results are displayed in Table 9. Two different combinations of measures improved the rural classification: intersection density paired with building density and intersection density paired with building area density. The first of these resulted in three false positives, and the other only resulted in two false positive areas. This further improved the already well performing classification from intersection density, which resulted in 10 false positive areas.

Table 9. Rural segment analysis using combined thresholds

Rural / Rural Town			
Measures	Threshold 1	Threshold 2	False Positives
1. Intersection Density 2. Building Density	185	710	**3**
1. Intersection Density 2. Building Area Density	185	1,400,000	**2**
1. Building Density 2. Street Density	710	65	**100**

4.2 APPLICATION OF THRESHOLDS

Out of the four scenarios tested, rural areas were best classified using the 0.25-mile segmentation and 0.125-mile buffer scenario and urban areas were best classified using the 0.50-mile segmentation and 0.25-mile buffer scenario. From these scenarios, Urban Core segments were best identified as having a population density exceeding 5,900 residents per square mile and an intersection density exceeding 200 intersections per square mile, while Urban segments were best differentiated from Suburban segments using an intersection density threshold of 110 intersections per square mile. Rural Towns were best identified as having an intersection density exceeding 185 intersections per square mile and building area density exceeding 1,400,000 square feet per square mile.

These thresholds were used to create an automated context classification of KYTC District 7 for visual inspection. The flow chart in Figure 8 shows the process used to determine the context of each segment. First, a context was identified as belonging to a rural or urbanized area according to the U.S. Census Urbanized Area Boundaries. Once split up, rural segments were copied into one Excel spreadsheet and urban segments were copied into another. Rural segments were then classified as either Rural or Rural Town based on their intersection density and building area density. If the densities of the segment were both greater than the corresponding thresholds, then it was classified as Rural Town; otherwise, it was classified as Rural. Urban segments were then classified similarly using a two-step process to first filter out the Urban Core segments, and then classify the remaining urban segments. In the urban spreadsheet, an “if” statement classified the segment as Urban Core if its densities exceeded the intersection density and population density thresholds. A second series of “if” statements then determined the final classification. If the segment was previously identified as Urban Core, the context was automatically set as such; if not, the segment was classified as Urban if its intersection density was above the threshold and was classified as Suburban otherwise.

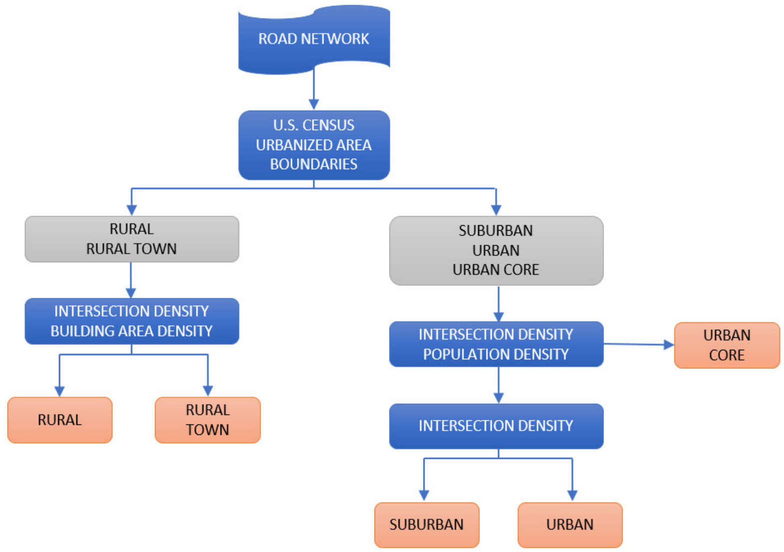


Figure 8. Classification automation flow chart

The two maps in Figure 9 compare the automatic classification to the manual classification, showing areas the classification did well and areas the classification could be improved. As mentioned before, characteristics of the Suburban context like building setback, block length, and building density vary greatly. This makes Suburban characteristics blend with Urban characteristics resulting in Urban segments to be classified among predominantly Suburban segments (Figure 9b).

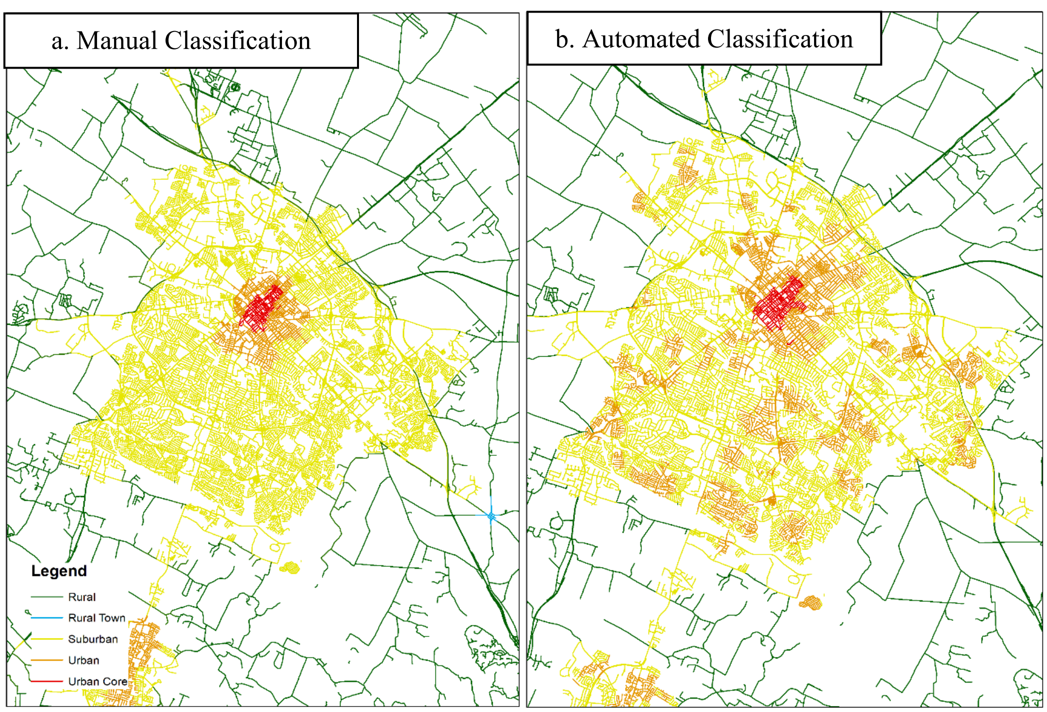


Figure 9. Manual vs. automated classification

Upon completion of the automated classification, a visual inspection is recommended to ensure correct and accurate classification and serve as a quality control effort as well. When using this method, a practitioner would need to examine hot spots of Urban areas, Urban and Urban Core boundaries, and Rural Town areas to ensure they are classified correctly. This would need to be followed by a manual adjustment of these misclassified segments. The automated process provides practitioners with a good start of the context classification, ensuring that the process becomes less intimidating and the classification is more consistent.

CHAPTER 5. CONCLUSION

The overall goal of this project was to create an automated classification process that would assign the appropriate context to each roadway segment in an area, based on that area's characteristics. This was done in a four-step process that involved manual classification of roads in the study area, segmentation of roads and creation of each segment's influence area, ArcMap processing to divide rural and urban segments and to calculate measures, and a sensitivity analysis to determine which measures were useful. Four variations of the buffer width and length were tested to ensure results were not skewed based on an arbitrary influence area. Measures tested were population density, employment density, intersection density, building density, building area density, street density, and average block length.

The sensitivity analysis determined that urban segments were best divided by the 0.50-mile length and 0.25-mile width buffer condition, while rural segments were best divided by the 0.25-mile length and 0.125-mile width combination. For the study area used here, this project concluded that Urban Core segments could be best identified by intersection density and population density. Using an intersection density threshold of 200 intersections per square mile and a population density threshold of 5,900 residents per square mile separated 99% of Urban Core segments from other urban segments. It was also found that Urban and Suburban segments were more difficult to separate because of the varying characteristics of the Suburban context; nonetheless, Urban and Suburban segments were best separated using an intersection density threshold of 110 intersections per square mile. Finally, this study revealed that Rural Town clusters were successfully identified using an intersection density threshold of 185 intersections per square mile and a building area density threshold of 1,400,000 square feet per square mile, as this combination identified all Rural Town areas correctly and only identified two Rural areas as Rural Town.

There is future research potential in applying these processes, measures, and thresholds to other districts of Kentucky and even in other states to automatically classify roadways based on context. Aside from the mountainous region of eastern Kentucky, much of the topography and development in the state is quite similar to that of KYTC District 7, so the thresholds identified may be applicable to these areas. Even though this may not be the case nationwide, the final measures identified would likely still perform well in differentiating contexts. State agencies could perform an analysis on these measures to find thresholds that fit their study area. The manual classification of KYTC District 7 only took around 12 hours to complete and contained over 7,200 miles of roadway and thus, the manual classification process would be very feasible for state agencies to complete. The thresholds found in the analysis could then be used in a statewide automatic classification.

This would be beneficial because of the enormous amount of information that is gained from understanding the context of a roadway. Context informs of the roadway's likely user groups and equips the practitioner with an idea of what facilities are needed to accommodate these users. Furthermore, it provides insight to the access and mobility demands of the area and of the operating speeds of the road. From this, designers can implement necessary and customized approaches to mold the area to the community and can take actions to develop appropriate driver speeds in an area where the current speed may not be safe for all users. In the future, context may even be able to provide a "toolbox" of effective, low-cost, context-specific projects to improve safety, mobility, and access, similar to the approach the Maryland DOT has taken with their context guidance. Practitioners may compare the context to the current facility to determine whether the facility serves the needs of the community in the first place. They may also be able to compare the current context to the context they expect or want an area to feature in the future. They may be able to implement projects that will lead an area to grow or change in a way that better suits the community.

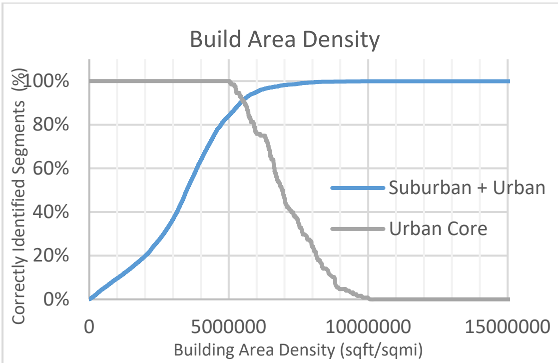
The benefits of automating context classification are familiarity, speed, and consistency in the classification. Using a data-driven approach rather than an entirely visual inspection removes any initial guessing on the part of the practitioner, making the process more approachable when considering classifying an entire district or state. The automated approach gives the practitioner a starting point and they are only required to perform a visual check of the boundaries and locations of different context areas at the end of the process. Further, this also makes the classification process faster, making a state-wide classification less expensive and more approachable. Finally, it improves the consistency of the classification. Different practitioners would likely classify a system differently when using a strictly visual classification; even a single practitioner would likely classify some similar areas differently, since the human mind incorporates opinion into judgement. A data-driven approach to context provides consistency in that it can identify which areas are similar to one another, giving the practitioner a starting point and reducing the pressure of visually comparing so many different communities based on qualitative descriptors.

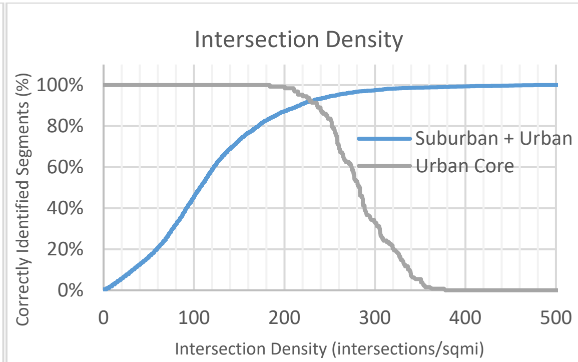
As previously mentioned, areas of potential future research include testing the applicability of this automated process, both throughout Kentucky and nationwide. Past this, research may seek to refine the automated classification through different measures, segmentation, etc. It may also seek to automate the process further using a ModelBuilder plan in ArcMap, so that the segmentation and calculation processes could be performed in the click of a button after loading in the data.

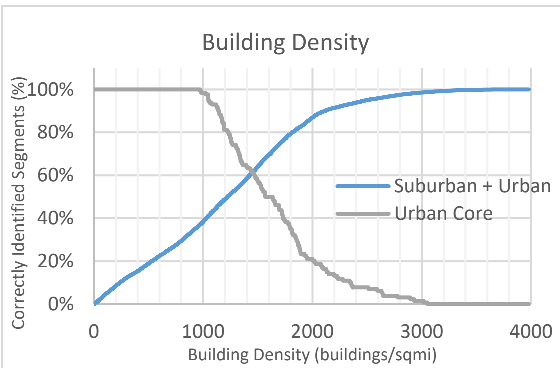
APPENDICES

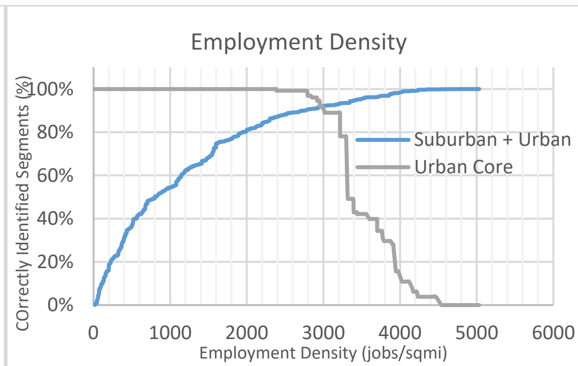
APPENDIX 1. SEGMENT ANALYSIS CHARTS

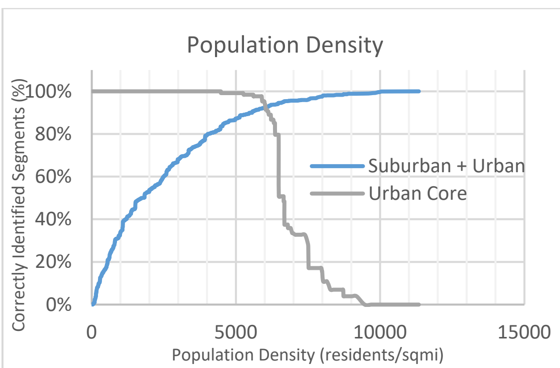
1.1 0.25-Mile Segments with 0.25-Mile Buffers – Suburban-Urban / Urban Core Separation

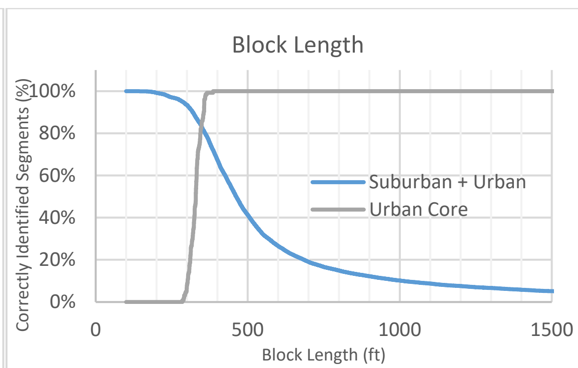


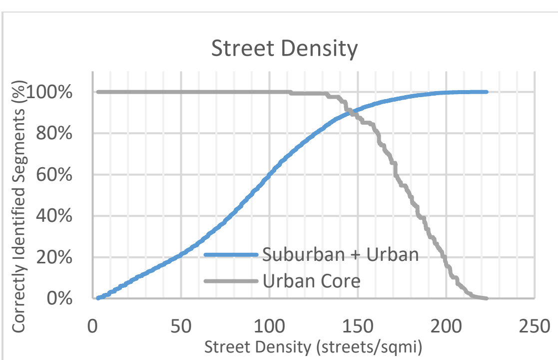




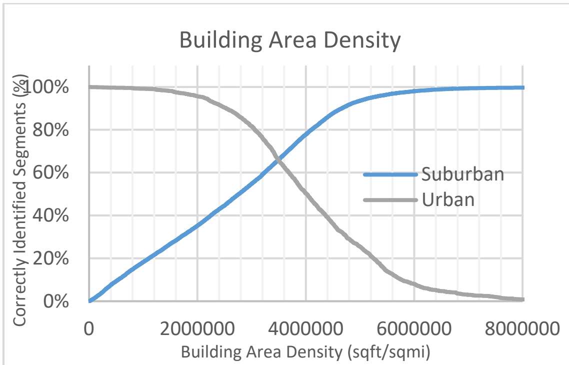


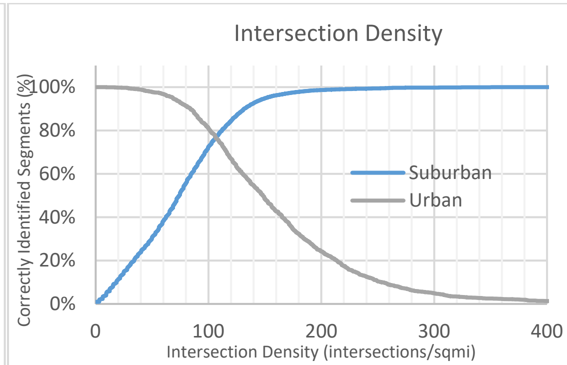


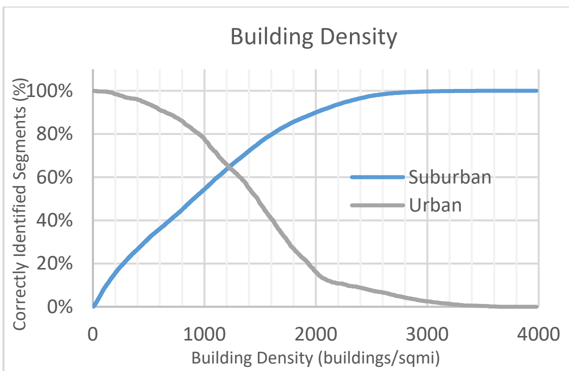


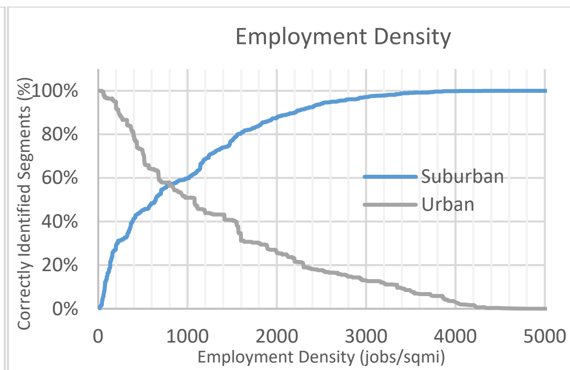


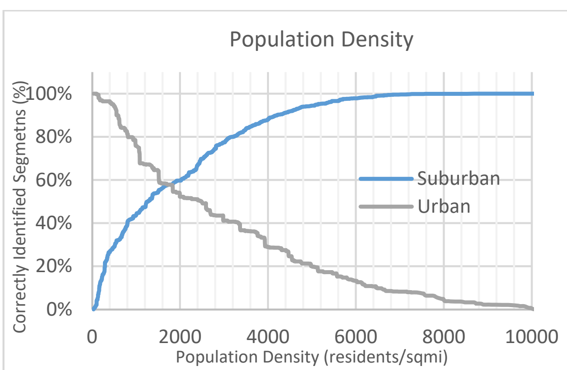
1.2 0.25-Mile Segments with 0.25-Mile Buffers – Suburban/Urban Separation

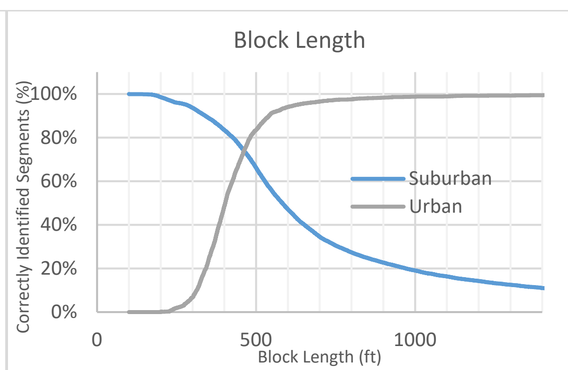


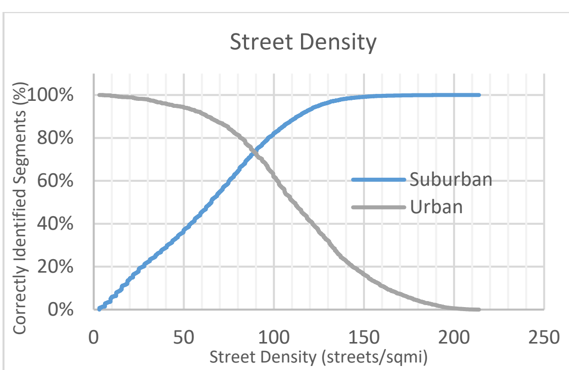




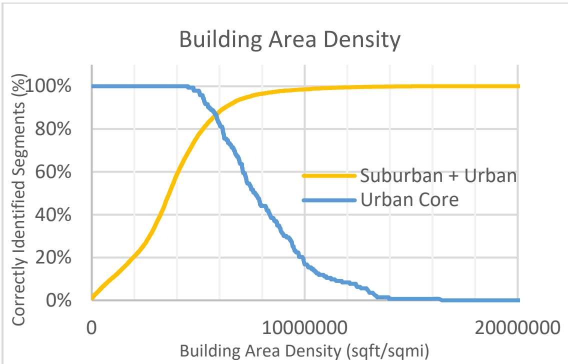


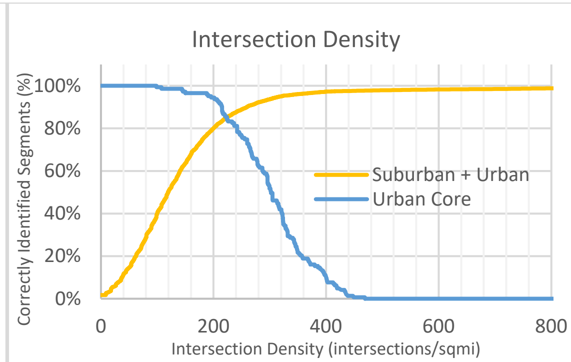


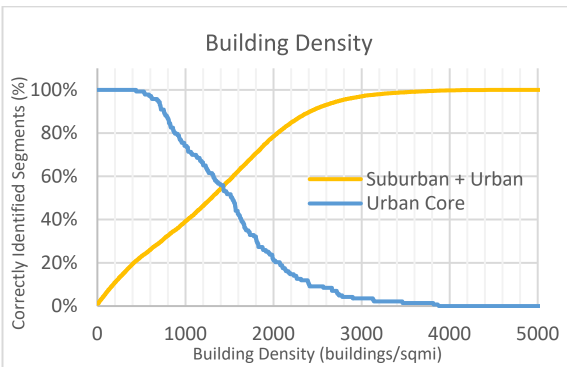


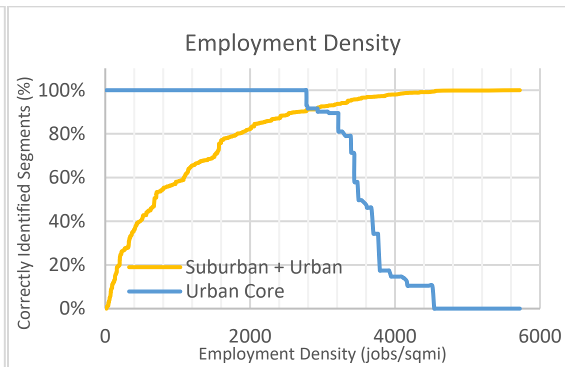


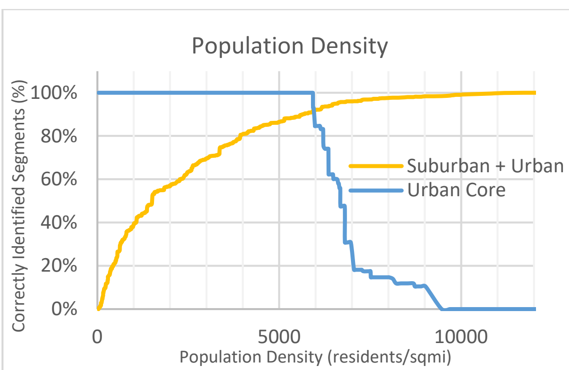
1.3 0.50-Mile Segments with 0.25-Mile Buffers – Suburban-Urban/Urban Core Separation

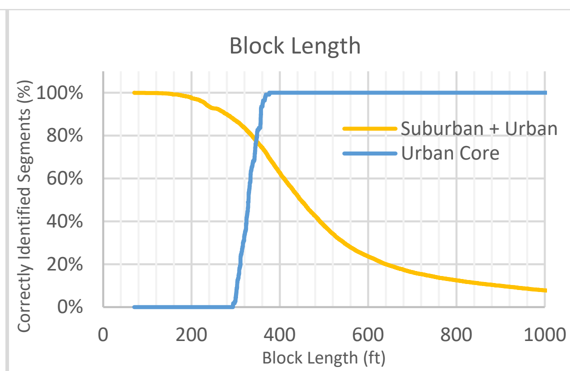


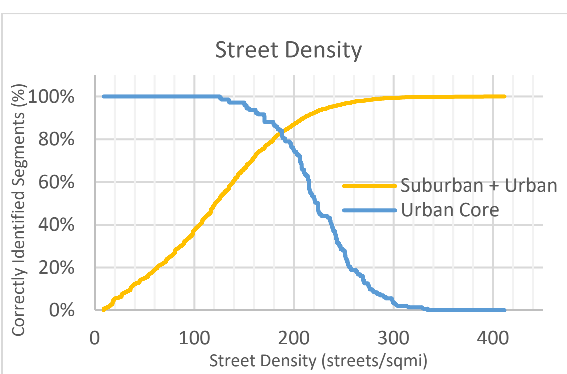




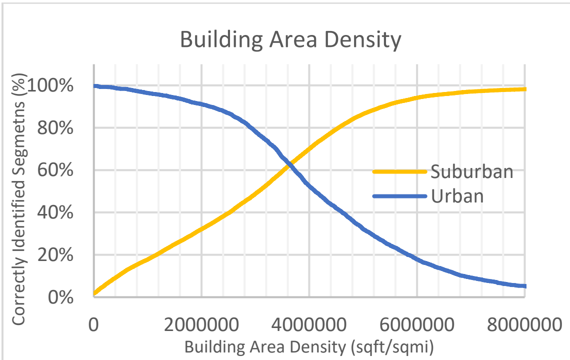


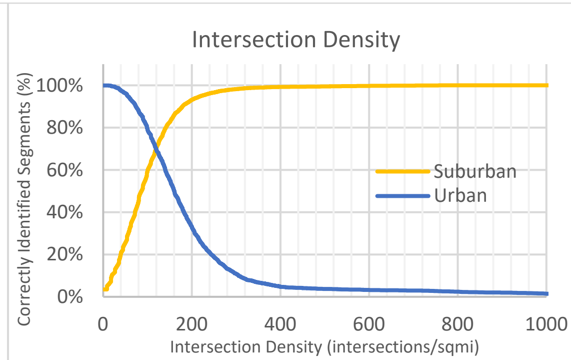


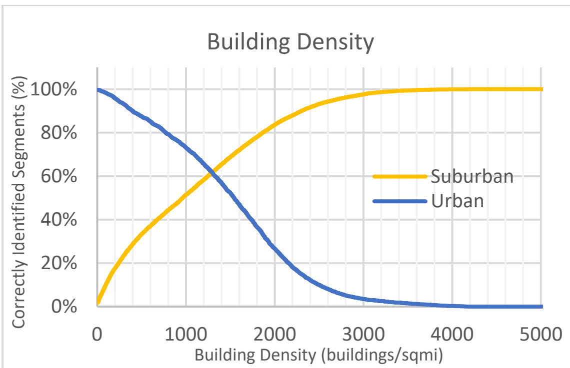


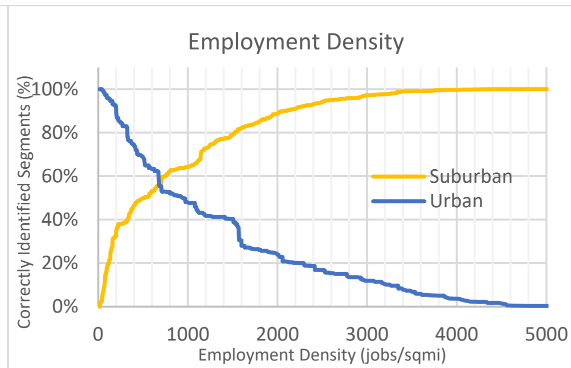


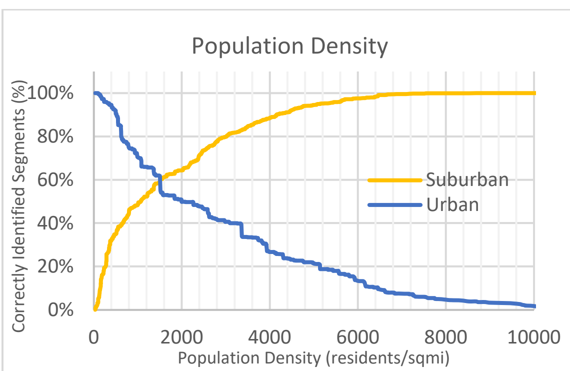
1.4 0.50-Mile Segments with 0.25-Mile Buffers – Suburban/Urban Separation

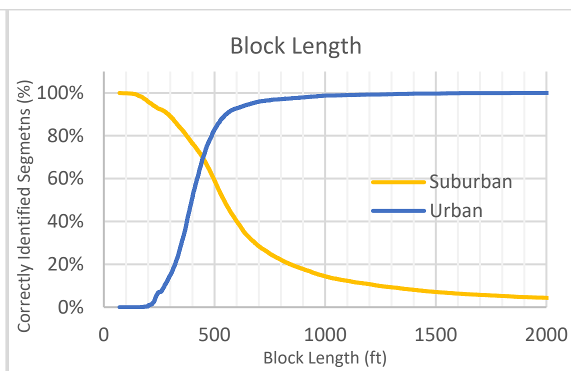


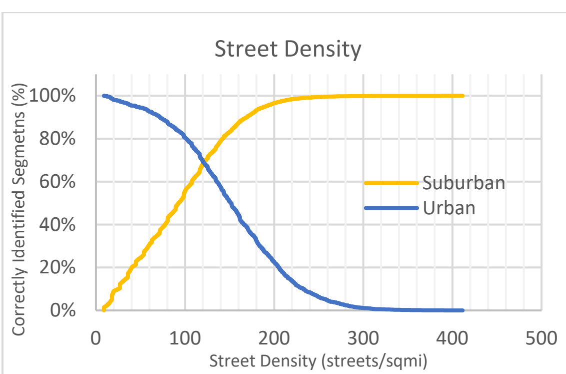




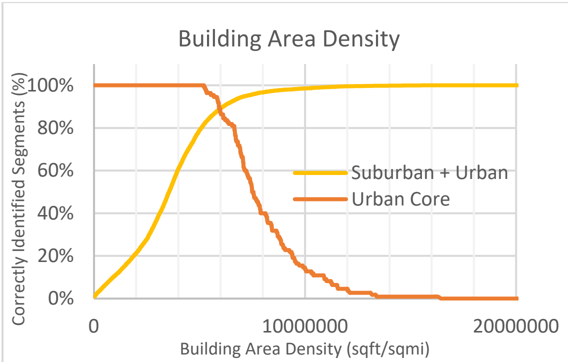


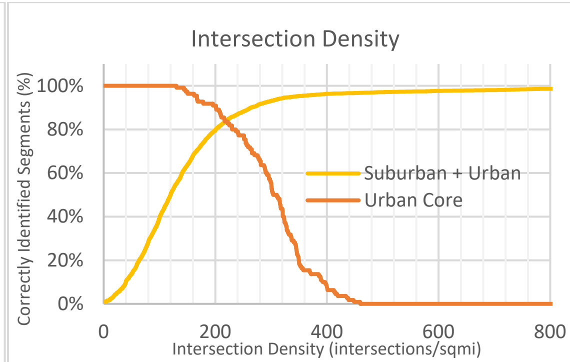


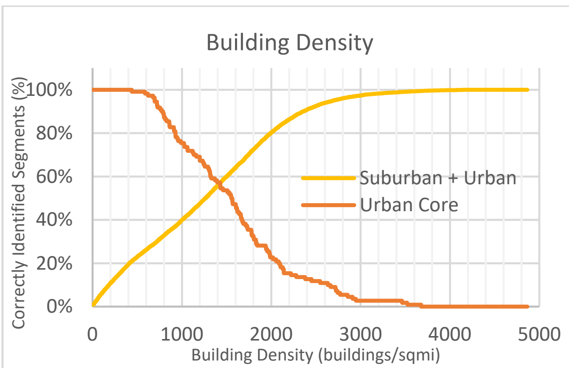


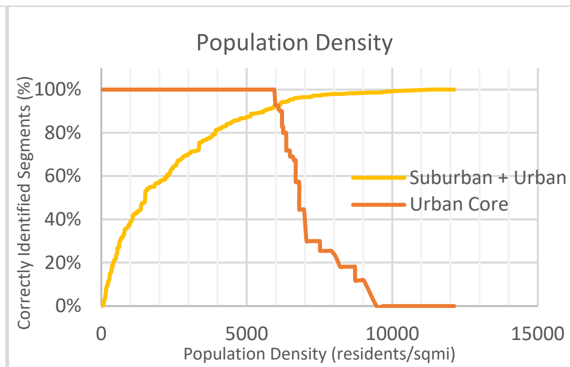


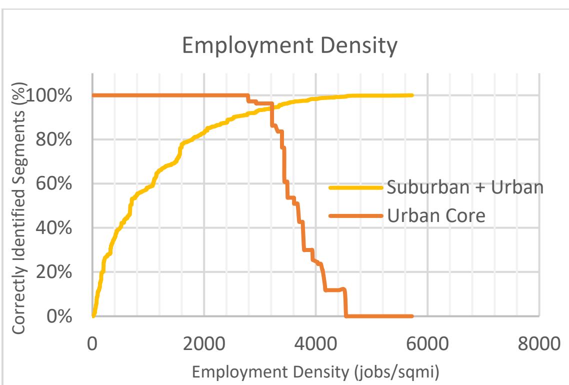
1.5 0.50-Mile Segments with 0.125-Mile Buffers – Suburban-Urban/Urban Core Separation

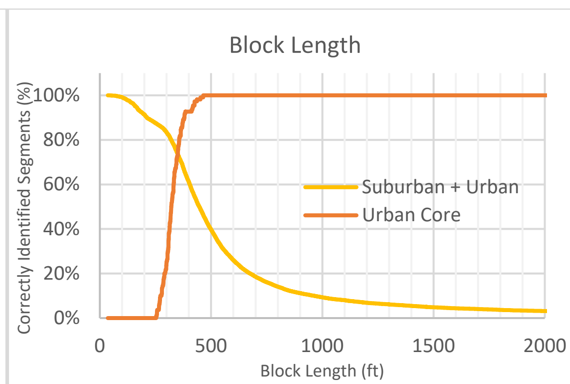


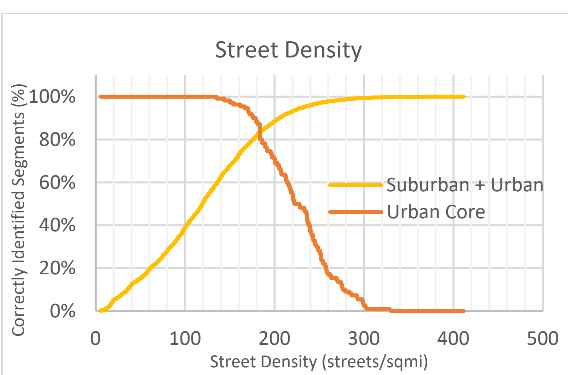




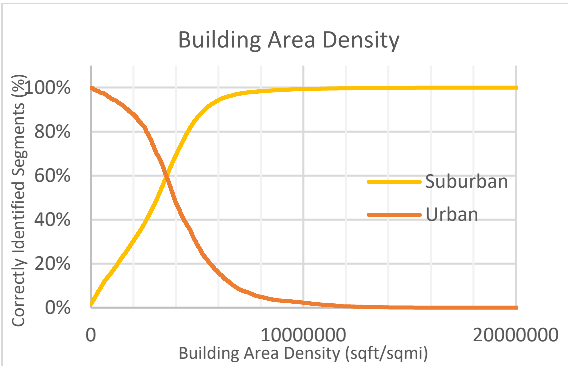


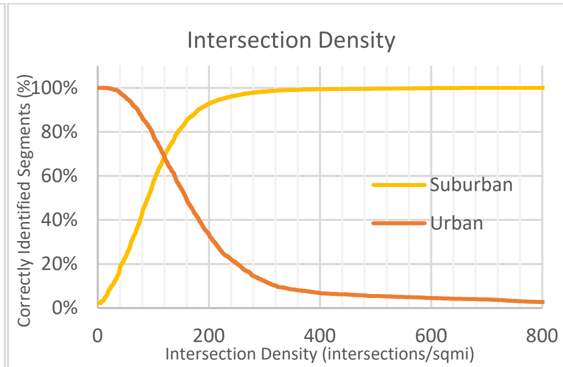


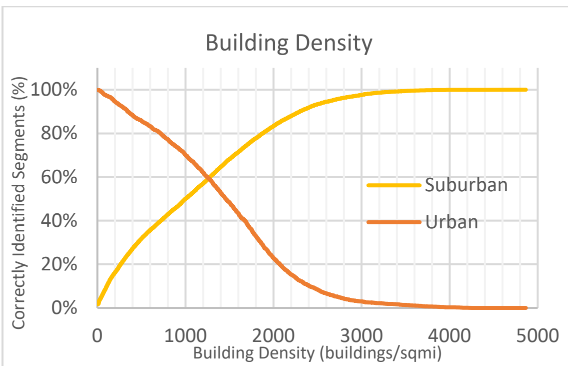


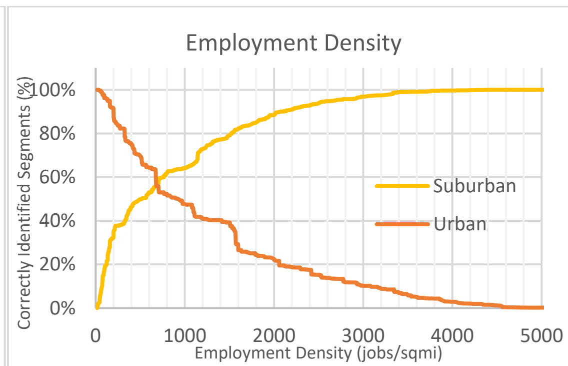


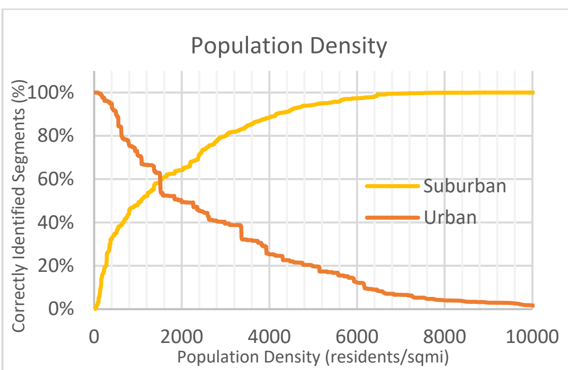
1.6 0.50-Mile Segments with 0.125-Mile Buffers – Suburban/Urban Separation

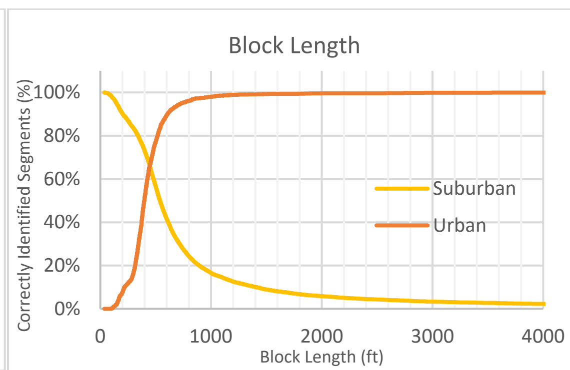


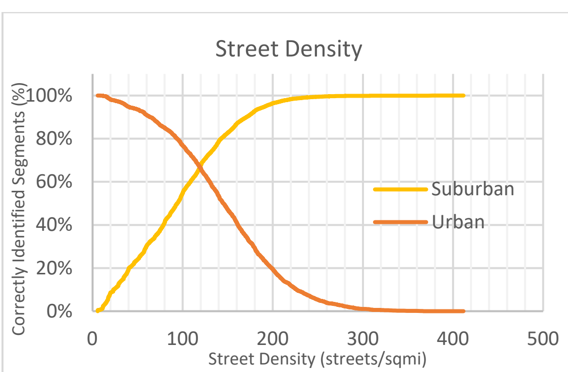




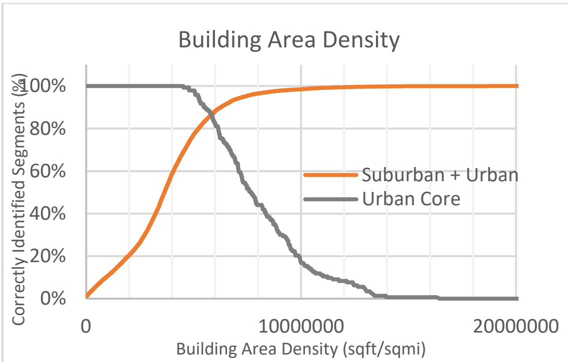


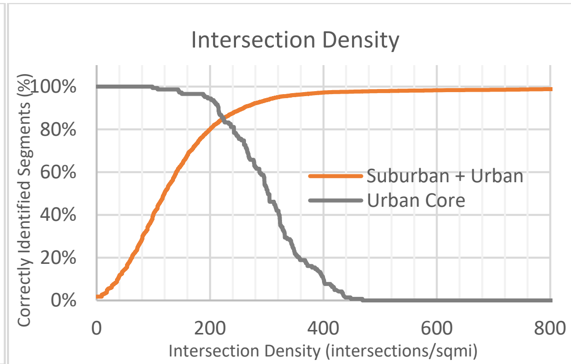


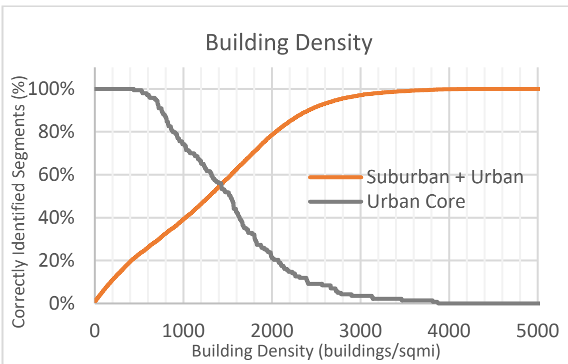


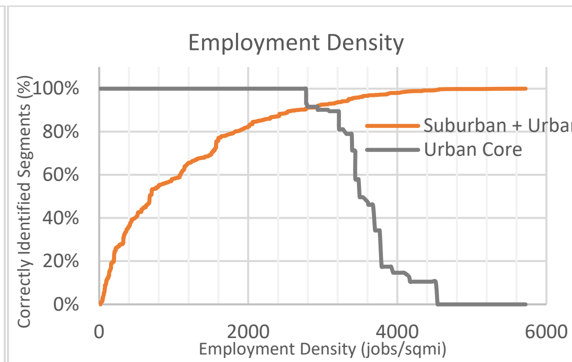


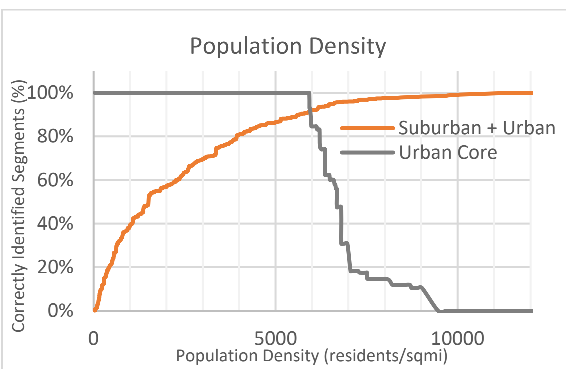
1.7 0.25-Mile Segments with 0.125-Mile Buffers – Suburban-Urban/Urban Core Separation

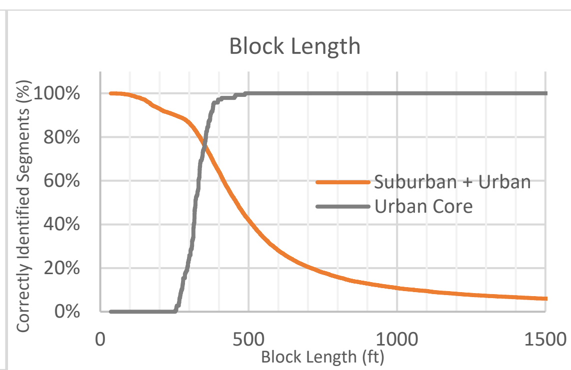


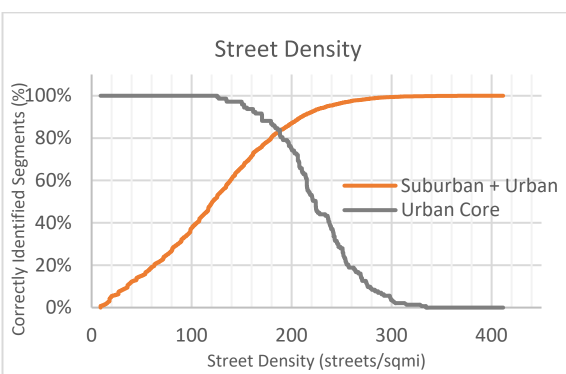




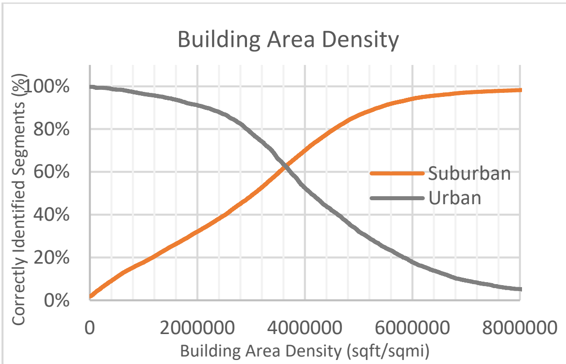


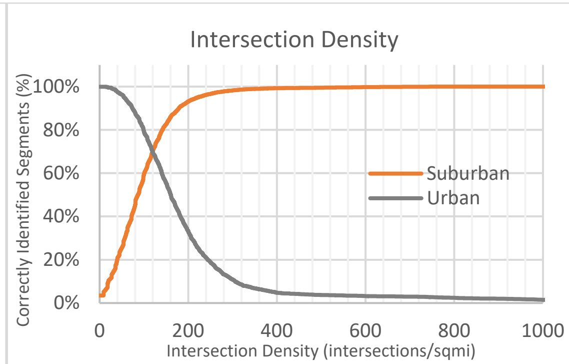


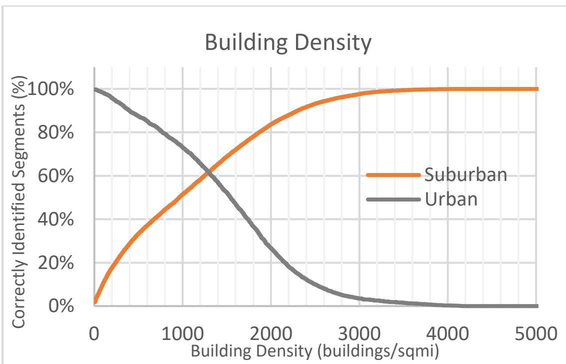


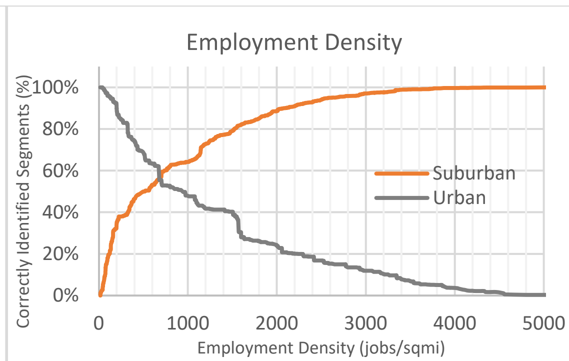


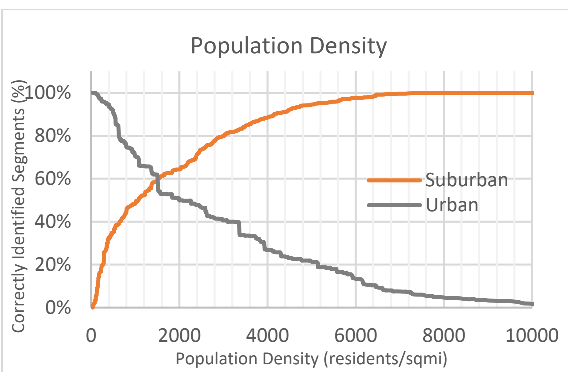
1.8 0.25-Mile Segments with 0.125-Mile Buffers – Suburban/Urban Separation

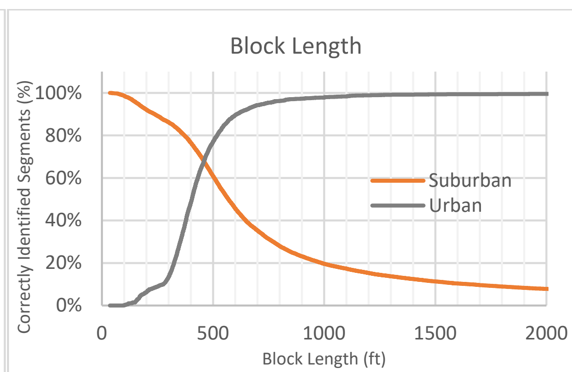


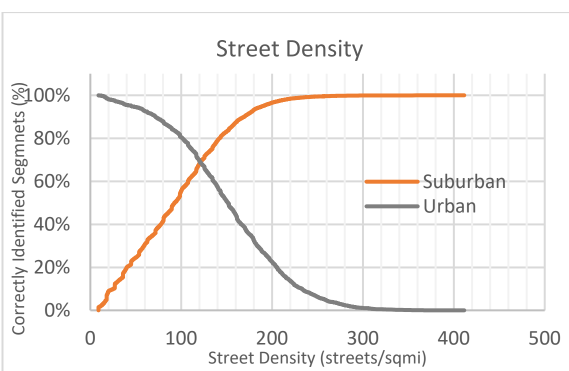




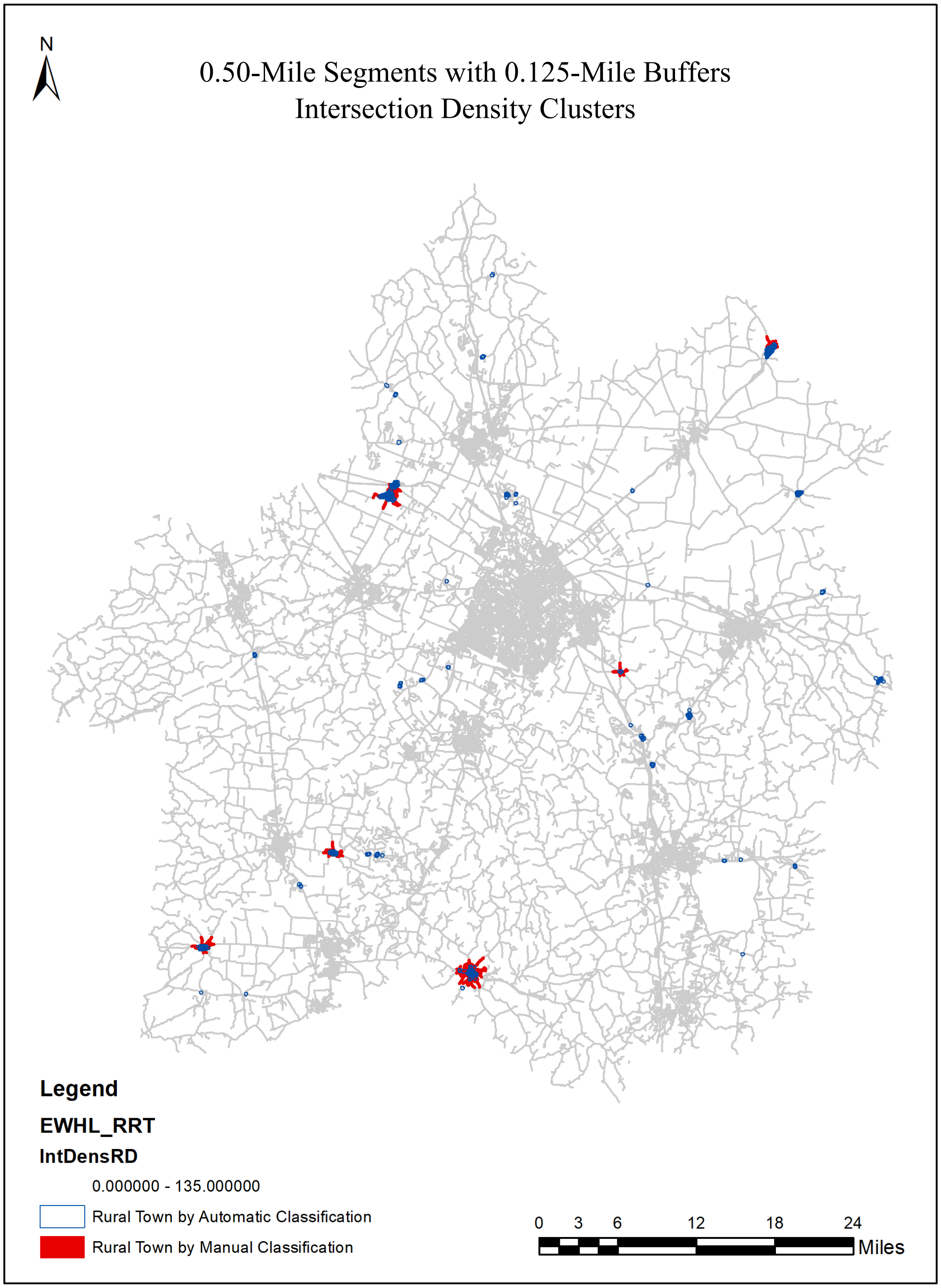


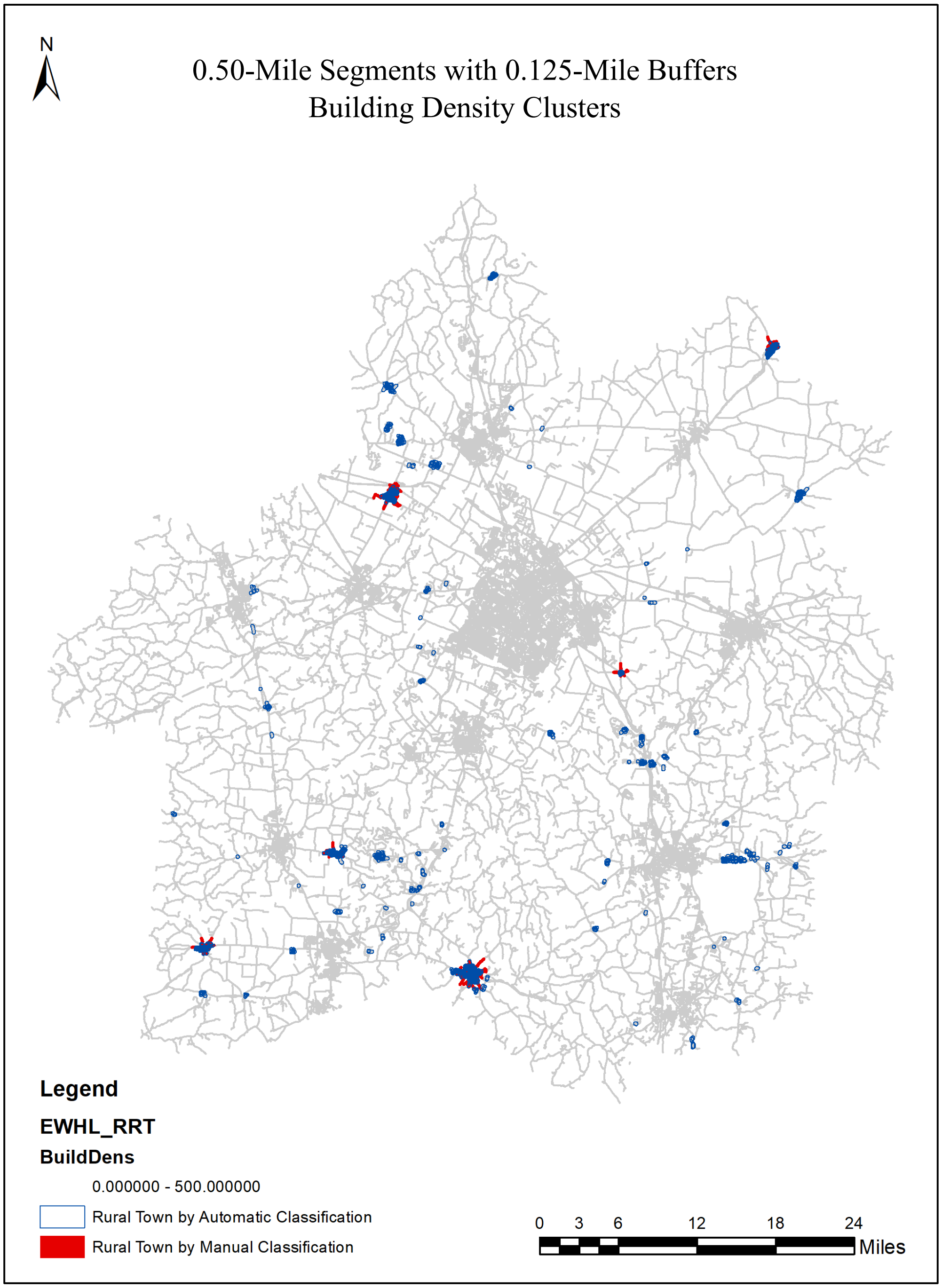


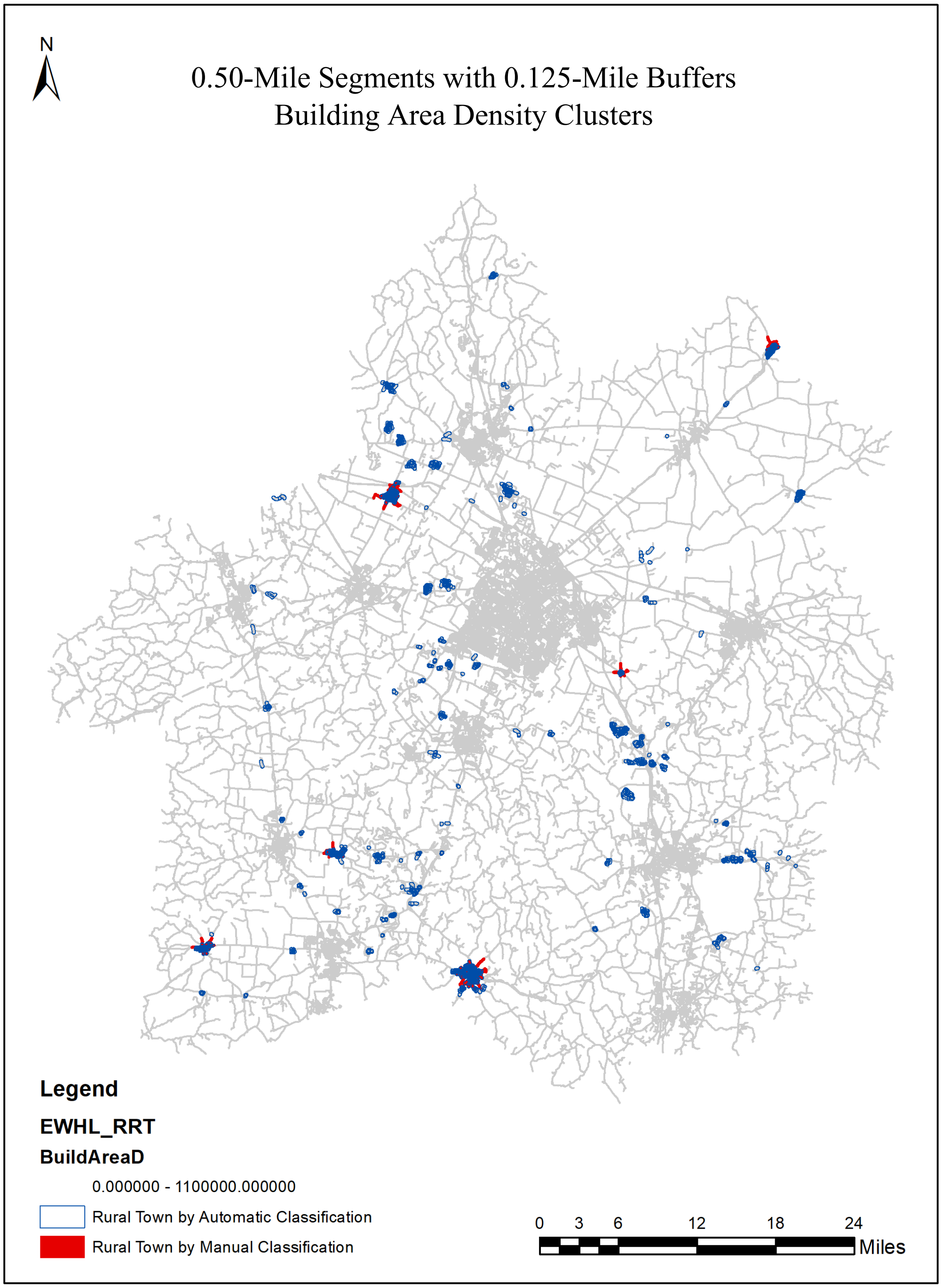


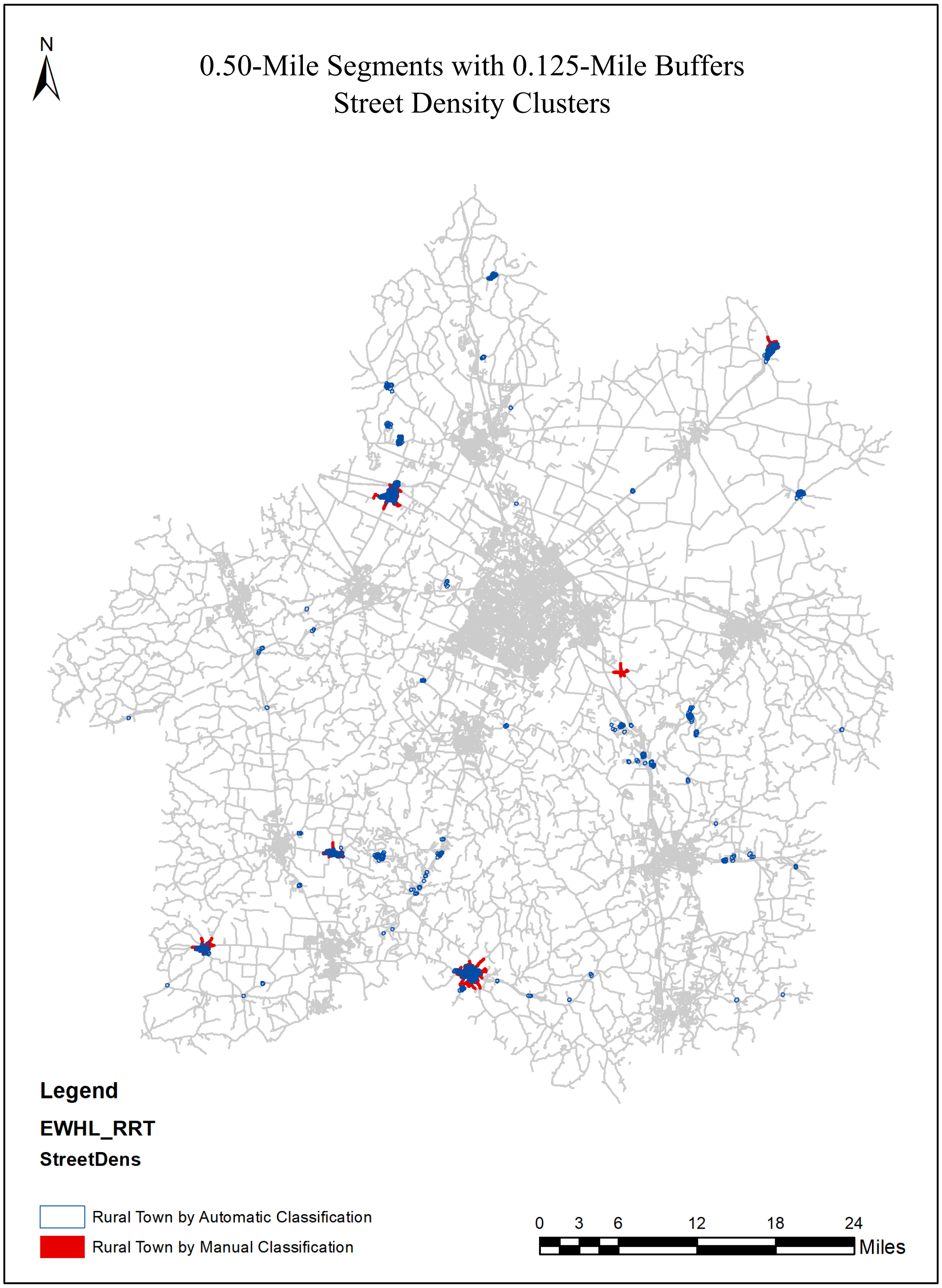


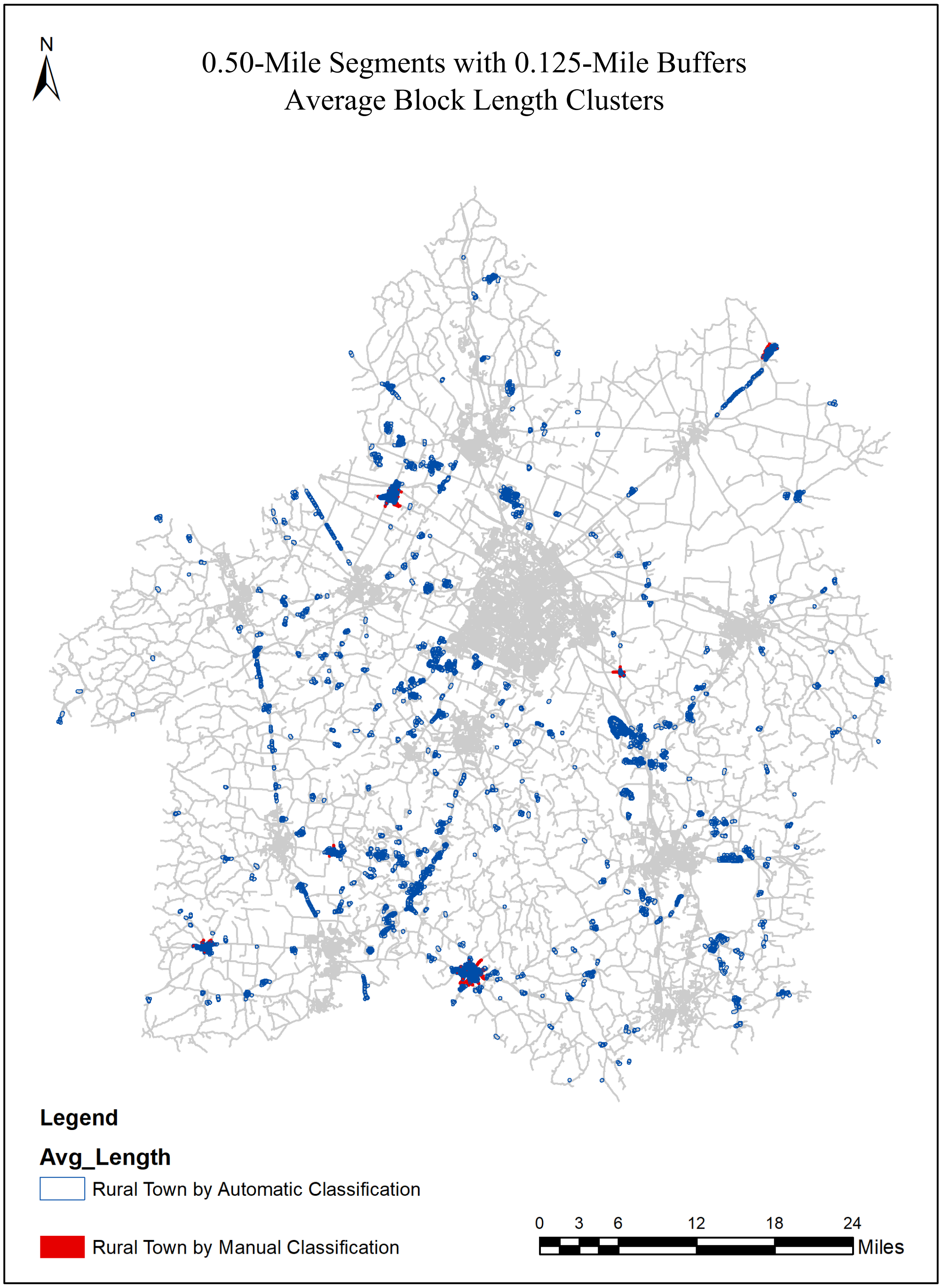
APPENDIX 2. CLUSTER ANALYSIS MAPS

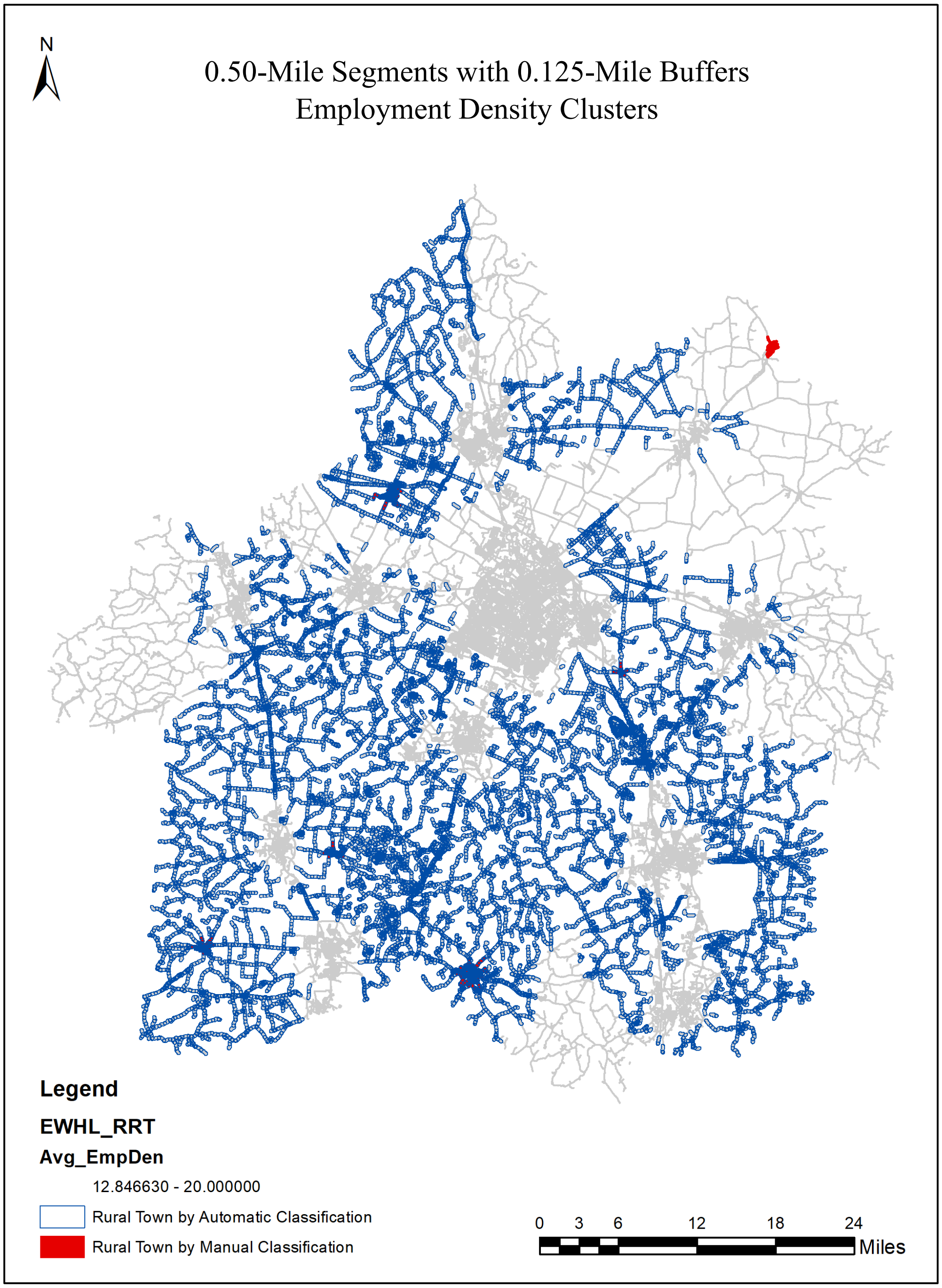


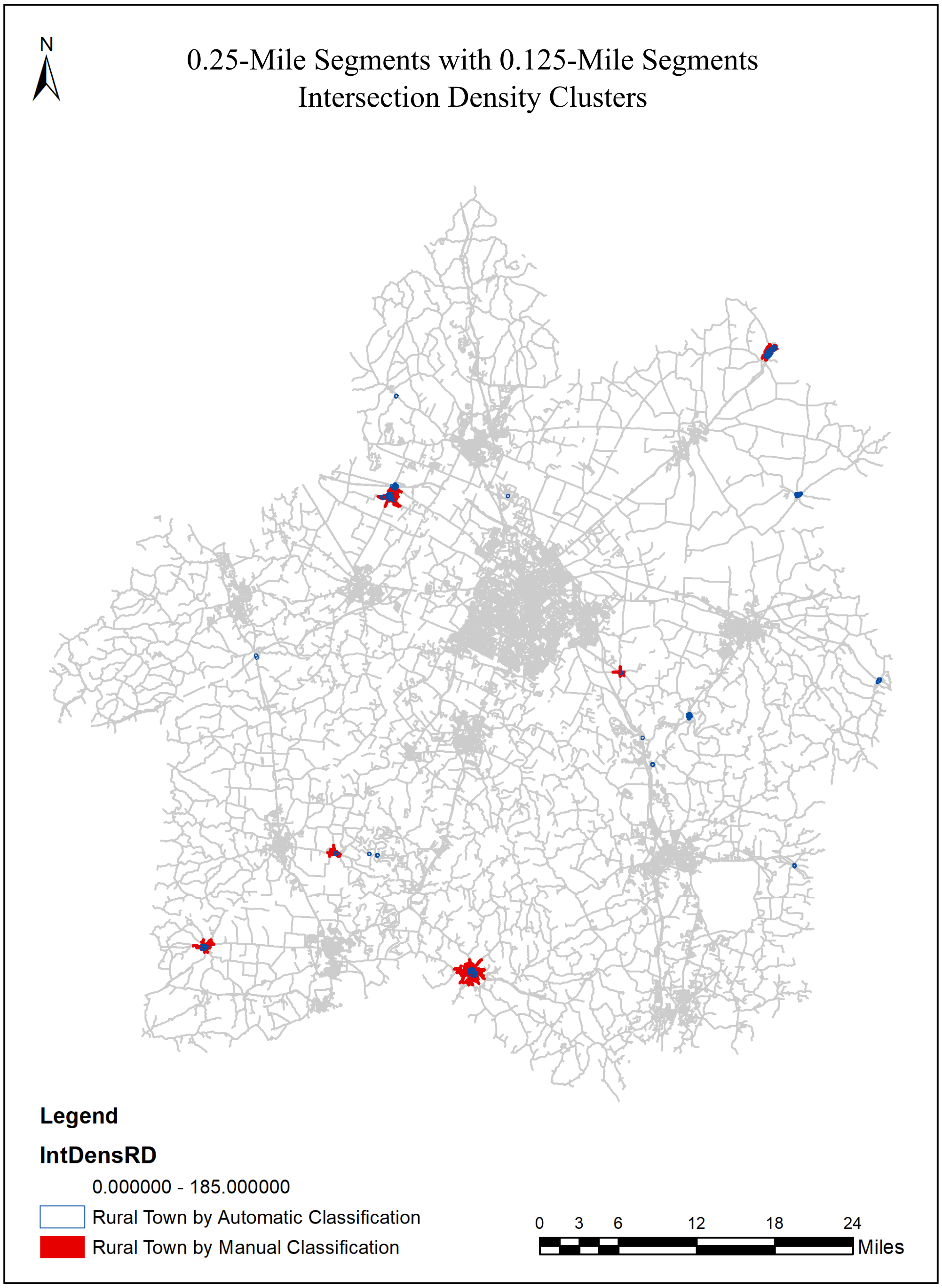

N
0.50-Mile Segments with 0.125-Mile Buffers
Building Density Clusters
Legend
EWHL_RRT
BuildDens
0.000000 - 500.000000
Rural Town by Automatic Classification
Rural Town by Manual Classification
0 3 6 12 18 24
Miles

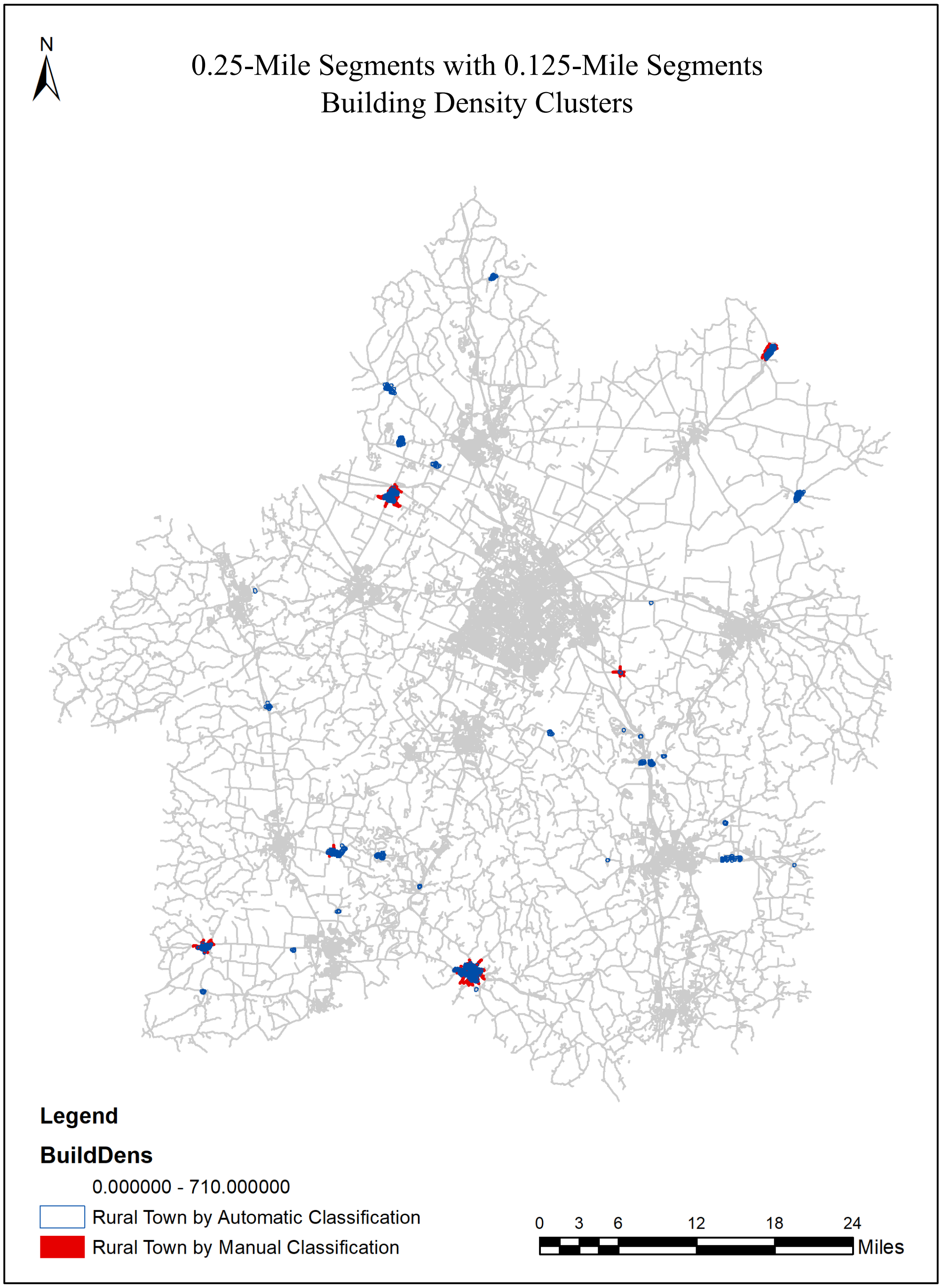

N
0.50-Mile Segments with 0.125-Mile Buffers
Building Area Density Clusters
Legend
EWHL_RRT
BuildAreaD
0.000000 - 1100000.000000
Rural Town by Automatic Classification
Rural Town by Manual Classification
0 3 6 12 18 24
Miles


N
0.50-Mile Segments with 0.125-Mile Buffers
Street Density Clusters
Legend
EWHL_RRT
StreetDens
Rural Town by Automatic Classification
Rural Town by Manual Classification
0
3
6
12
18
24
Miles


N
0.50-Mile Segments with 0.125-Mile Buffers
Average Block Length Clusters
Legend
Avg_Length
Rural Town by Automatic Classification
Rural Town by Manual Classification
0 3 6 12 18 24
Miles


N
0.50-Mile Segments with 0.125-Mile Buffers
Employment Density Clusters
Legend
EWHL_RRT
Avg_EmpDen
12.846630 - 20.000000
Rural Town by Automatic Classification
Rural Town by Manual Classification
0 3 6 12 18 24
Miles


N
0.25-Mile Segments with 0.125-Mile Segments
Intersection Density Clusters
Legend
IntDensRD
0.000000 - 185.000000
Rural Town by Automatic Classification
Rural Town by Manual Classification
0 3 6 12 18 24
Miles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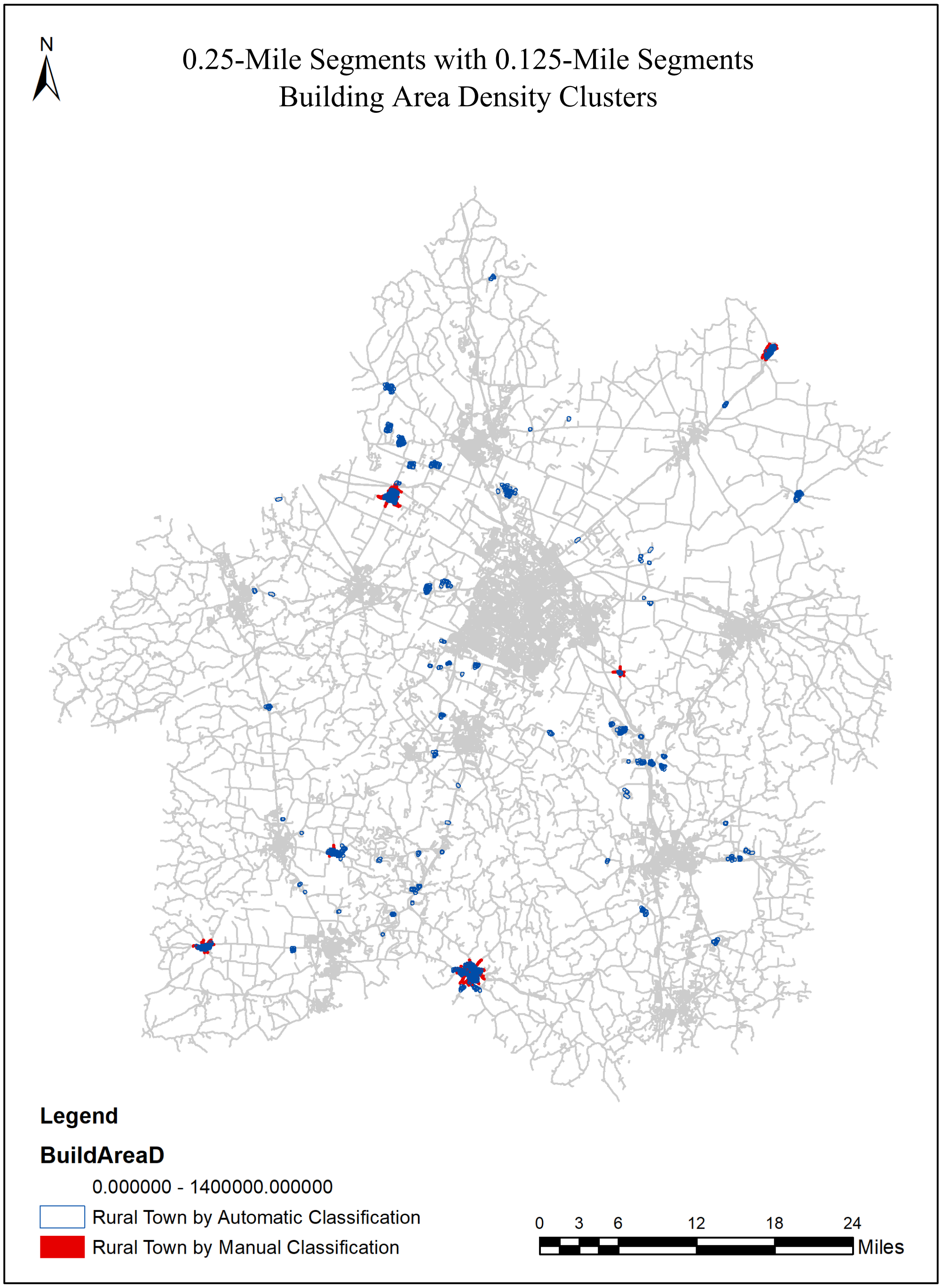
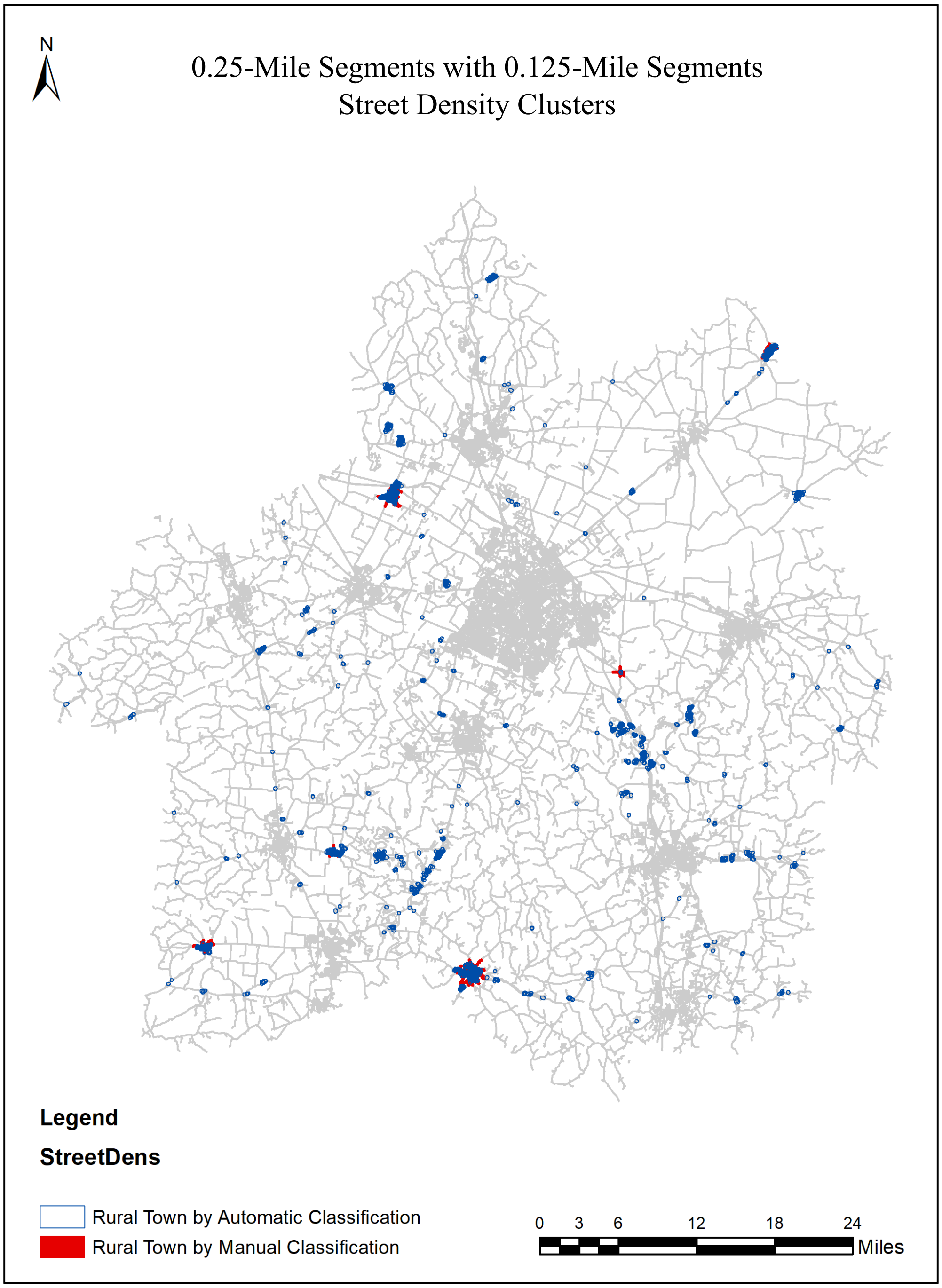
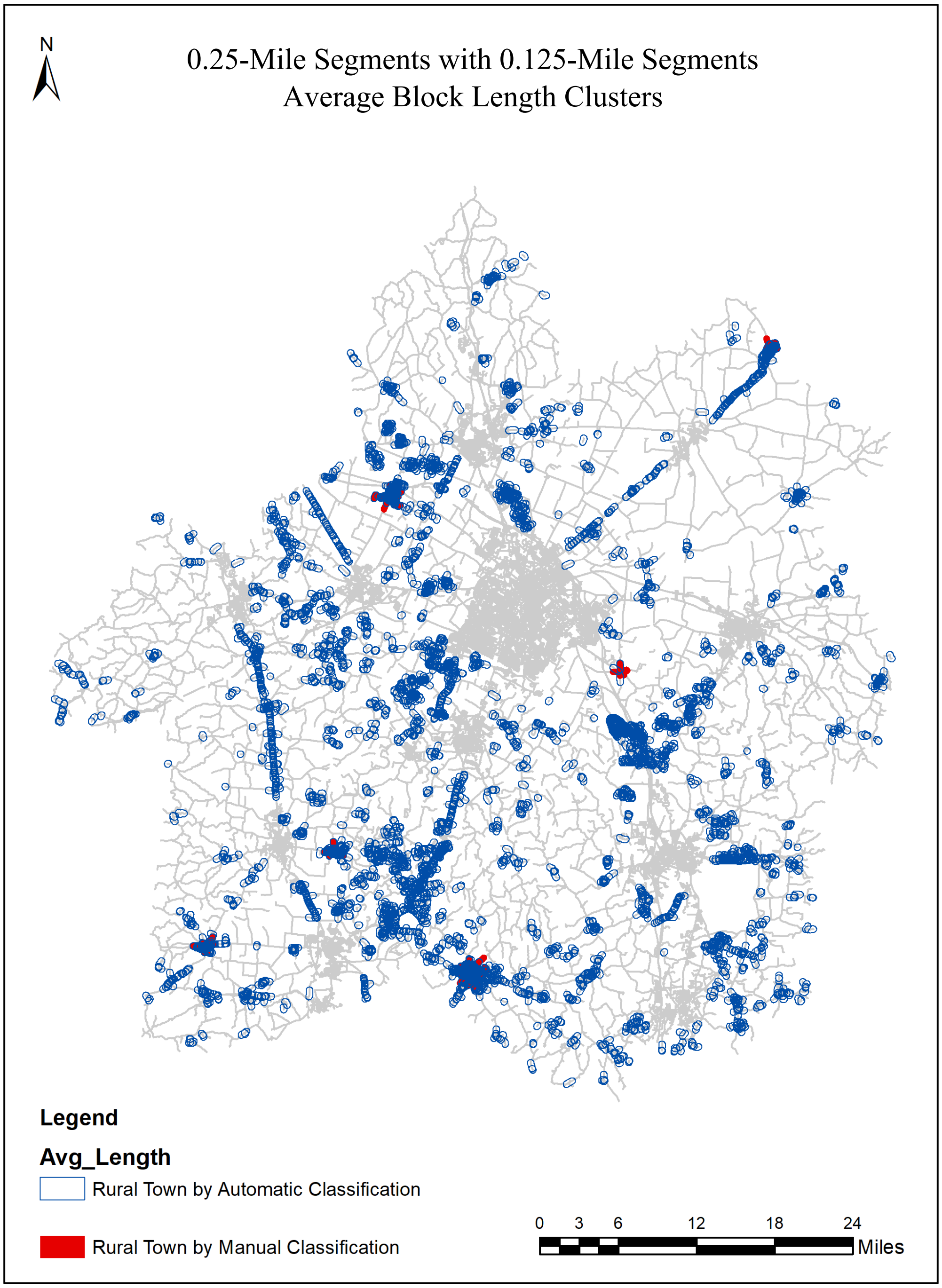
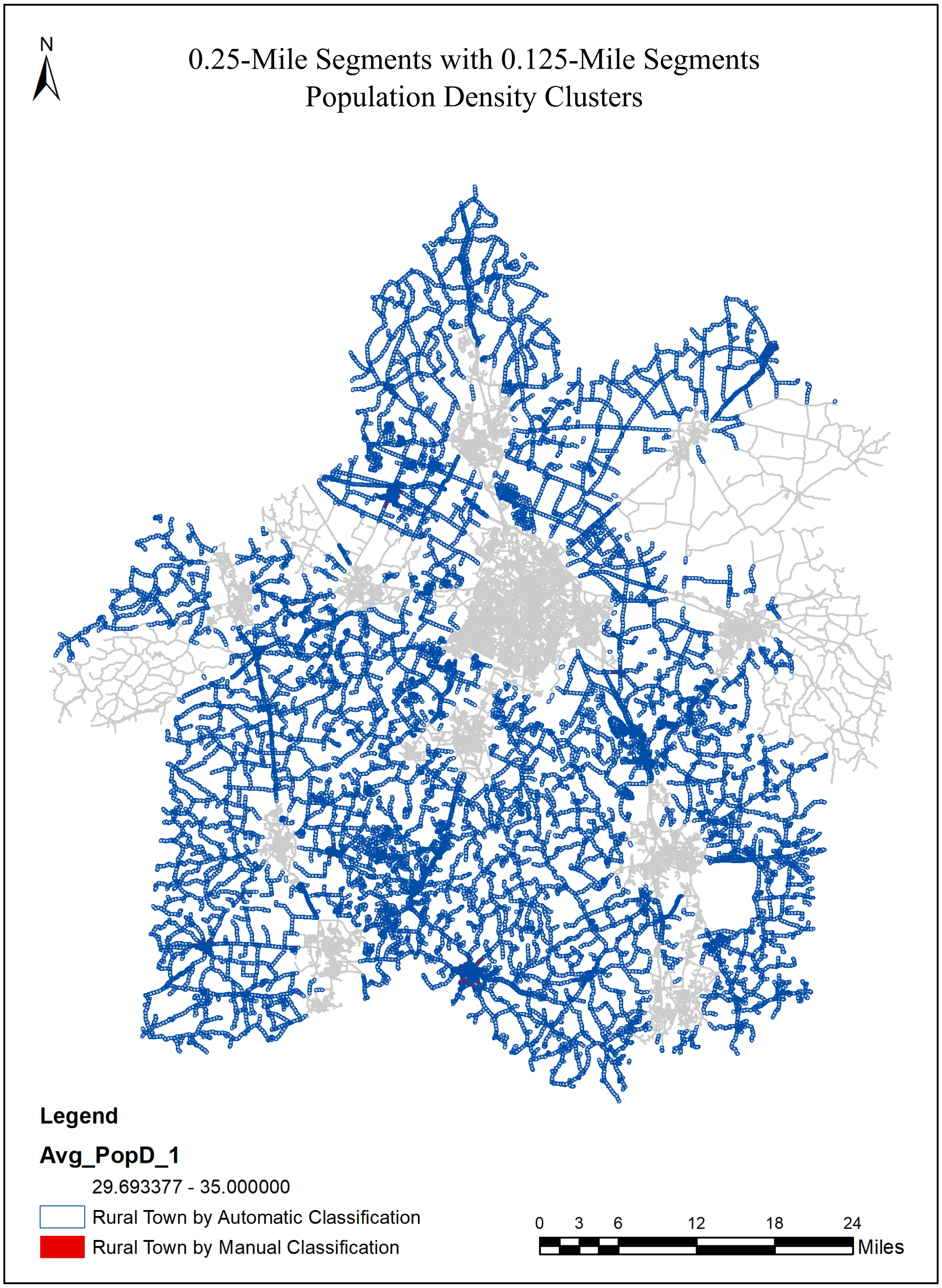
Building Density Clusters
Legend
BuildDens
0.000000 - 710.000000
Rural Town by Automatic Classification
Rural Town by Manual Classification
0 3 6 12 18 24
Miles


N
0.25-Mile Segments with 0.125-Mile Segments
Building Area Density Clusters
Legend
BuildAreaD
0.000000 - 1400000.000000
Rural Town by Automatic Classification
Rural Town by Manual Classification
0 3 6 12 18 24
Miles


N
0.25-Mile Segments with 0.125-Mile Segments
Street Density Clusters
Legend
StreetDens
Rural Town by Automatic Classification
Rural Town by Manual Classification
0 3 6 12 18 24
Miles



N
0.25-Mile Segments with 0.125-Mile Segments
Average Block Length Clusters
Legend
Avg_Length
Rural Town by Automatic Classification
Rural Town by Manual Classification
0 3 6 12 18 24
Miles


N
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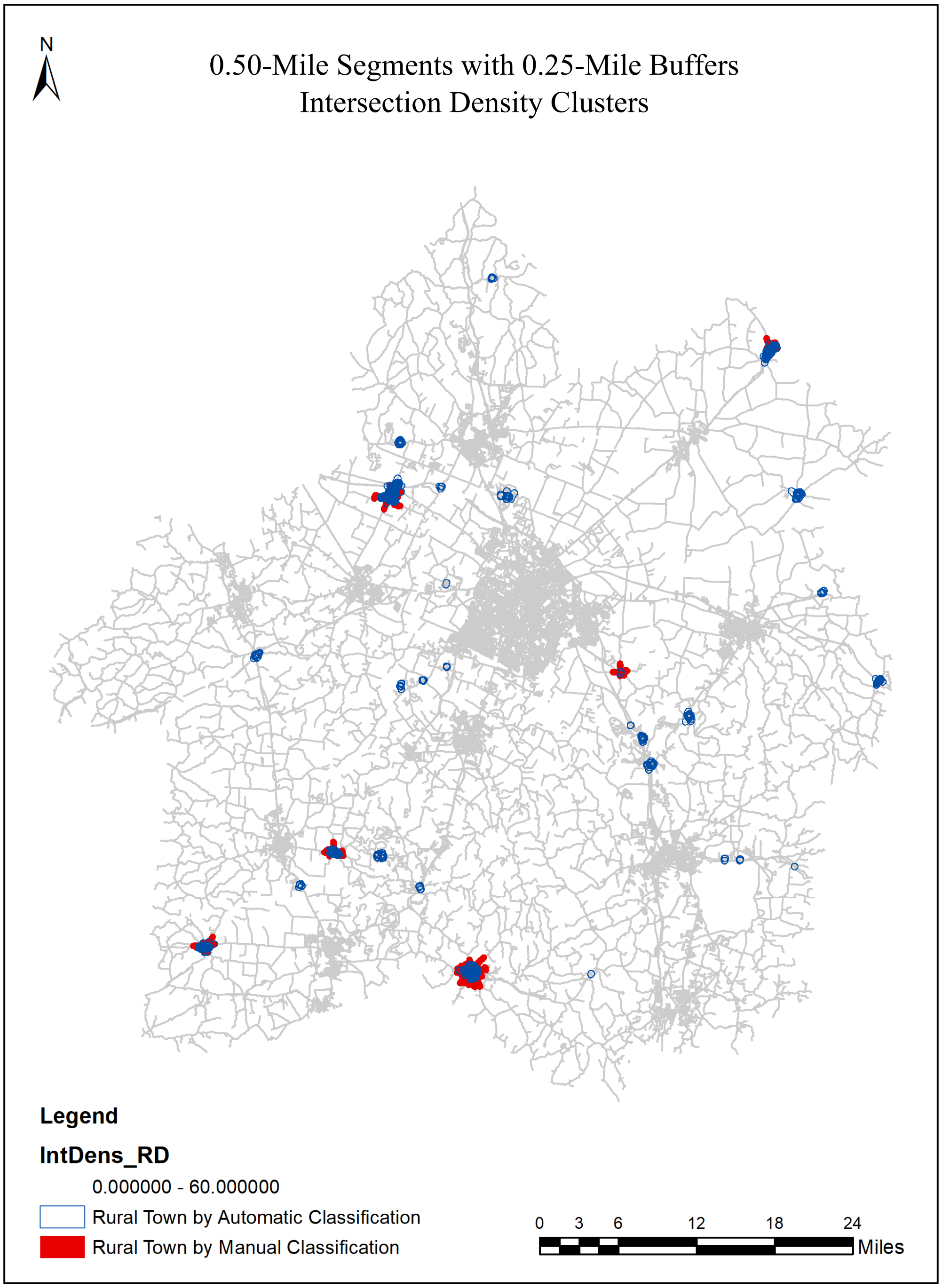
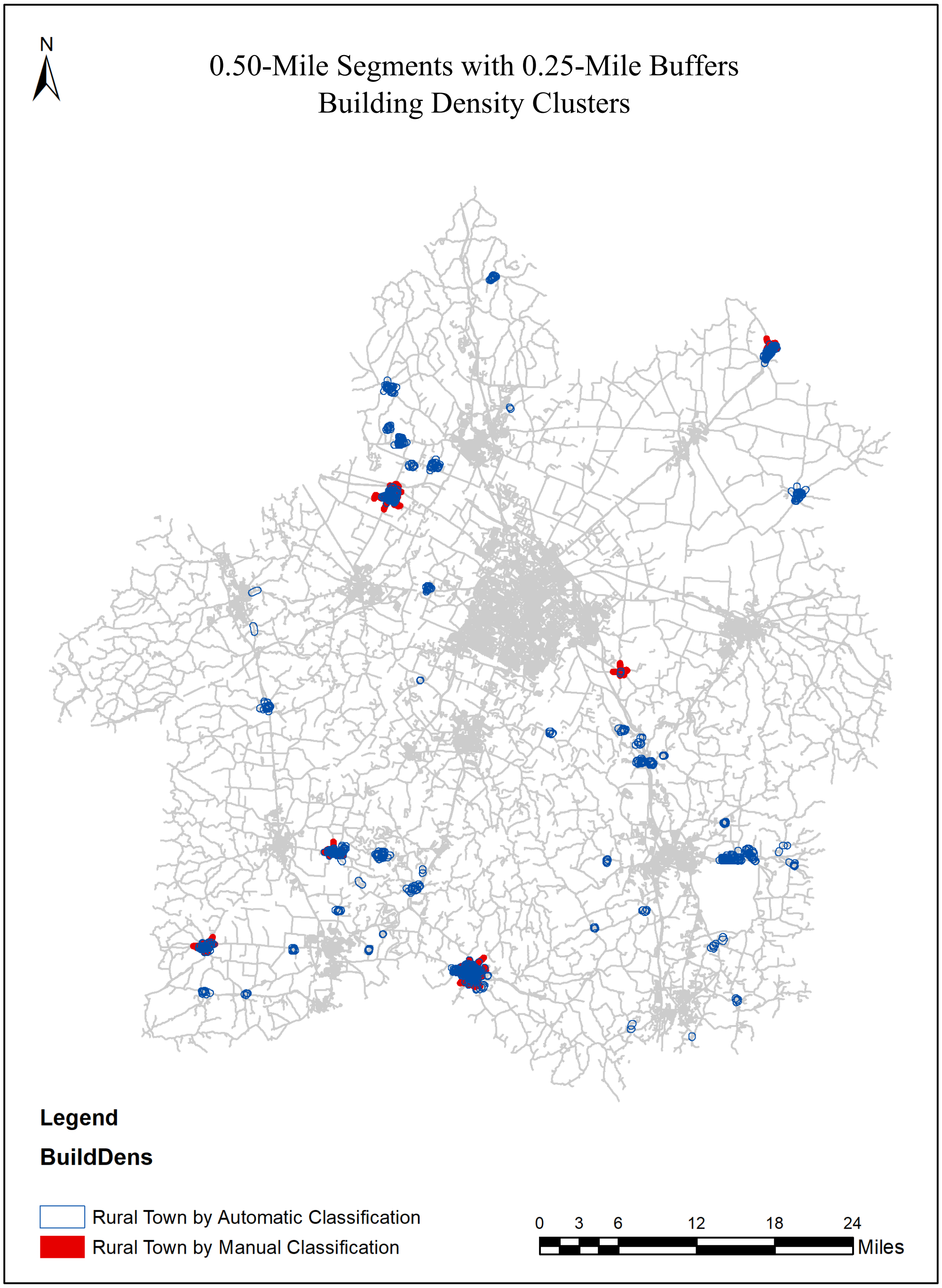
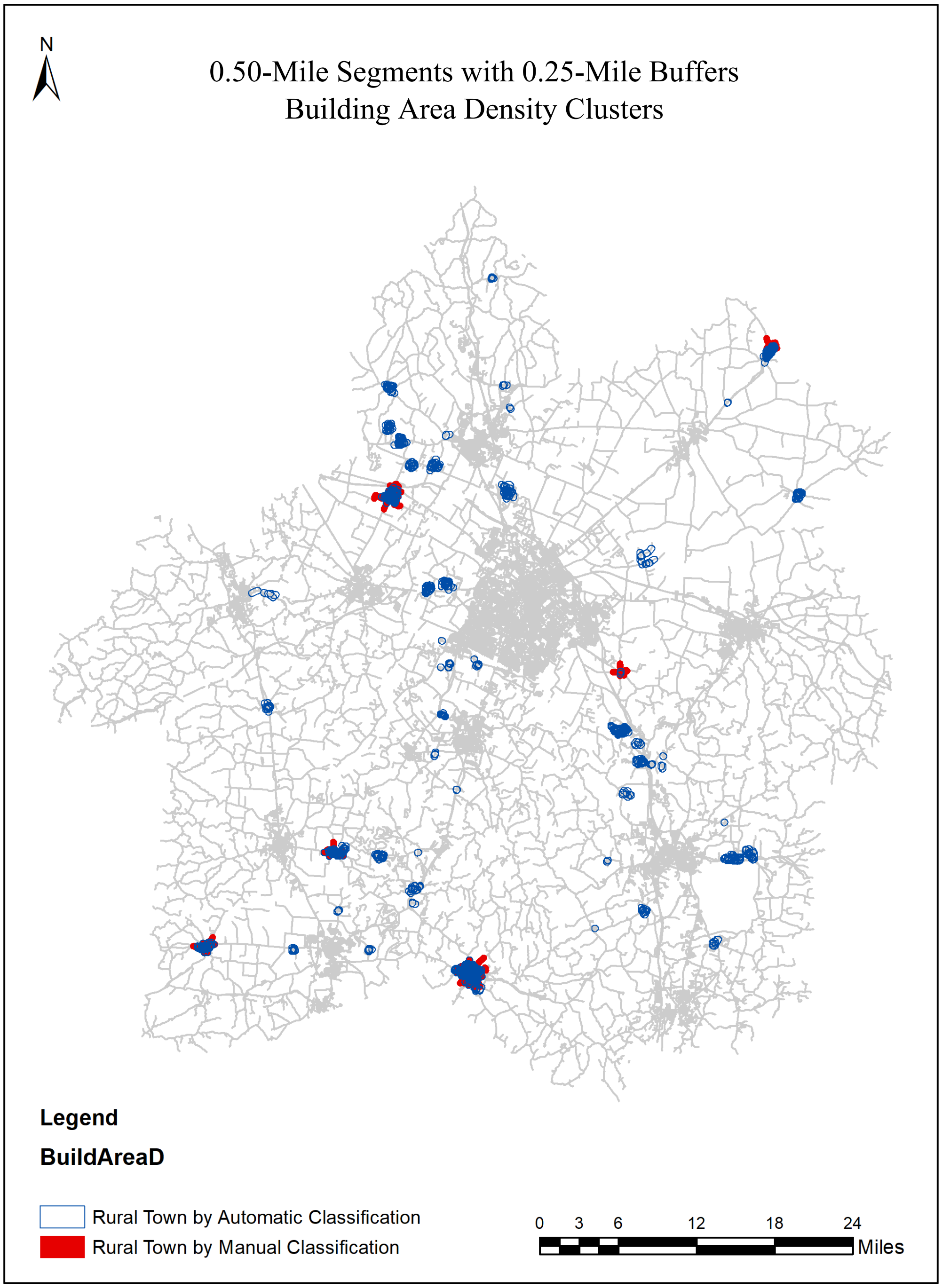
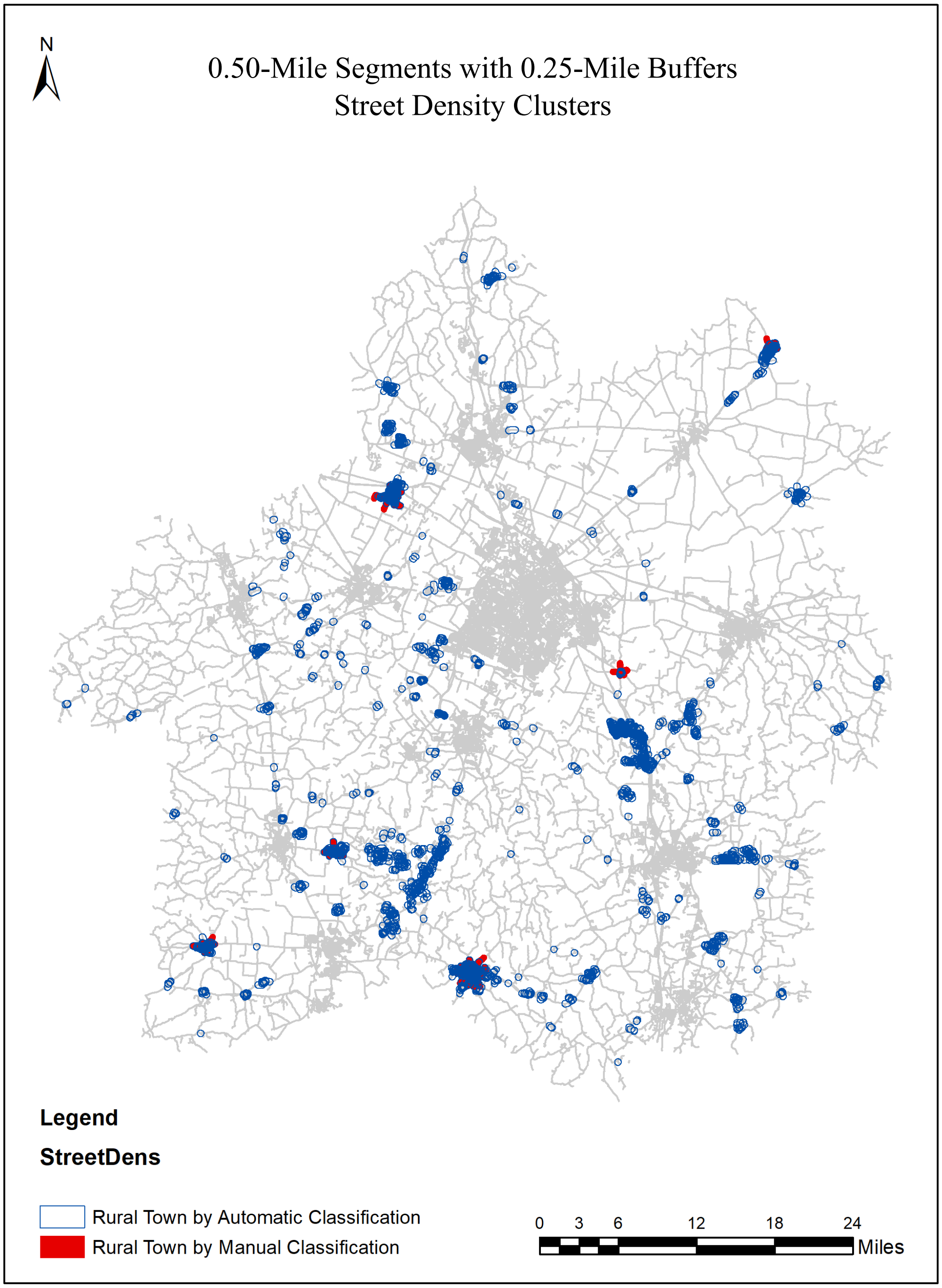
Population Density Clusters
Legend
Avg_PopD_1
29.693377 - 35.000000
Rural Town by Automatic Classification
Rural Town by Manual Classification
0 3 6 12 18 24
Miles


N
0.50-Mile Segments with 0.25-Mile Buffers
Intersection Density Clusters
Legend
IntDens_RD
0.000000 - 60.000000
Rural Town by Automatic Classification
Rural Town by Manual Classification
0 3 6 12 18 24
Miles


N
0.50-Mile Segments with 0.25-Mile Buffers
Building Density Clusters
Legend
BuildDens
Rural Town by Automatic Classification
Rural Town by Manual Classification
0 3 6 12 18 24
Miles


N
0.50-Mile Segments with 0.25-Mile Buffers
Building Area Density Clusters
Legend
BuildAreaD
Rural Town by Automatic Classification
Rural Town by Manual Classification
0 3 6 12 18 24
Miles


N
0.50-Mile Segments with 0.25-Mile Buffers
Street Density Clusters
Legend
StreetDens
Rural Town by Automatic Classification
Rural Town by Manual Classification
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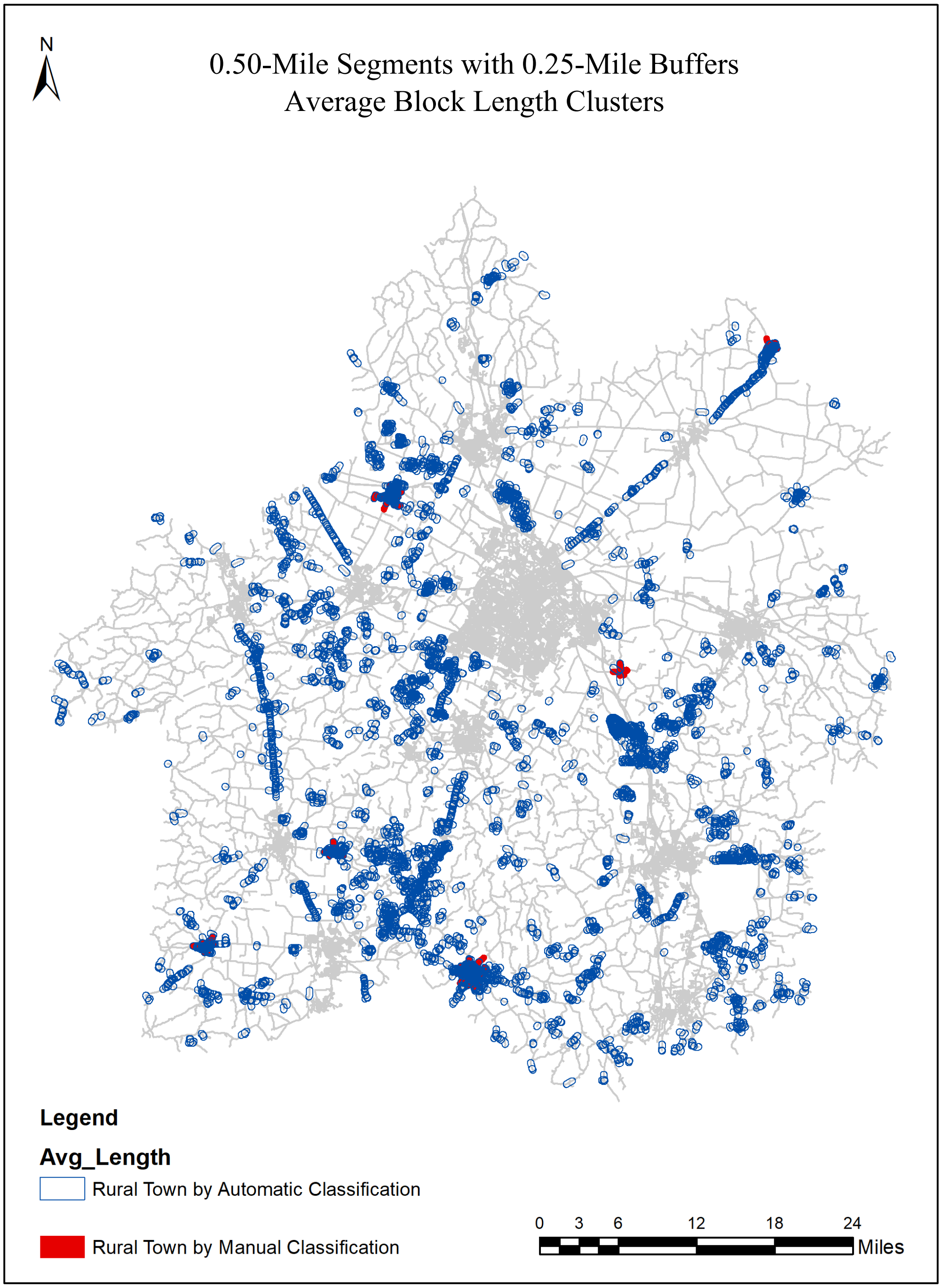
Miles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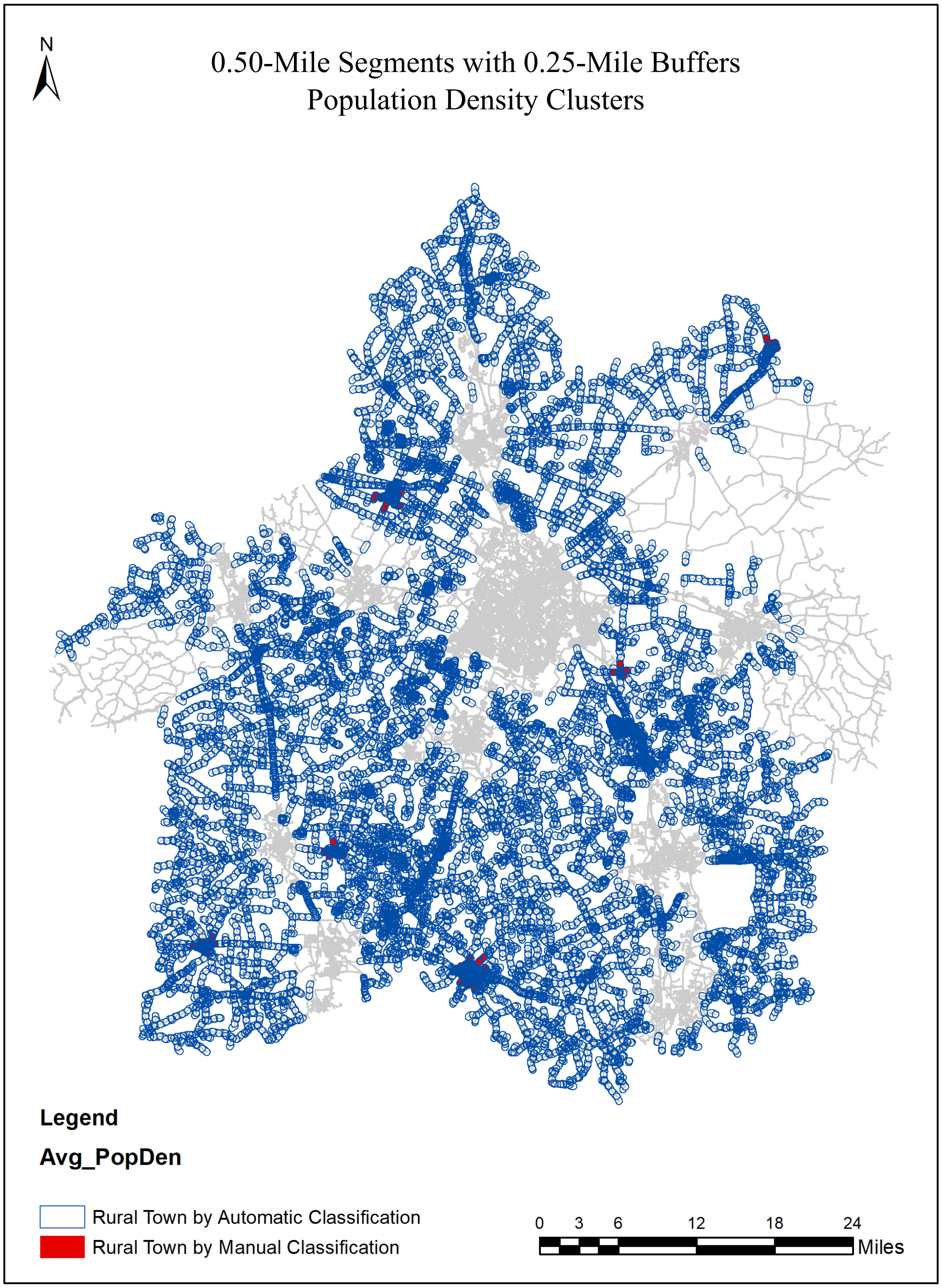
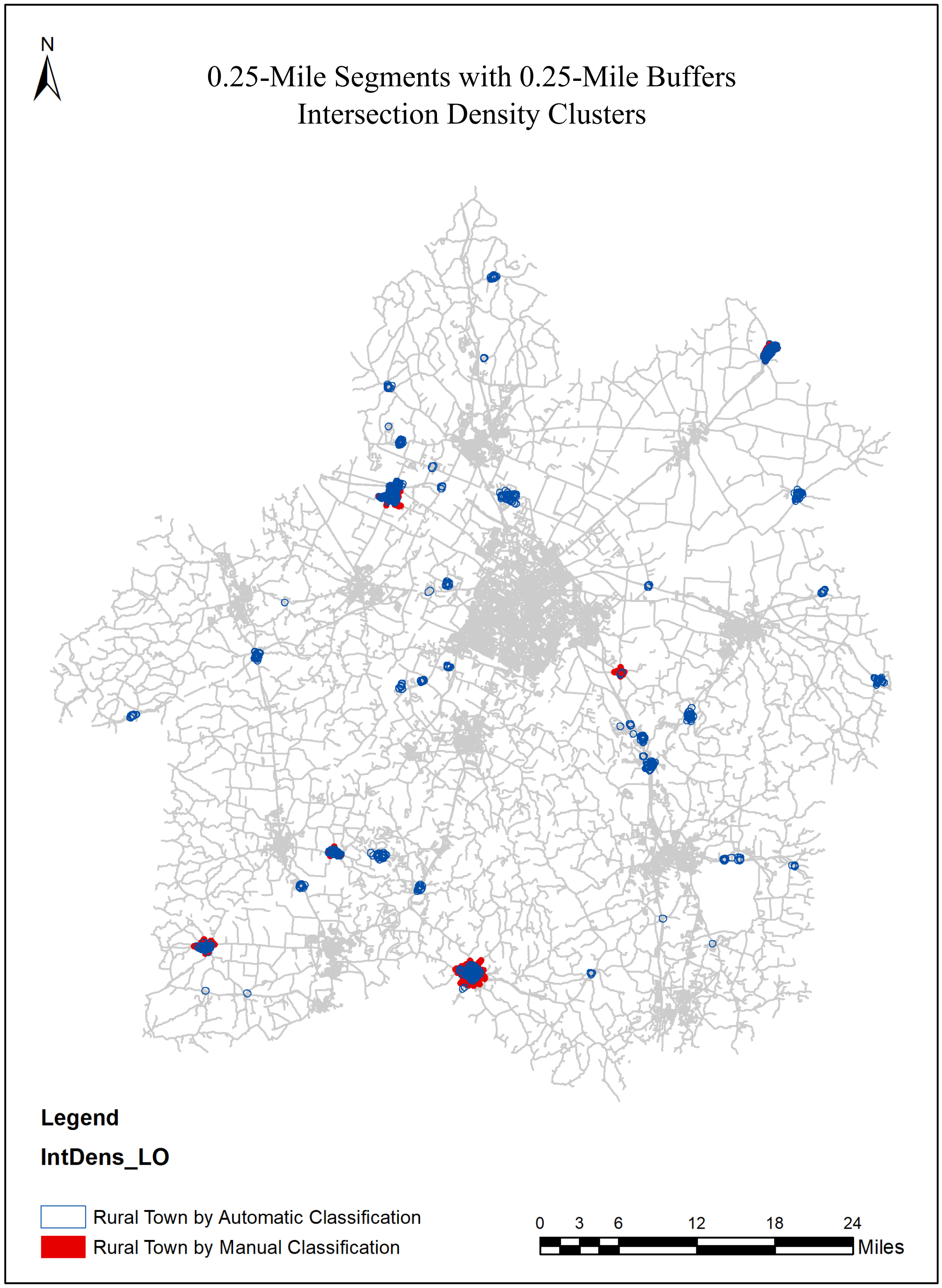
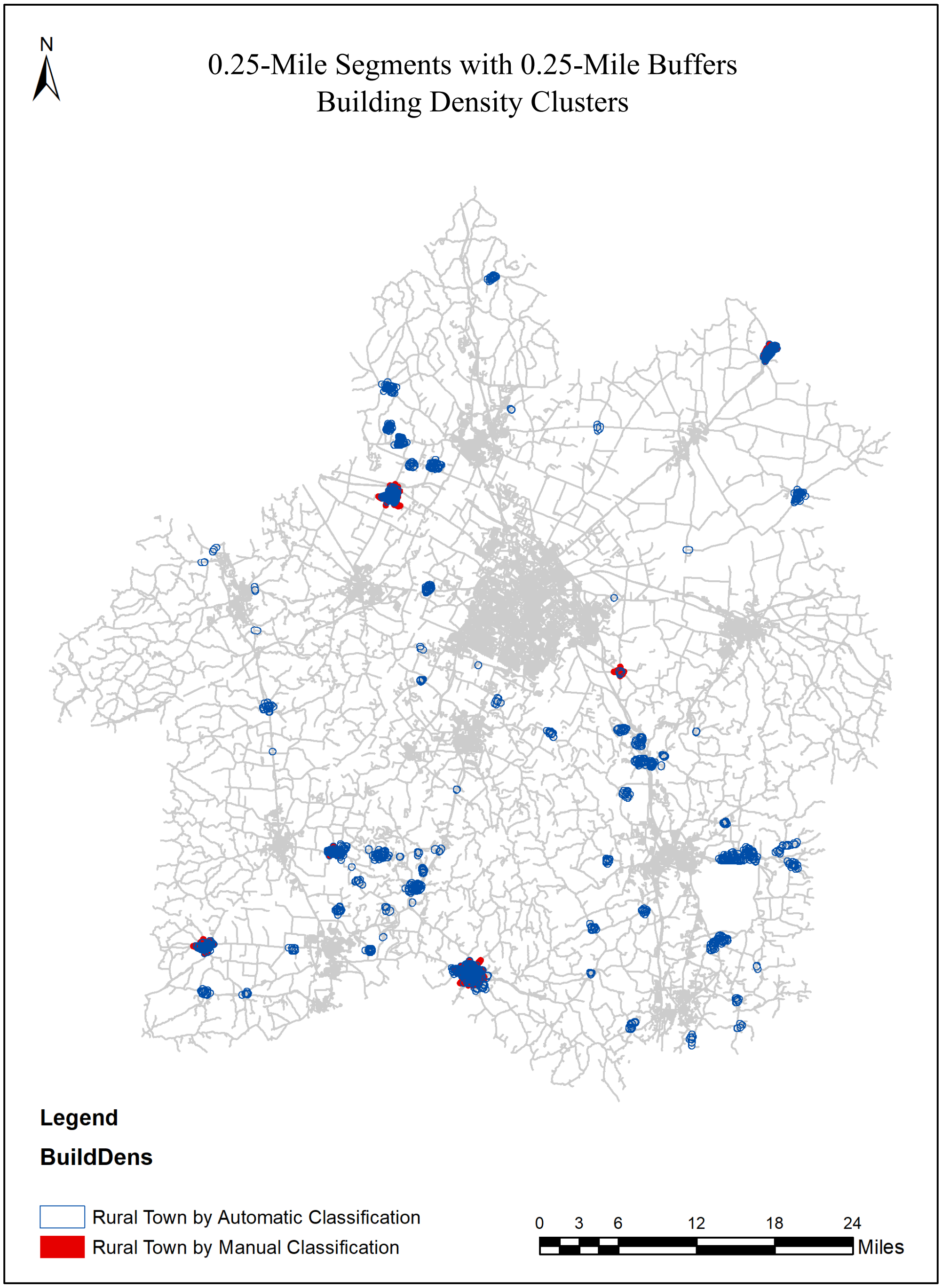
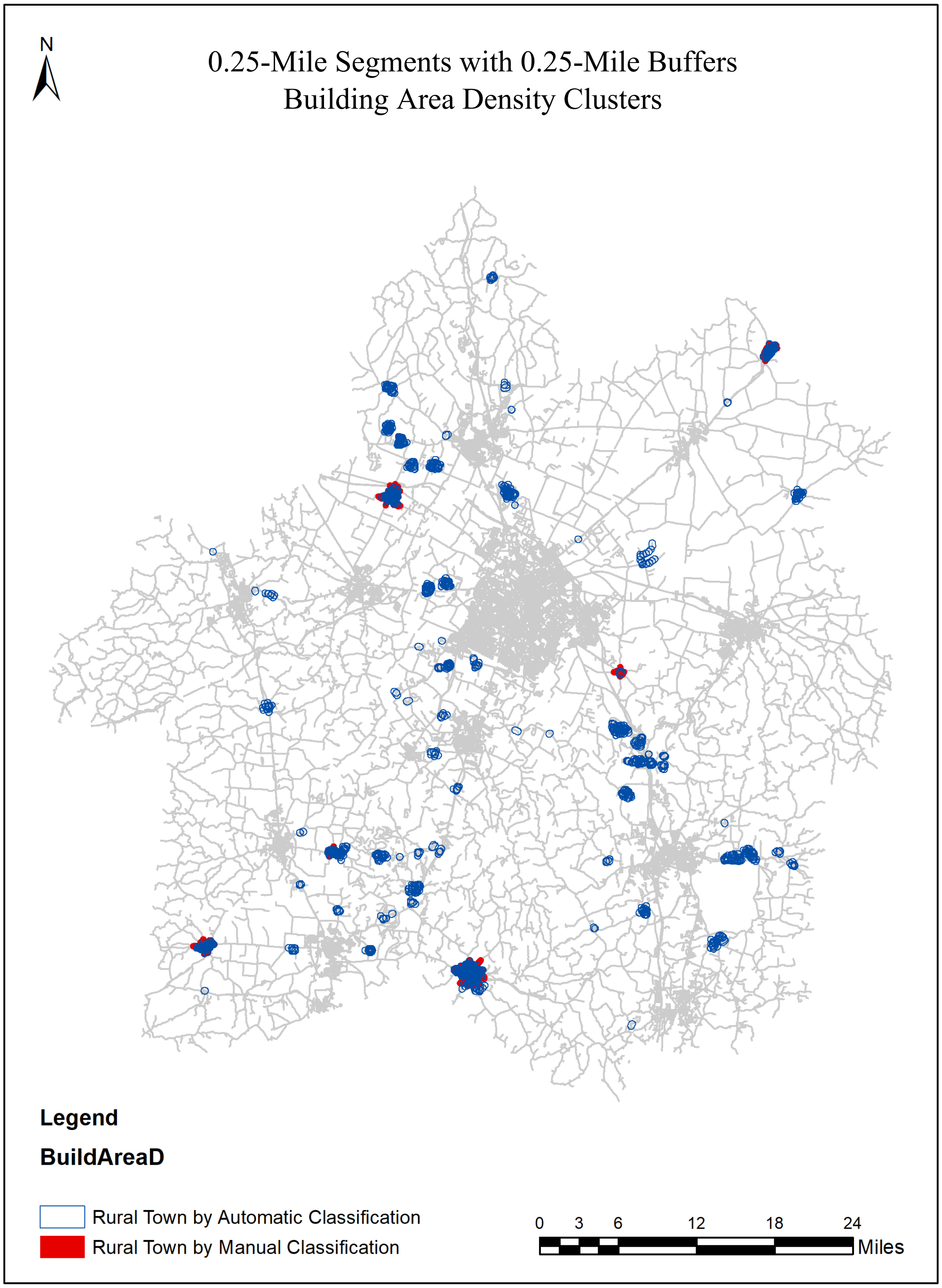
0.50-Mile Segments with 0.25-Mile Buffers
Average Block Length Clusters
Legend
Avg_Length
Rural Town by Automatic Classification
Rural Town by Manual Classification
0 3 6 12 18 24
Miles

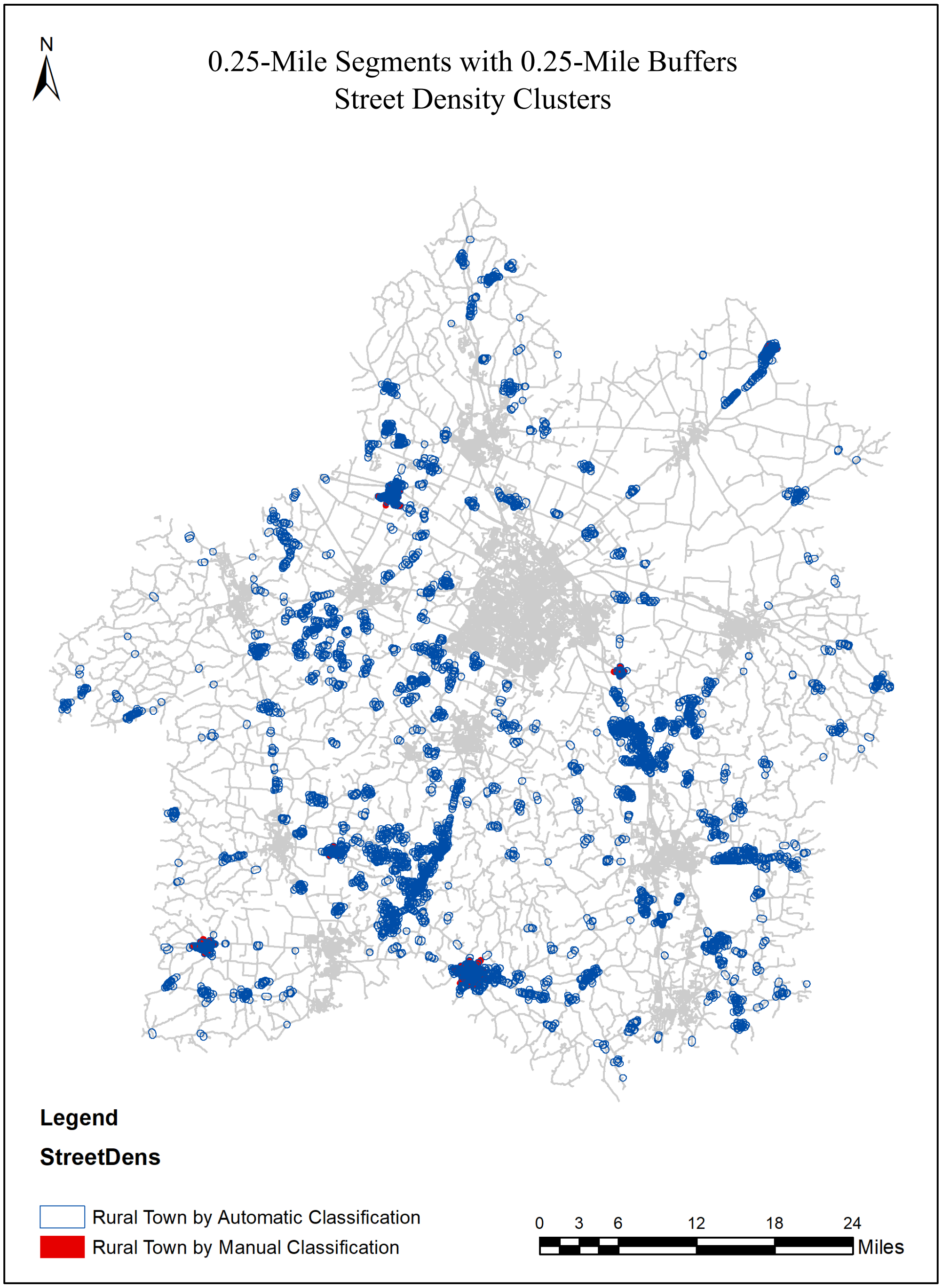

N
0.50-Mile Segments with 0.25-Mile Buffers
Population Density Clusters
Legend
Avg_PopDen
Rural Town by Automatic Classification
Rural Town by Manual Classification
0 3 6 12 18 24
Miles


N
0.25-Mile Segments with 0.25-Mile Buffers
Intersection Density Clusters
Legend
IntDens_LO
Rural Town by Automatic Classification
Rural Town by Manual Classification
0 3 6 12 18 24
Miles


N
0.25-Mile Segments with 0.25-Mile Buffers
Building Density Clusters
Legend
BuildDens
Rural Town by Automatic Classification
Rural Town by Manual Classification
0 3 6 12 18 24
Miles



N
0.25-Mile Segments with 0.25-Mile Buffers
Building Area Density Clusters
Legend
BuildAreaD
Rural Town by Automatic Classification
Rural Town by Manual Classification
0 3 6 12 18 24
Miles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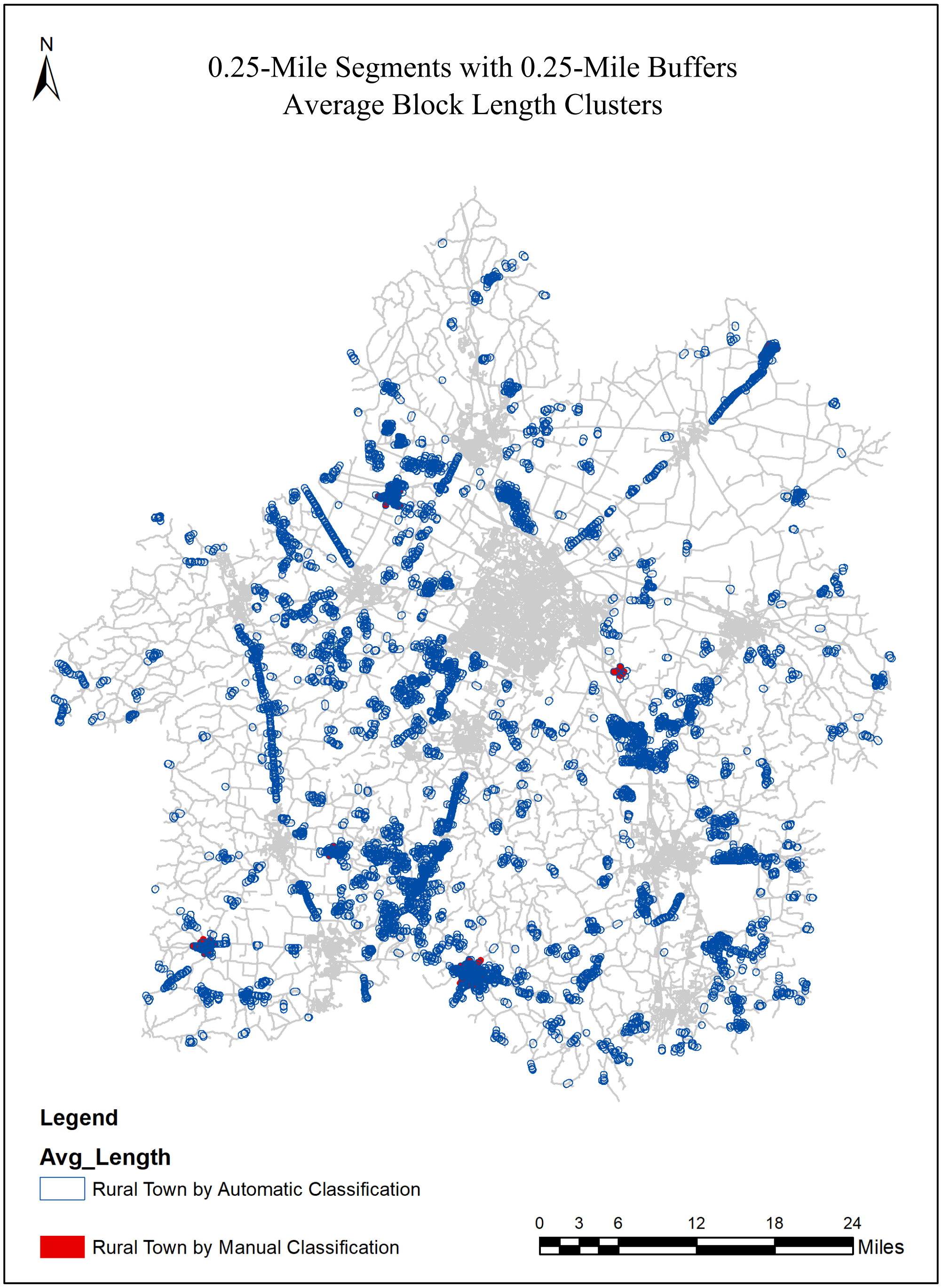
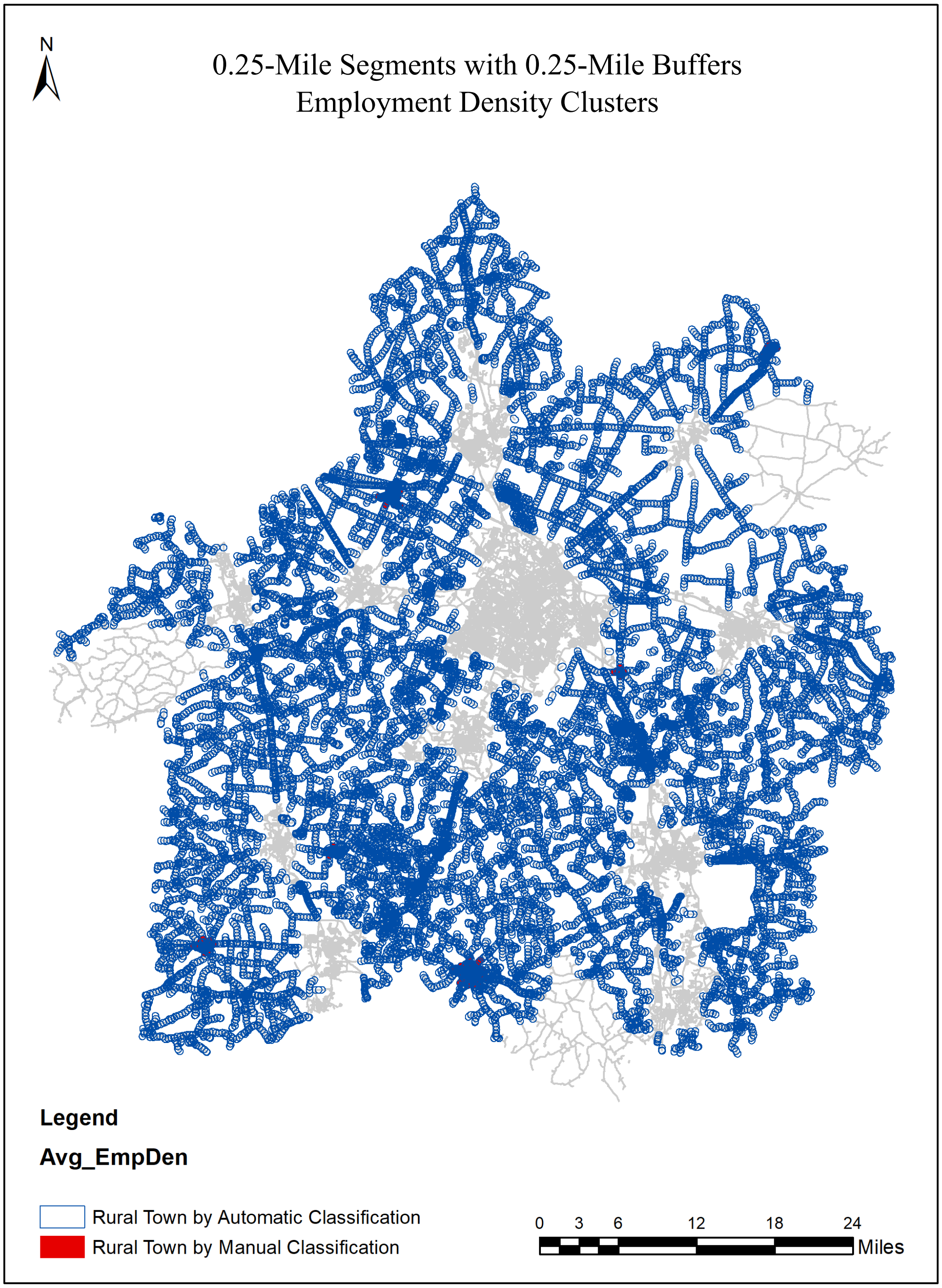
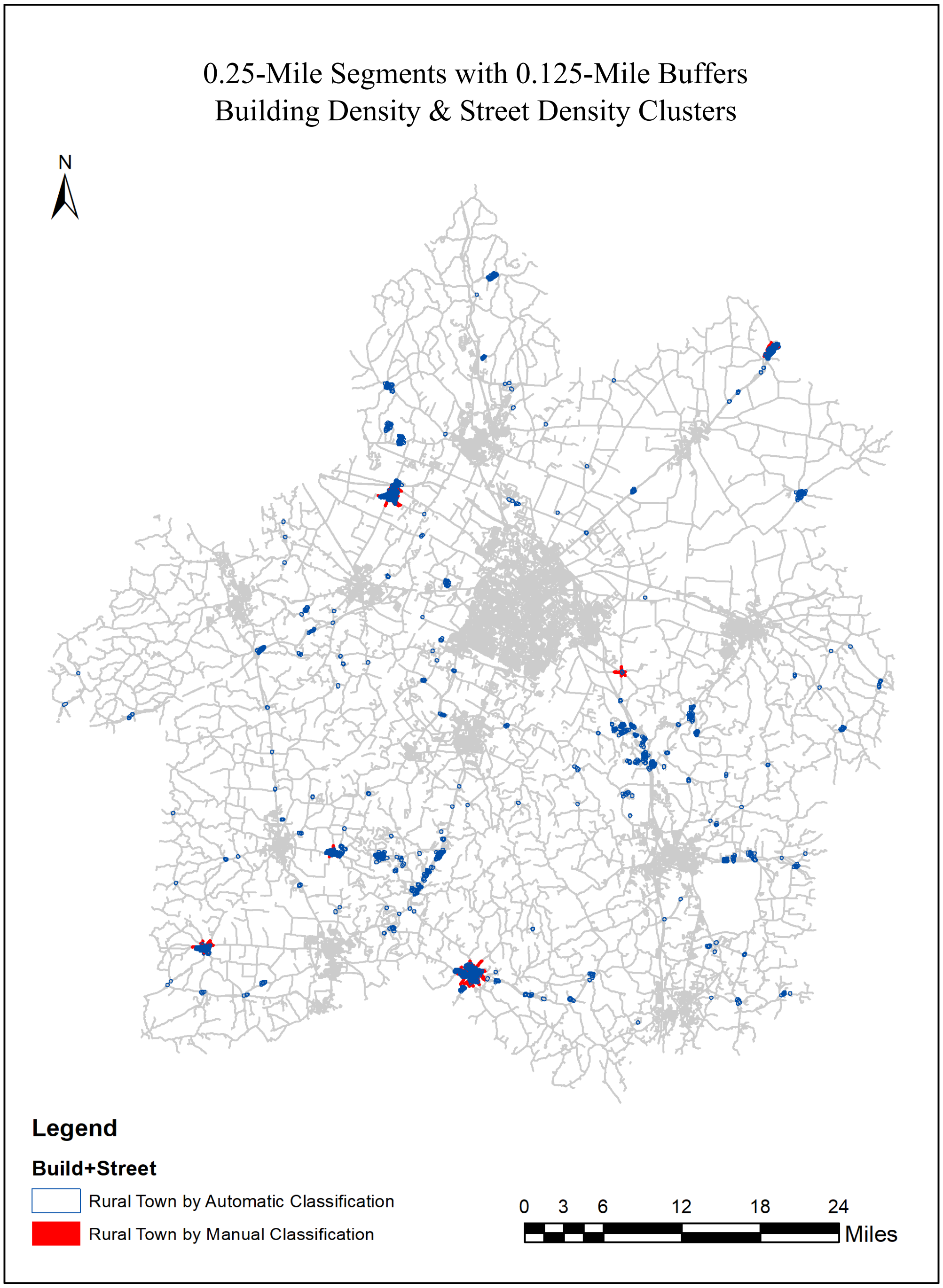
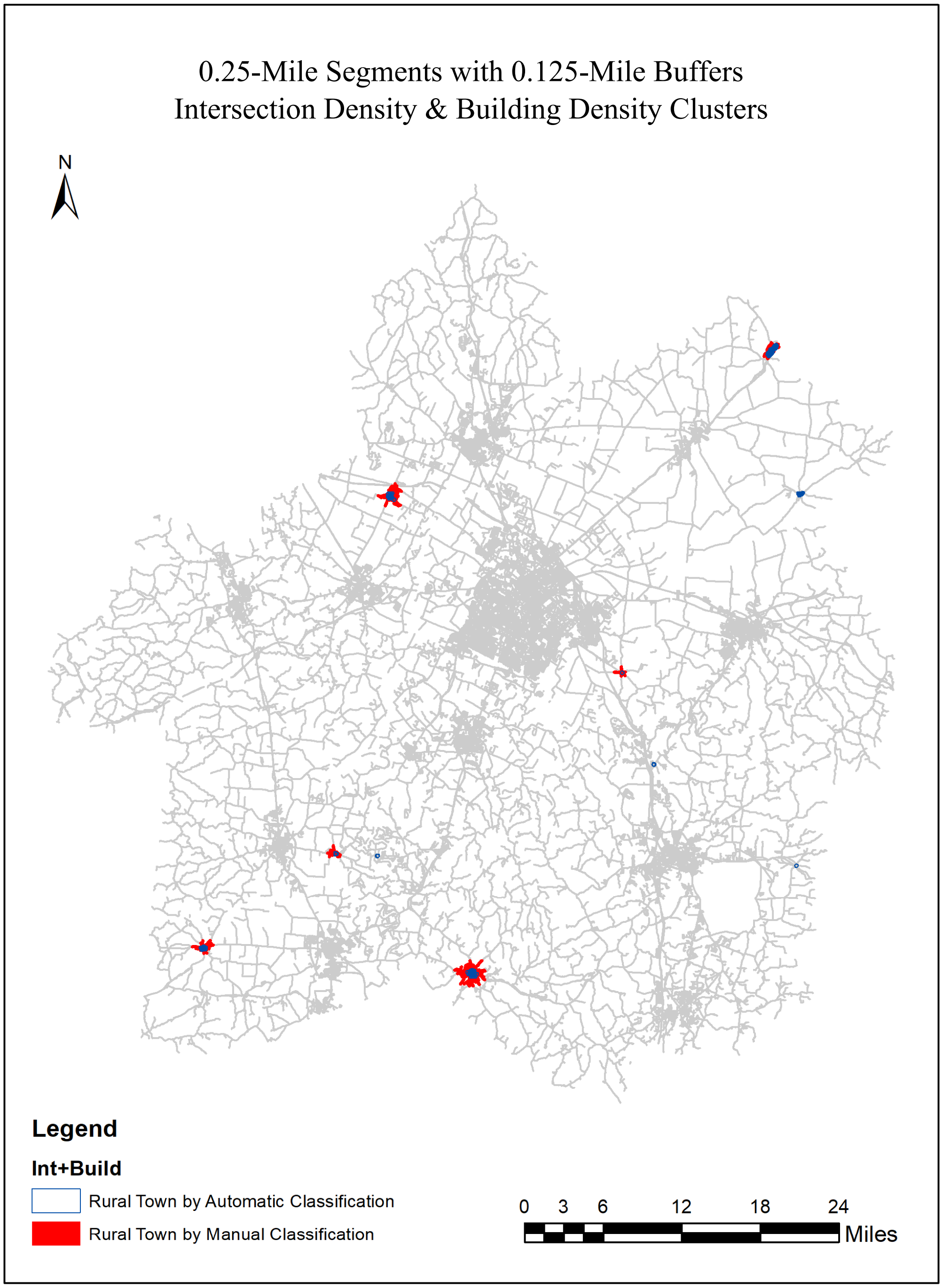
0.25-Mile Segments with 0.25-Mile Buffers
Street Density Clusters
Legend
StreetDens
Rural Town by Automatic Classification
Rural Town by Manual Classification
0 3 6 12 18 24
Miles


N
0.25-Mile Segments with 0.25-Mile Buffers
Average Block Length Clusters
Legend
Avg_Length
Rural Town by Automatic Classification
Rural Town by Manual Classification
0
3
6
12
18
24
Miles


N
0.25-Mile Segments with 0.25-Mile Buffers
Employment Density Clusters
Legend
Avg_EmpDen
Rural Town by Automatic Classification
Rural Town by Manual Classification
0 3 6 12 18 24
Miles


0.25-Mile Segments with 0.125-Mile Buffers
Building Density & Street Density Clusters
N
Legend
Build+Street
Rural Town by Automatic Classification
Rural Town by Manual Classification
0 3 6 12 18 24
Miles


0.25-Mile Segments with 0.125-Mile Buffers
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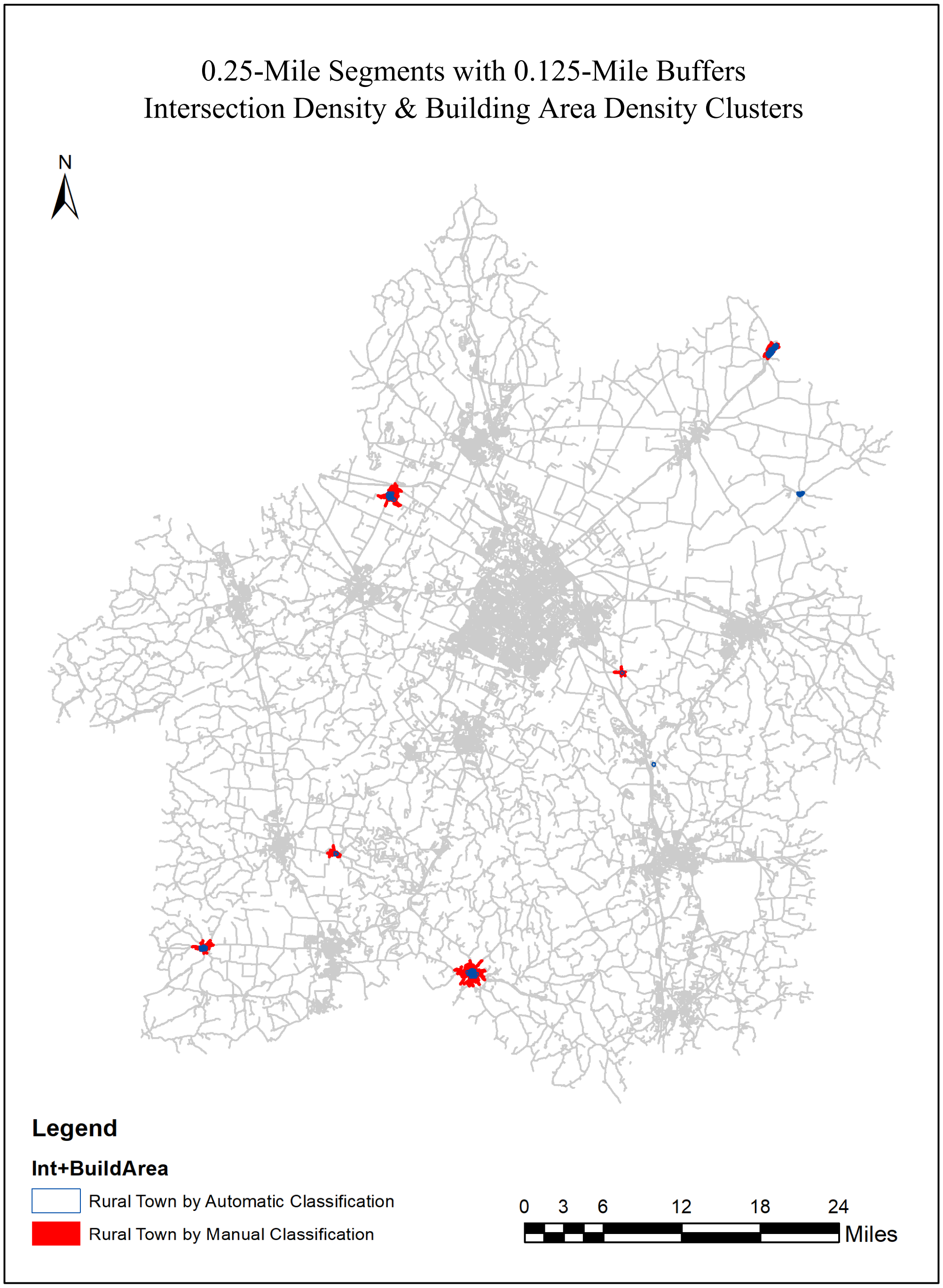
Miles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Intersection Density & Building Area Density Clusters
N
Legend
Int+BuildArea
Rural Town by Automatic Classification
Rural Town by Manual Classification
0 3 6 12 18 24
Miles

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Summer 2017	Intern at KYTC Department of Highways, Campbellsville Section Office