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# The Image from the Road: Towards Mapping the Phenomenological

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The Image from the Road:
Towards Mapping the Phenomenological


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**Abstract**

An area of focus, used in early and contemporary forms of cognitive geography research, is the 'cognitive map', a concept that suggests "that people hold a map-like database in their minds to which they can add and use to tackle geographical tasks".  Kevin Lynch, an urban planner in the 1960s, was an early adopter of the cognitive map approach to reveal spatial cognition, what or how people see their environment, specifically cognition of the urban environment.  Lynch's research aimed to develop empirical methods, to identify how people make spatial relationships.  Contemporary tools like machine learning are now considered relevant for such tasks.  The proposed methods outline steps for categorizing a neural network image knowledge base grounded in perception theory.  Categorizations and cartographic representations are made using GIS and locally weighted regression of the experiential phenomenon of structural density along roadways in Faytteville, Arkanasas.  An alternative method of characterizing the city, one that accounts for the phenomenological as experienced from a human field of view during travel is offered.

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**Introduction**

The surface of the earth is the site of a geographer's work. Human movements, behaviors, and attitudes are some of the subjects of that work. A geographer's "task is to give an account of the earth as the world of man" (Pickles 1985). The world view of each individual is a complex "milieu" of "personal experience, learning, imagination, and memory" (Lowenthal 1961). It is in the process of constructing analysis and representations of such data that scientists create a "rational reconstruction of an irrational world" (Pickles 1985). What methods have been part of reconstructing personal experience, learning, imagination, the irrational, the seemingly invisible relationships that construct our world? Cartography is a basic product of such geography, and the work here intersects contemporary methods of mapping these relationships with the body of research designed to study human behavior in space, or behavioral geography.

The proposed methods of mapping the phenomenological build towards a quantifiable behavioral geography. Contemporary technology in Geographic Information Systems (GIS) and machine learning bring the possibilities of the methodologies used in foundational behavioral geography back into question. What methods of analyzing and visualizing the unseen are now tangible? Evaluating technology and its use in geography at this contemporary moment is relatable to the discipline at the start of the 1960s when the paradigms of geography were rapidly shifting and adapting to new methodologies. At that time, at least two streams of inquiry were simultaneously being defined, quantitative geography, or spatial science, and behavioral geography, out of human geography (Gold 2009). This research is within the realm of contemporary behavioral geography and research within its allied disciplines that also address behaviors in space and that ask questions about methods and representation.

At its essence, behavioral geography wants to describe "what people do and why they do it" rather than to describe behavior strictly by the expectations of a mathematical spatial model.

(Castree, Kitchin, and Rogers 2013a).  In their book *Spatial Behavior,* geographers Reginald

Golledge and Robert Stimson believe that it took years of development and critique to get

behavioral geographers to go from just describing the *what* and to determine by what processes

can describe the *why*.  They describe this evolutionary time this way:

> Thus there emerged a message that superficial and general representations of the natural, human or built environments (whether verbal, cartographic, or mathematical) were no longer enough.  What was required for both understanding and explanation was insight into 'how and why things are where they are.' This theme became known as a *process-driven* search for explanation and understanding.

Geographers were drawn to inspiration that could improve understanding of these

*processes* (Gold 2009).  While spatial science of the 1960s "looked to mathematics, systems

theory and positive economics," human geography turned "to the social sciences, the humanities,

the arts, planning, architecture and design," disciplines that dealt intimately with human

interaction.  In the current 2016 *Oxford Dictionary of Human Geography*, the authors define

behavioral geography as "the study of human spatial activity as the outcome of decisions made

by individuals within the constraints set by society and the environment, and according to their

perception and understanding of the situation."  It is not only relevant to remember Golledge and

Stimson's description of a *process* driven research but that the role of *perception* and *cognition*

in the process is paramount and should be considered in defining behavioral geography theory.

It is proposed that machine learning, or the computational modeling of human learning

processes, offers a contemporary technology that can address a behavioral geography research

based in perception and cognition processes.  Methods for building a process driven inquiry for

cognitive or behavioral geography is presented.  The process by which cognition can be

interpreted with contemporary means is through a neural network.  The proposed methods do not

build or train a neural network to model human cognition however, for a neural network to be

trained, a knowledge base of classified images must be developed.  Therefore, a process to

determine and quantify a baseline classification system for a neural network knowledge base is described through reanalyzing methods of historical precedent.

Drawing on the work of Kevin Lynch (1960s), which began to shape methods of scientific inquiry about built environments, the proposed methods include review and assertions made in the texts of *The Image of the City* and *The View from the Road* as a guide in developing a process of mapping and categorizing a knowledge base of the phenomenological, the invisible yet cognitive data that humans experience. Questions raised during Lynch's research and other developments of the quantification of behavioral geography regarding human cognition about the built environment are reexamined. The presented proposal approaches building the knowledge base for classifying images by quantifying the perceived phenomenon of a city's structural density from the viewpoint of a traveler on a road.

Further statements about urban mapping, perception, and contemporary technology capabilities are made to contextualize the work within the larger theoretical framework of behavioral geography, urban geography, and urban planning and design. The municipal boundaries and appropriate data of Fayetteville, Arkansas are used to define governmental classifications of a built environment. The element of structural density is used as the variable of measurement and is extracted using tools within Geographic Information Systems (GIS) to calculate values from geographical positions on roads in Fayetteville.

An alternative method of characterizing the city, one that accounts for the phenomenological, like structural density, as experienced from a human field of view during travel is offered. Representing the idea of Lynch's *image* and *legibility* studies, new maps of Fayetteville are used to represent the analysis and characterize the city through the lens of the phenomenological. We will look at quantification methods based in perception theory and

compare the relevance of the conceptual approaches.  Comparisons between different

Fayetteville road classifications and their phenomenological structural density will also be made.

The proposed methods intersect historical quantitative and qualitative geography paradigms by

looking at the object of *perceptions*, or *phenomena*, of built environments and the *processes* to

describe those *phenomena*.

**Background**

Because the proposed methods involve paradigms from a cross section of disciplines, we will summarize topics from these disciplines that relate to the proposed methods. To understand the methods by which to quantify the element of phenomenological structural density along a road, it is important to contextualize cognition and perception within the existing theoretical frameworks in the discipline of geography. We will also review the development of behavioral geography as a rebuttal to spatial science, or the statistical modeling of human decision making in space, as well as the criticisms of behavioral geography methods and how behavioral geography is used in contemporary geography research. Because the proposed methods rely on quantification of phenomenological elements from the viewpoint on a road, we will summarize planning and design of roads and highways in cities. We will consider human perception about space and built environments to ground the proposed methods on assessments about Lynch's city *image* and *legibility*.

**Precursors, the *Image*, and Cognitive Mapping**

The theoretical basis for behavioral geography did not solely develop as a reaction to spatial science of the 1960s but had its roots in earlier 20th century works. In his summary of behavioral geography in 2009, John R. Gold identifies early 20th century works of F.P. Gulliver, C.C. Trowbridge, George Hardy, and Kenneth Boulding, among others, as key bibliographic sources for behavioral geography to develop between 1960-1980. Gulliver and Trowbridge (1907 and 1913, respectively) researched the way in which orientation and way-finding is processed from maps, often with children as the subjects. Their findings would show a preference for an egocentric orientation system, recognizing "home as an anchoring point" as opposed to using points of the compass to navigate (Castree et al. 2013a). Just a few decades later, ideas about how human psychology and culture could shape human perception of

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environment were characterized in the work of George Hardy in *Le Géographie Psychologique* (1939) into what was termed psychographic geography.

In a text entitled *The Image* (1956), Boulding, a social scientist, argued that human behavior is rooted, as summarized by Gold, in the result of our "organized impressions of the world that people develop through their experiences," that perception of every aspect of the world around us becomes a constructed "image" of reality. Boulding asked whether there should be a new interdisciplinary study based on the concept of the "image" (Hickman 1957).

The early 20th century behavioral theorists each contributed in their own way to the parameters of research in the decades to follow. In the *International Encyclopedia of Human Geography*, John Gold writes that the practice of behavioral geography from the 1960s – 1980s was initially a counter to structuralism, or spatial science, but the broad base of research allowed for both positivist, the objective, and non-positivist, the subjective, to coexist. Both cognitive science and humanistic threads during the early development of behavioral geography made it possible for applications "with almost any scale of cognitive-behavioural problem, from the interior spaces of buildings to understandings of the cosmos" (Gold 2009). However, Gold finds that all of the research during the peak of behavioral geography study can still be classified into three concentrations, all of which include either cognitive science or humanistic intellectual basis: decision-making, natural hazards, and placeness (Castree et al. 2013a). Gold concludes that these behavioral studies in the early 1960s were adjacent to the positivist theories of spatial science and not only functioned as a corrective agent but as a catalyst for "work that expanded research horizons and re-conceptualized the relationships between people and their environments in quite different ways from those conventional in geographical discourse" (Gold 2009).

By the late 1960s, a "consolidation" of best practices began to emerge and Thomas Saarinen's *Perception of the Environment* offered a "simple organizing framework for research findings arranged around spatial scale," (Gold 2009). Saarinen's framework gave voice to a commonly held ideal that behavioral geography could "assist practical planning and design by offering critical insight into the relationships between people and their environment" (Gold 2009). The intentions of the proposed methods are to apply in a direct way to design of the built, or objective, environment. This importance of the objective environment in spatial behaviorist theory was described by Golledge and Stimson (1997):

> "It incorporates the belief that the physical elements of existing and past spatial systems represent the manifestations of a myriad of past and present decision-making behaviors by individuals, groups, and institutions in society. The outcomes are observable landscapes and built environments, and the spatial behaviors that occur within them. The total objective environment thus was seen to encompass not only the *physical* (or natural) environmental phenomena, but also the *built* environment that derived from individual and collective decisions and activities."

Because the objective environment became of great concern, behavioral geography concerned itself with the built environment, and aligned research towards understanding the behaviors that presented themselves through the cognition of the physical spatial relationships of human experience (Gold 2009). Thus, representing cognition through cartography, or a "cognitive map" remained a tool throughout the development of behavioral methodologies. Cognitive mapping and spatial behavior studies presented themselves generally in three representational types– spatial learning of children, ideas of placeness. and understanding of the built environment.

Using children as subjects, research about spatial learning leaned on developmental psychology while ideas about "placeness" were theorized by Yi-Fu Tuan as he began writing early in the 1970s about the emotional connections people have regarding places (Tuan 1974). Tuan set forth a way of distinguishing a human relationship to space and place in *Topophilia*

(1974). He wrote that space as defined by modern society is "bounded and static, a frame for objects" and has a limited mode of perception. Whereas, "place" goes beyond structured space and is informed by psychological meanings of things like love, fear, and pleasure (Tuan 1974).

As with Tuan's writings, Peter Gould and Rodney White also begin to focus on humanistic themes of human relationships to space. In *Mental Maps* (1974) they attempt to represent cognitive or psychological relationships between interviewees and local and regional understandings about "place". They conceived human emotions induced by or related to spatial knowledge, such as stress or ignorance, into cartographic representations. The concurrent research of Anne Buttimer (1972) was less cartographic but also suggestive of a quantifiable geography of human cognition and suggested that residential and urban planning should be interdisciplinary with human behavior science and consider metrics of "livability".

Directing the "image" concept toward perceptions of urban environment, architect and urban planner Kevin Lynch published *The Image of the City* in 1960, organizing the central theory and methodology of his book around the concepts of Boulding's assertions that there is an organization and quantifiable information about one's "image" of experience.

Lynch worked to develop empirical methods for identifying how people make spatial relationships through primary experience, or perception, and secondary media, (i.e. maps). Themes about perception, what we experience through our senses, and cognition, what we understand, were critical components of Lynch's methods. His studies interpreted the visual quality of three U.S. cities, Los Angeles, Boston, and Jersey City, through the recording of what was understood about the cities by a small sample of residents. This type of data, which can be called cognitive data, was recorded through a series of secondary media, like sketches and interviews, created by the participants. Lynch further interpreted this media and created

"cognitive maps" that aimed to visually describe the participants' perceptions or "image of the city" (Lynch 1960).  The analysis stated that people understood their surroundings in consistent ways, citing five recurring city feature types that Lynch categorized as: paths, edges, districts, nodes, and landmarks (Figure 1) (Lynch 1960).



Figure 1   Paths, Edges, Districts, Nodes, Landmarks. Diagrams derived from drawings in *The Image of the City*.

This approach, to quantify seemingly unquantifiable information, relies, of course, on the assumption that there is *something* to quantify.  The idea of a cognitive map, or a mental map, is the idea that a person holds a "map-like database in their minds to which they can add and use to tackle geographical tasks (Castree, et al. 2013b).  Lynch's publication and the attempt to visually quantify cognition became very popular due to its straightforward methods and adoption of familiar geographic tools, like mapping, and helped to establish Boulding's concept of the "image" as a key part of the methodological frameworks used in early behavioral geographical research (Gold 2009).  It also launched the empirical trajectory for researchers, across several disciplines, to develop methodological approaches to research regarding the topics of spatial knowledge and its applications (Kitchin 2000).

Researchers utilized the techniques of Lynch's cognitive mapping process as a way to identify decision-making behavior from the way people construct and organize their spatial knowledge (Castree et al. 2013a).  "Although Lynch neglected questions of meaning, the speed with which other workers replicated his approach indicated that a viable research paradigm had

been created," and specifically influenced the work of Gould and White to find organized

patterns in the mental maps of people's preferences for places and regions (Gold 2009).

**Criticisms**

A review of behavioral geography development, the "image", and cognitive mapping is

necessary to reexamine the paradigm and its applications in contemporary GIS spatial analysis

and machine learning.  Before an application can be appropriate, criticisms of the paradigm will

be addressed.  Almost immediately, especially with the cognitive science and humanistic streams

of inquiry, debate and criticism abounded (Gold 2009). One of the major critiques against the

cognitive science stream pointed to the quick adoption of cognitive mapping as having a shaky

foundational knowledge of cognitive theory:

> "Most behavioral and perception geography really owes its place in the modern discipline
> to the idea that such images could and should be measured using rigorous scientific
> methods. A first critical assumption is not that subjective environmental images exist, but
> rather that such images are capable of being readily and accurately measured...Although
> we can accept that researchers performed competently within the limitations of their basic
> methodological framework, there are strong grounds for questioning whether it is
> possible to extract an individual's actual thoughts from revealed preferences and images
> as derived in current research." (Bunting and Guelke 1979)

Even though interpreting cognitive map knowledge from interviews and sketches became

a pervasive methodology, critics questioned its validity and over simplification, citing a lack of

attention to psychological frameworks  (Bunting and Guelke 1979; Kitchin 2000).  Even Tuan,

concurrently theorizing about spatial behaviors, evaluated the use of mental maps as non-

scientific: 'So far as I can tell, the mental maps of this book [Gould and Whites' *Mental Maps*]

are opinion and information surveys represented in cartographic form' (Bunting and Guelke

1979).

The prevalence of uncertainty surrounding method was not isolated to the use of

cognitive mapping.  By the 1970s critiques were also coming from another branch of human

geographers, the radical geographers (Gold 2009). Concerned with the social context of research, the critique was that the subject matter and methods of behavioral geography was plagued with "parochial American interests" and neglected to consider the social structures that created the situations being studied (i.e. in natural hazard studies it was often "poverty and landowning policies that forced large concentrations of people to live in hazard-prove zones rather than any deficiencies of knowledge") (Gold 2009). Once rooted in the positivist tradition, criticisms from radical geography and a growing 'humanistic' geography, now argued that "behavioral geography's positivist basis depersonalized and dehumanized the people and places that were studied," essentially counteracting the original aims and ambitions of behavioral geography in the first place (Gold 2009).

The main critique of early 20th century behavioral geography methodology is that researchers never quite define a solid theoretical framework by which to quantify perception and cognition of space. It is however, a basic theoretical principle of behavioral geography that "man reacts to his environment as he perceives and interprets it through previous experience and knowledge" (Bunting and Guelke 1979). It is through the development of the process driven approaches to explain perception and spatial cognition that behavioral geography was able to disrupt the normative models of spatial science and push human geography to address the quantification of methods. By reexamining these fundamental processes with contemporary analytical tools to explain perception and cognition the proposed methods of using GIS spatial analysis to build a knowledge base for machine learning applications is relevant.

**Behavioral Geography in the Contemporary Discipline**

By the 1980s behavioral geography started to become marginalized and was pursued in different countries to different degrees and in the U.S. the 1980s saw behavioralists become

narrow-minded in their methods and lost the majority share of the established frameworks to the humanists who shared part of the same theories (Kitchin 2000). Even though behavioral geography is no longer a specific subdiscipline of geography, as it was between 1960s-1980s, the embodied nature of its theories reside in the "recent interest in embodiment, sensory geographies, emotional geographies, non-representational theory, actor-network theory, performativity and ethnomethodology, amongst others, [and] has turned attention back, in diverse ways, to human behaviour" (Gold 2009).

With contemporary technology and applications, particularly the proposed use of GIS and machine learning, many methodologies that were previously open to empirical criticism, can now apply robust but clear methods with empirical integrity (Kitchin 2000). Kitchin suggests that regarding cognitive mapping research there are three principle ways to remove bias and maintain empirical integrity. The first is to use "multiple strategies of data generation and data analysis," the second "is to generate and analyze data at a disaggregate level" (computing power now allows analysis at the individual or aggregate level), and third, is to use natural settings to collect cognitive data as lab settings could disrupt the data because it is less representative of the experiences in the natural world (Kitchin 2000). Kitchin does not believe that doing these three things will completely validate cognitive mapping as a tool and includes in his writings the need for more sophisticated methods to reveal spatial thought, including possibly brain scans, structured tests in real world environments, and inter disciplinary and cross-cultural research. The proposed methodology aims to address these concerns and is further discussed in methodological considerations.

Behavioral geography has been able to give insights and practical understanding to such a wide range of applications that it is hard to not recognize its merits, regardless of the issues

present in the large scope.  Conceptually, behavioral geography research has given understanding

to urban planning, answering questions about how people engage the built environment.  Of

particular significance are studies of child, gerontological, and disability geographies that strive

to apply findings to improve experience and design of the built environment (Gold 2009). In the

technical realm, behavioral research has informed spatial communication in geographic

information and navigation systems and their interfaces, and is directing the discourse for how to

build virtual environment systems (Kitchin and Freundschuh 2000; Kitchin 2000).  Even without

direct acknowledgment to behavioral geography, research built upon the tenants of behavioral

geography will continue to inform answers to questions about our spatial behavior.

**Methodological Considerations**

The pivotal methodological moment that the proposed methods aim to manipulate and

improve with contemporary means is Kevin Lynch's 1960 and 1971 works that considered first

person perceptions of urban environments. With *The Image of the City,* Lynch was able to

develop a notation or language of identifying urban space from what might be experienced by a

pedestrian or traveler through the city.  The five urban structures that Lynch recognizes as

themes through the three cities studied are paths, edges, districts, nodes, and landmarks.

Mapping methods were created for each structure as seen in the legend (Figure 2).  The notation

was used during the mapping process of several major cities.  A few examples of the Boston

*image* as mapped by Lynch are shown in Figures 3 and 4.

A more descriptive explanation of these elements is relevant to the proposed data

collecting methods.  As defined by Lynch, paths are any element with which a person traverses

(i.e. streets, railways) and is thought to be from where the strongest sense of the city, or *image* of

the city is observed.  Edges are not paths, but the thresholds of spatial reference and can include

shorelines and walls.  Districts are seemingly two-dimensional areas that an individual feels "inside of", having an "identifying character" about the forms and structures.  Nodes are moments with which a traveler through the city interacts as a change in path such as a junction but are also considered along with districts and can be conglomerations of structures with certain characteristics, such as a district's "core".  And finally, landmarks are external foci with which one's attention is drawn but a person does not necessarily "enter within them" (Lynch 1960).

The definitions and notations were created by Lynch and his team of research students from participants' responses.  The research included interpretations of first-person interviews about impressions of physical elements of the cities, sketches of the cities drawn by participants, and verbal descriptions of the cities recorded by participants as they traveled through the cities. The merits and criticisms of this type of limited first person "cognitive" analysis have been discussed, but to reduce the analysis to its essence of an ethnographic, or individualistic, approach is the critical element used for the methods proposed here.

Taking Lynch's methods to describe a city's *image* even further, he expanded his study, along with other researchers, to exclusively look at the *image* from the path, specifically from interstate or highway routes in *The View from the Road*.  Lynch believed that it is from the path that the city image is perceived the strongest.  The question of the image of the city from the road is one of the critical elements of Lynch's methods that is used in the proposed approach of the analysis of roads in the Fayetteville, AR study site.  Lynch used an analog approach to collect views from the road with the use of photography and sketch (Figure 5 and 6).  This method of view collection is the basis for the image collection proposed to build a knowledge base of a neural network.

Figure 3 Legend for Figures 3 and 4. (Kevin Lynch 1960)
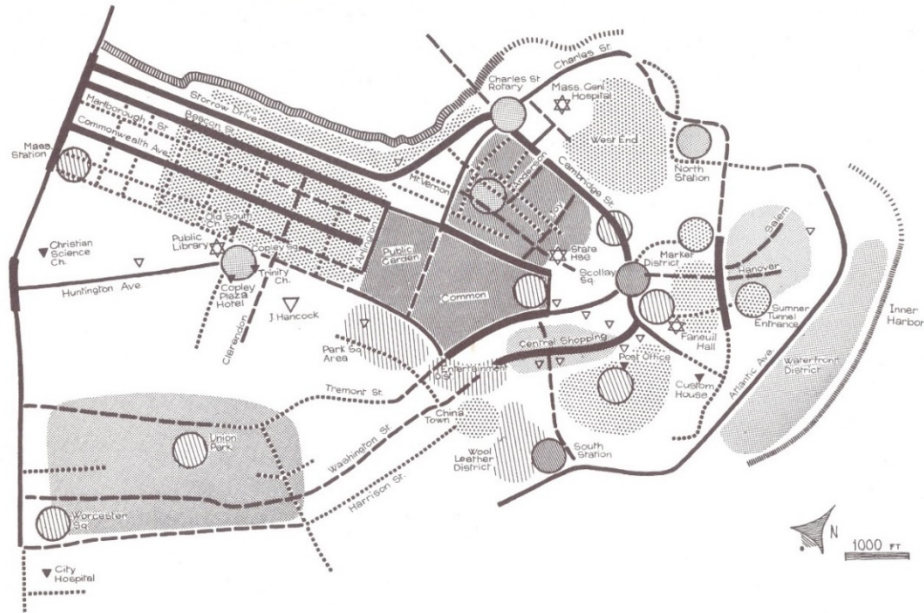


Figure 2 *The Boston image as derived from sketch maps* (Map by Kevin Lynch, 1960)
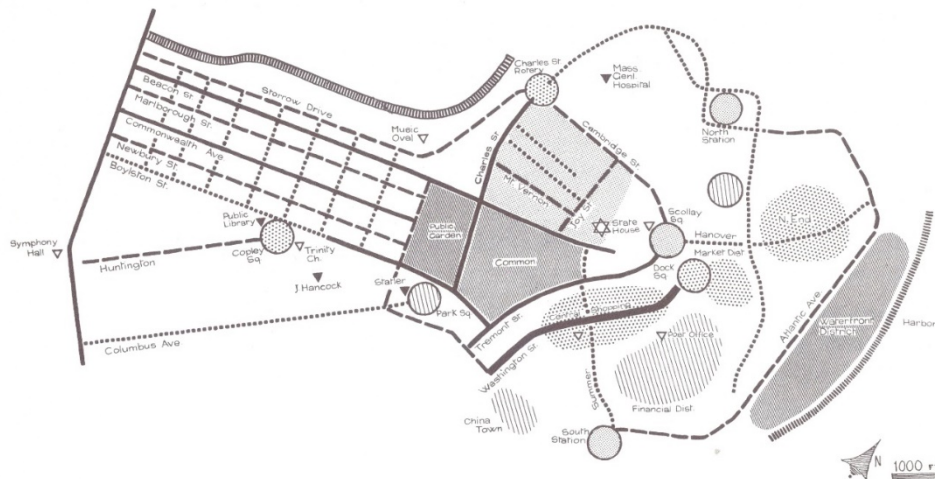


Figure 4 *The Boston image as derived from personal interviews* (Map by Kevin Lynch, 1960)

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Lynch's new work aimed to describe the strength of a city's *image* and the potential to design for specific *images* of a city.  Similar approaches used for *The Image of the City* were utilized to obtain city *images* from five major cities.  Lynch was interested in highways because of concern with the "visual formlessness of our cities" (Appleyard et al. 1971).  As an urban planner and designer, he wanted to know if the expressway could "reestablish coherence at metropolitan scale?" (Appleyard et al. 1971). Because the highway is a typical typology of the American city, the experience of the city from a vehicle and from the road is a critical element to understand for urban design  (Appleyard et al.1971).

The definitions and notations in *The View from the Road* were created by Lynch and his team of research students from first person interviews about their impressions of physical elements of the cities, sketches of the cities drawn by participants, and verbal descriptions of the cities recorded by participants as they traveled through the cities.  The merits and criticisms of this type of limited first person "cognitive" analysis and have been discussed, but to reduce the analysis to its essence of an ethnographic approach is the critical example used for the research discussed here.

The analysis of this research aims to follow the three suggestions Robert Kitchin gave to improve the use of a perceptive and cognitive mapping approach.  First, to use "multiple strategies of data generation and data analysis," pertinent data needs to be collected.  The scope of the proposed methods is only to investigate the validity of one way of data collection and analysis to build a classification system for a neural network knowledge base.  Even though it does not address "multiple strategies", it does build upon foundational cognitive principles of behavioral and human geography, which allows scientific inquiry to progress.  Comparison

between the proposed data collection and analysis and Lynch's data collection and analysis would be an initial step of building a framework for inquiry.

To identify the *image* from the road, the most travelled routes within Fayetteville are identified. To capture what elements are visible from the routes, topography and built structures are considered. Further mention of some unidentified elements pertinent to the *image* will be addressed but note that here it is stated that due to some limitations to data acquisitions and analysis, certain elements, such as vegetation, are not analyzed in this data set.

The second enhancement Kitchin stresses is to analyze data at "disaggregate level". Efforts are made in this research to consider the view from the road ethnographically, or from an individualistic viewpoint, establishing data collection points from the spatial viewpoint of a person on a highway. This method is common in this segment of human geography and specifically in urban geography, where understanding spatial structures through the perspective of the individual or group is crucial data (Dwyer and Limb 2001, 1-20). The difference here, however, is that each data collection point is not from an actual person but from a prescribed collection point along road vectors in GIS database. Using GIS allows for the quantitative analysis relative to human perception to be applied to each data point concurrently on several streets and highways.

Lastly, Kitchin's final request for cognitive mapping improvement is to collect data from a "natural" and not a lab setting. It is the challenge of the methods proposed to express an analysis that could be replicated and used in further research to train neural networks to identify elements like density of urban structures, or in other words, to identify the *image* of a city. Because this is not a "natural" setting, one might think that the same critics of early behavioral geography research would apply, however, by reducing data collection to only include physical

parameters from the environment, other unknown variables of human perception and cognition do not have to be addressed. It is a goal of the research to begin to set baselines by which to test against social science's understanding of human perception and cognition and to build a methodology grounded in space and geography.
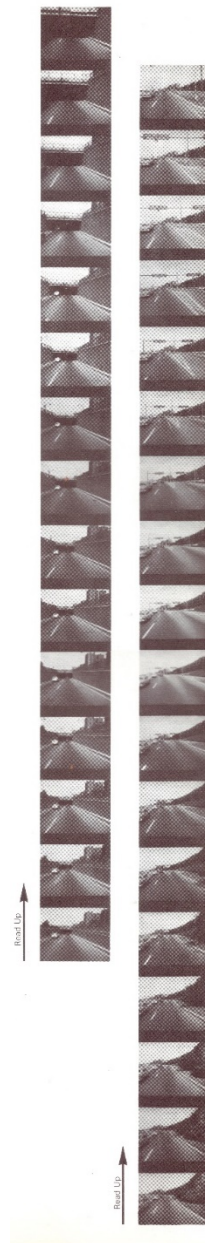


Figure 5 Images of driving sequence. (Created by Appleyard, et al. 1964)
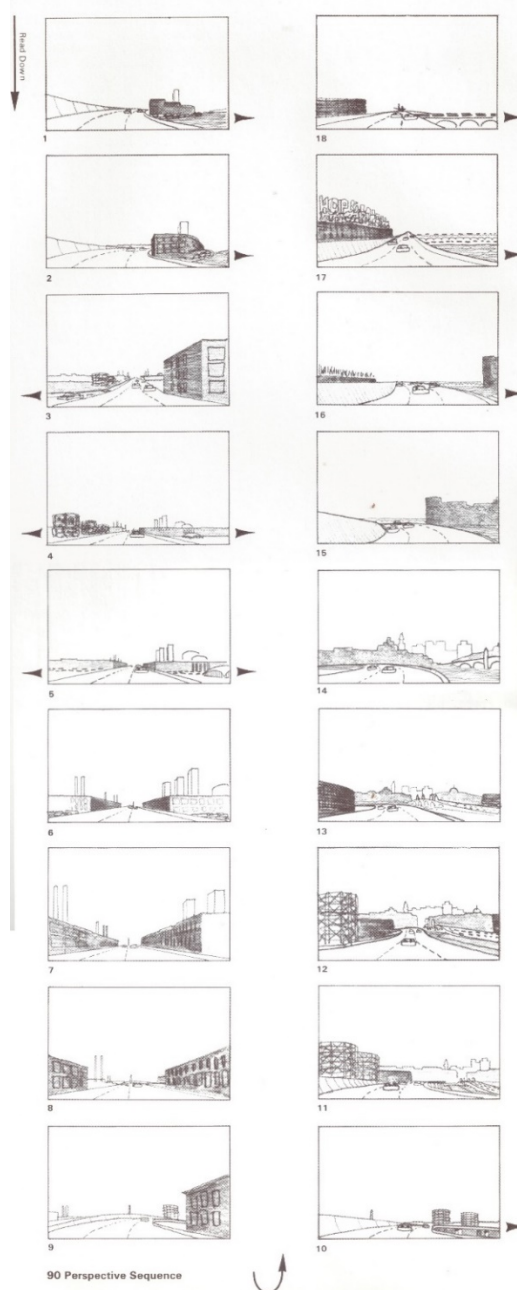
Figure 6 The Boston image as derived from personal interviews (Map by Kevin Lynch, 1960)

**Highways**

Highways designed in the early 20<sup>th</sup> century began to differentiate between transportation functions and pleasure driving through a series of state and federal movements that identified sightseeing routes throughout the continental states  (Weingroff 2017).  From federally supported scenic roads through parks and forests as well as considerate state and federal parkway constructions, as conceptualized by Frederick Law Olmstead in the late 19<sup>th</sup> century, to President Dwight D. Eisenhower's National System of Interstate and Defense Highways in the 1930's, road design was adapted from the initial goal of recreation to then engage commercial traffic (Weingroff 2017).  Even the original parkways were quickly overtaken by commercial traffic or as a method to arrive from point A to point B.   Lynch asks, can roads become art?  Lynch solicits road engineers, urban designers and planners, landscape architects, and architects to consider that the fundamental visual form of our spatial experience should be shaped and can be shaped without impeding flow (Appleyard et al. 1971).

If highways can be art, the raw materials are vision, touch, and sense of spatial sequence. Experiences of driving differ not only by perception of each driver or passenger but also through other experiential circumstances like whether a drive is for recreation or commuting, how a view is framed through a windshield, or the ebbs of flows of  dynamic or static sequences (Appleyard et al.1971).  Although several distractions from operating a vehicle are possible, an automobile ultimately captivates its passengers into a sensory experience that secludes or traps sound, smell, and temperature separate from the outside environment.  The interior forward facing experience of the highway is potentially more dynamic than the understanding of a highway from a pedestrian near to the highway.  A pedestrian has more opportunity to stop, engage, or redirect his/her spatial sequence.

"The driving experience can now be described as being a sequence played to the eyes of a captive, somewhat fearful, but partially inattentive audience, whose vision is filtered and directed forward.  It is a sequence which must be long, yet reversible and interruptible." (Appleyard et al.1971)

The Lynch research of city perception from highway travel attempts to identify several features of experience such as visual accessibility to landmarks or "goals" made possible or hindered by multiple elements of attention, the changing of the field of view, confinement of space, and orientation of route.  A robust notation system was used to address mapping these phenomena and others for specific routes (Figures 7 and 8).

It is with this work that the methods begin to become familiar to contemporary technological capabilities, specifically the relevance of methods used in contemporary neural networks for object recognition, the use of Google Street View to view first person perspectives of any mapped route, and availability of well documented Geographic Information System (GIS) street data.  It is for these contemporary connections that *The View from the Road* is used as the underlying methodological framework for this analysis.  The historical behavioral geography context and the work of Lynch provides a mode of inquiry for the proposed methods, for it is by the process of inquiry and method that "concepts provide us with analytic power, while measurement procedures provide us with the necessary techniques to pin down our analyses to the world of experience".
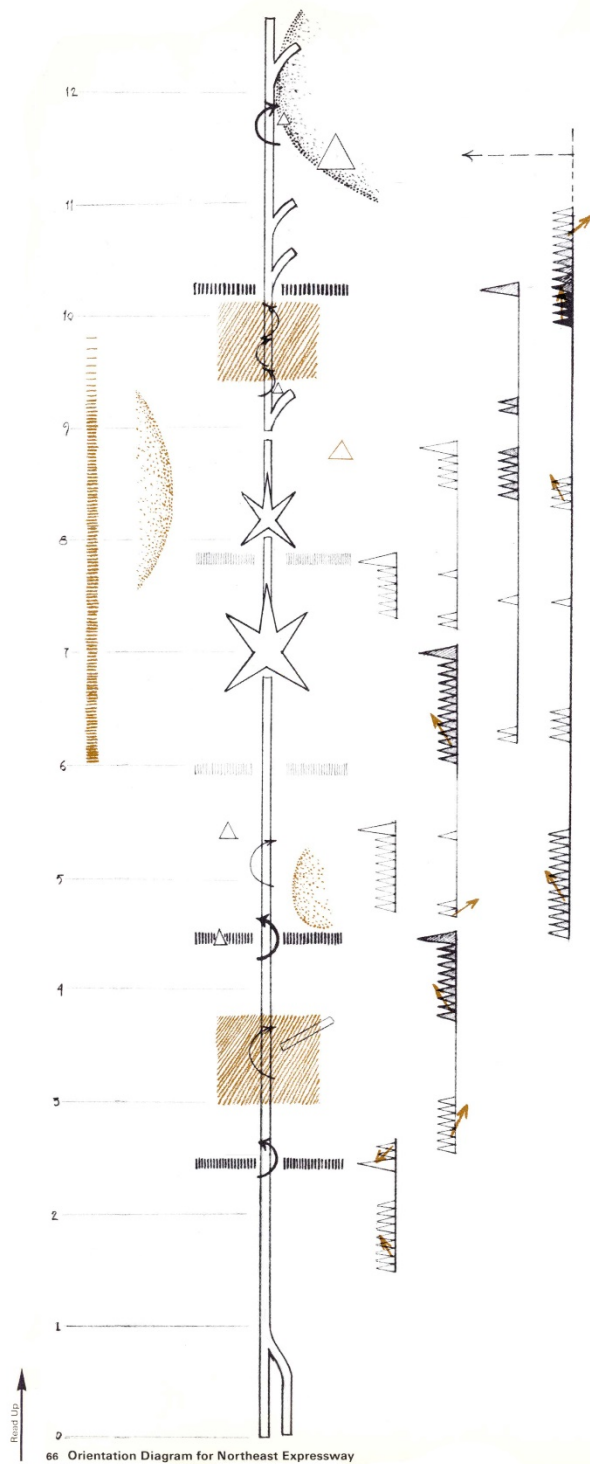
Figure 7 *Orientation Diagram for Northeast Expressway* (Created by Appleyard et al. 1964)
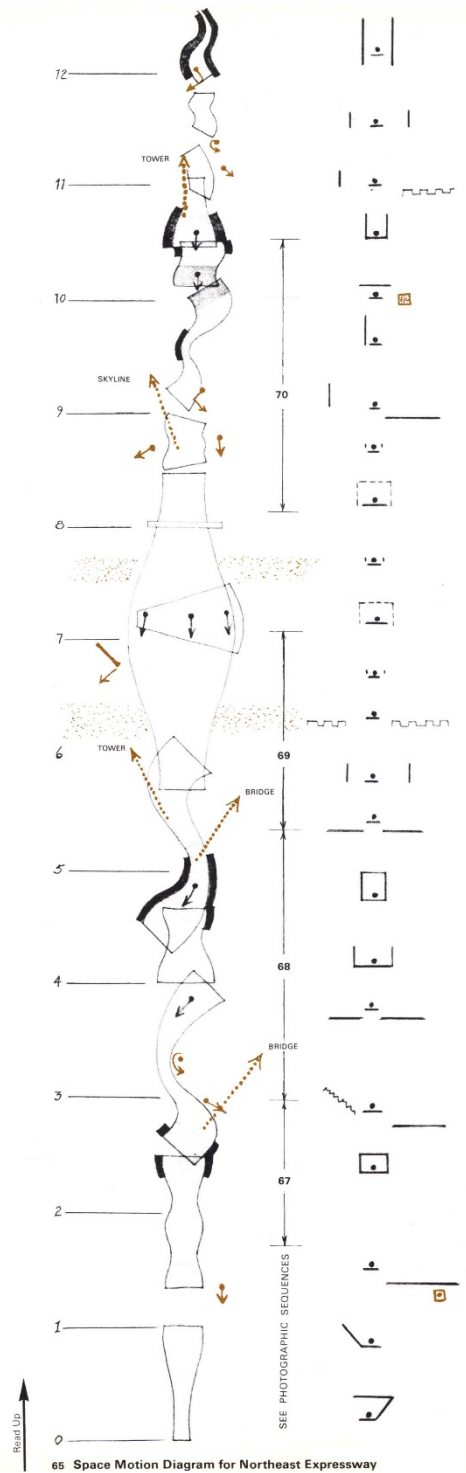


Figure 8 *Space Motion Diagram for Northeast Expressway* (Created by Appleyard, et al. 1964)

**Perception**

Considering human perception for such analysis, a definition and basic understanding of perception theory is required. Perception related to the scientific analysis within geography and spatial science is discussed as well as an introduction to the basics of neural networks that should be qualified for the proposed methods of building a knowledge base for neural network training.

> "The concept of perception is itself rich in ambiguity. In some cases, the concept is used 'to designate a world view, an outlook on life, or some other very general cognitive product.' This interpretation has little to recommend it from an analytic point of view. It does remind us, however, that there are some extraordinarily interesting problems in phenomenological philosophy and that 'images' of great generality may have tremendous significance to human decision making". (Harvey 1973)

It has been discussed that perception has been an underlying concept within a cognitive-behavioral approach to geography problems. However, as Harvey maintains in 1969, that the development of a clear measurement for perception is problematic and as such that "geographers have, at various times, been attracted to different formulations"(Harvey 1969) based on the objective of the research. Because the research builds on the concepts of the *image* of a city to categorize views from a road, it is reasonable that the formulation of a definition for perception would in this case, consider the external stimuli and internal processes.

Geographer Reginald Golledge describes the relevance of describing the external and internal environments this way,

> "Problems peculiar to the researcher attempting to search for theory in geography arise from the fact that he must be interested not only in the external physical environment and the internalizing of human actions, but also with the interface between the two. This raises the entire problem of how to represent cognitive and physical worlds, and how to use behavioural processes to explain overt activity in the physical world." (Golledge 1973)

John Pickles, a geographer that exposes some of Golledge's unanswered questions about the true relationship between the 'external' and 'internal', asks

"What relationship exists between objective reality and the world inside our heads? How can we determine the nature of the relationship between man in the world and the world in man?... From the information that is received from an individual, how can we spatially represent what is known?...What is the philosophical distinction between real and perceived environments?...What is the nature of the image or cognitive map?...How can we determine appropriate real measures against which to measure the representation of reality?" (Pickles 1985).

Humans have five major perceptual systems – vision, hearing, touch, balance, and taste or smell (Mather 2006). Structures within the human brain process perception with the cerebral cortex being the largest portion of the brain devoted to memory, cognition, perception, and consciousness. Over half of the neurons in the cerebral cortex are dedicated to vision (Mather 2006). There seems to be a common understanding among neuroscientists and other cognitive scientists that some perceptions of the world are just simply understood and not constructed in our brains (Mather 2006). These examples would include sounds, sights, and smells that people identify in the same or similar ways (Mather 2006). The underlying principle to the "theory of perceiving, then, is a theory of knowing the environment" (Carello and Michaels 1981).

One view of perception is labeled *direct* and is characterized by the "detection of information" (Carello and Michaels 1981). An opposite position of perception is termed *indirect* and deals with how input is processed in connection with symbolic representations and memories (Carello and Michaels 1981). There have been determined concrete mathematical relationships between external stimuli and brain processes. For example, light stimuli through the eye is known to have "three levels of synapse between photoreceptors and brain" (Mather 2006). There is also a measurable difference in a stimuli's "intensity" and "magnitude" such as "the brightness of a light, the loudness of a sound, or the heaviness of a weight increases as stimulus magnitude increases"(Mather 2006).

This idea aligns itself with 1930s mathematician, Alan Turing, whose concept of "universal computation" states that "all sufficiently powerful computing devices are essentially

identical," and that "any one device can emulate the operation of any other device" (Mather 2006). Thus, the prevailing notion about computers and human brain function is that that computers can be designed to imitate the brain processes (Mather 2006). Essentially, this theory says that external stimuli to the brain can be measured mathematically (Mather 2006).

"In some sensory judgements, such as brightness, sensory magnitude increases rapidly at low stimulus intensities, but flattens off or saturates at higher intensities. In others, sensory magnitude shows the opposite pattern. If the data are plotted on logarithmic axes rather than linear axes, they fall along straight lines in the graph. This means that sensory magnitude data conform to a power law, in which sensory magnitude grows in proportion to stimulus intensity raised to a power" (Mather 2006).

Not only should the measurement of perception be more clearly defined, but a clearer understanding of how perception is represented in the brain is also needed. The first view has a direct correlation between the external stimuli and "internal activity" within the brain and can then be treated quantitatively. The alternative view involves "symbolic representations, in which the state of the world is described using limited set of abstract symbols. Each symbol would represent a perceptual object or a property of an object" (Mather 2006). Quantitatively, the symbolic representations "the computations involve comparisons between symbols to test for equality, and the combination between symbols to test for equality, and the combination of symbols to create new symbol structures" (Mather 2006). It is recognized that the symbolic representations in the human brain are utilized in human cognition (Mather 2006).

It is both the *direct* and *indirect* representations of perspective that humans experience the built environment. Architect Steven Holl says that "architecture, more fully than other art forms, engages the immediacy of our sensory perceptions. The passage of time; light, shadow and transparency; color phenomena, texture, material and detail all participate in the complete experience of architecture" (Holl 1991). There are moments that architecture is experienced as a whole, when the continuum of the space is sensed. However the urban or city experience is

fragmented and only experienced in parts, lending itself to the idea of symbolic representations in the brain (Holl 1991), much like Lynch's symbolic representations of urban spaces.

The study site is a built environment, specifically the built environment as perceived from the viewpoint of a being in a vehicle. Much like the theoretical approaches of cognitive mapping predecessors, it is presumed in this research that the site is 'objective' or 'external' and that the visual stimulus of driving will produce an 'internal' process (Pickles 1985). This concept is necessary to frame the research within the views of perception from the geography, social sciences, and architecture and urban design. Even considering the criticism, the ideas held within the process and representations of cognitive mapping are pertinent to this research.

**Study Site**

Fayetteville, Arkansas in Washington County was chosen as the study site, to discover and then create a method for mapping and categorizing phenomenon at points along the city's routes (Figure 13).    Like many towns developing towns of the time, Fayetteville's street grid of the 19th century was organized around commercial districts that resulted from transportation infrastructure.  The original commercial district was a street system organized around a town square while a railway depot on a nearby Dickson Street began to establish a second (Nelson Nygaard 2016).  Thus, the development of the city's transportation infrastructure of rail and highway in the 19th century and early 20th centuries grew from these centers and contained a mix of land uses and pedestrian and vehicular traffic uses.  As the design of American cities began to be affected by more auto-oriented demands, land uses also began to spread out and become separated.  Post-World War II land and road development patterns in Fayetteville also saw separation of residential areas into low density suburban areas.  Contemporary city planning in Fayetteville aims to address the "unintended fiscal, social, and environmental impacts of sprawling, auto-oriented development patterns" (Nelson Nygaard 2018).

The current mobility plan for the city includes a Master Transportation Plan that commits to improving and creating multi-modal transportation networks through Fayetteville and the region. The plan includes some general and some tangible goals with common themes about fostering and enhancing connectivity, walkability, safety, and sense of place.  These concepts align with the tenants of a contemporary behavioral geography theory that could aid in the characterization of cities for future design enhanced by an understanding of how the city is experienced.

The site used for the proposed methods is the auto-oriented highway and streets of Fayetteville.  Lynch defined path as the element that has having the greatest potential for humans to experience a city and therefore, streets and highways are chosen.  Even with the ambition to create a

multi-modal transportation network for Fayetteville, understanding that highways and streets are used more frequently and by more people than any other path in the city supports that the site selection be restricted to this singular path type. How one engages visually with a city or built environment through these routes is the topic of questioning here and as such, a survey of data about these routes is presented.

To understand the kinds of routes that are traveled in this city and the region in which it intersects, simple questions are asked. What are the routes of the research site? What type of routes exist? Which routes do people spend the most time traveling? How long and how far do people travel most regularly? The Northwest Arkansas Regional Planning Commission (NWARPC) is the Metropolitan Planning Organization of the Metropolitan Planning Area (MPA) of Northwest Arkansas. Counties in the region include Benton and Washington Counties, Arkansas and McDonald County, Missouri. Some major municipalities include Bentonville and Rogers in Benton County and Springdale and Fayetteville in Washington County. The data collected in the study becomes more specific to Fayetteville, but the following description of routes are presented regionally. The 2040 Metropolitan Transportation Plan (MTP), produced by the NWARPC, begins to answer some of the questions about how people use transportation routes.

Published in 2015, the MTP focuses on research that describes regional patterns and growth including traffic forecasting. By using traffic count data from the Arkansas Department of Transportation (ARDOT), the MTP can quantify the way in which people in the region utilize the transportation network. By traveling the interstates, highways, roads, and streets of the region, people are connected to several municipalities and go through different planning zones, population densities, and road functional classes (Figure 15). As of 2015, all Fayetteville streets are classified as Alley, Residential, Local, Collector, Minor Arterial, Principal, Hilltop-Hillside

Overlay District and Downtown Master Plan and make up close to 10% of the land area (Nelson Nygaard 2016).

The Arkansas Highway Transportation Department (AHTD) uses road functional classification as defined by the Federal Highway Administration (FHA). It is the policy of these entities that in order to design roads based on efficiency that the network of routes must classified "according to the character of service they are intended to provide" (AHTD 2013). For example, some roads might have the objective of connecting residential neighborhoods to commercial centers while others might be for freight or long-distance travel (FHA 2013). No single road or highway is independently accountable for all travel and neither does the volume of traffic on one road or highway stay consistent along the path's trajectory. Therefore, functional classifications are assigned to segments of roads based on the traffic flow. Functional classification of roadways and streets are increasingly more important as they determine street characteristics, adjacent land-use, funding eligibility, and metrics and expectations on "preservation, mobility, and safety" (FHA 2013). It is for the purposes of understanding the relationship between these governmental classifications and phenomena they facilitate through the built environment that is of value here. For building a knowledge base for a neural network based on classification of phenomena instead of traffic volume to be useful and comparable to existing classification methods, it is not only important for the site to be points along highways and streets but to understand the predetermined classification of the points based on the road functional class they fall.

Functional classification for Fayetteville and the Northwest Arkansas region includes the standard "Arterials", "Locals", and "Collectors". The types range on a spectrum of mobility and accessibility with "Arterials" being the most mobile, "Locals" the most accessible, and

"Collectors" a more evenly distributed of both mobility and accessibility (FHA 2013). Table 1 references the characteristics of each classification as defined by the FHA. Other determinants describe subcategories of these classifications and in the case of the Fayetteville site, some of those subcategories like "urban" or "rural" and "major" or "minor" are used. The Fayetteville transportation analysis for the city's masterplan characterizes each functional classification even further by describing typological nature. For example, in Table 2, the FHA classification of "Principle Arterial" is a "Regional Link" street type that "serves low-density residential areas, open spaces." These types of character definitions begin to describe the current state of the road, giving insight into how municipalities qualify and quantify the path. The results of the proposed methods will give further insight into knowing about the relationship of these classifications and the mode of experiencing the phenomena of built environment density.

| Street Type | Definition | FHA Classification |
| --- | --- | --- |
| Urban Center | Serve the dense, mixed-use downtown core<br>Accomodates heaviest pedesrian activity<br>Incorporates bike/transit facilities as needed | Local Road |
| Regional High Activity Links | Regional connector carrying local and regional multimodal traffic<br>Serves a variety of densities and land uses | Local Road |
| Regional Links | Regional connector carrying local and regional multimodal traffic<br>Serves low-density residential areas, open spaces | Principal Arterials |
| Neighborhood Links | Spines through residential neighborhoods<br>Collects vehicles, cyclists and pedestrians from residential streets and connect to Regional Links | Minor Arterials/Collectors |
| Residential Links | Provides access to local residences<br>Functions as shared spaces for vehicles, cyclists, and pedestrians | Local Road |

Table 1 Definitions of Street Types in the Fayetteville Mobility Plan. (Derived from table by Nelson Nygaard 2018)

| Functional Classification | Distance Served (and Length of Route) | Access Points | Speed Limit | Distance between Routes | Usage (AADT and DVMT) | Significance | Number of Travel Lanes |
|---|---|---|---|---|---|---|---|
| Arterial | Longest | Few | Highest | Longest | Highest | Statewide | More |
| Collector | Medium | Medium | Medium | Medium | Medium | Medium | Medium |
| Local | Shortest | Many | Lowest | Shortest | Lowest | Local | Fewer |

Table 2 Relationship between Functional Class and Travel Characteristics. (Derived from table by the FHA 2013)

The purpose of most of the vehicle travel in Northwest Arkansas is commuting to work (NWARPC 2015). While other modes of transportation are used, most Northwest Arkansas workers commute to work by either car, truck, or van, according to the 5-year estimates of 2013 conducted by the American Community Survey (ACS). This means that 90% of work commuters 16 years and older in Benton and Washington Counties, Arkansas and McDonald County, Missouri use these types of vehicles to travel to work (NWARPC 2015). How much time are people experiencing the communities they drive through from their vehicles? Figure 9 shows the time it takes to commute to work in Washington county, where Fayetteville is located. The highest percentage of people in Washington County travel fifteen to nineteen minutes to get to work.

Throughout both Washington and Benton counties the Daily Vehicle Miles Traveled (DVMT) (Figure 10) and Annual Vehicle Miles Traveled (AVMT) (Figure 11) between the years 2009 to 2014 has increased. The population has also increased between the two counties so the DVMT per capita has stayed relatively unchanged at about twenty-three to twenty-four miles (Figure 12).

Within Fayetteville, Daily Traffic Volumes (DTV) are highest in the north-south traffic

corridors, with the mobility analysis by the city citing that more than half of commuters flow in

this direction.  The highest volume is on Interstate 49 between Fulbright Road and Highway 16

with 65,000 to 80,000 vehicles per day (Nelson Nygaard 2018).  Some specific road segments in

Washington County have seen over a 100 percent increase in Annual Daily Traffic (ADT) from

2009 to 2014, most notably, Hwy. 412, Hwy. 112 in Washington County. Over 43 and 97

percent increase in ADT was also reported for segments of I-49, Hwy 265, and Hwy. 16 within

Fayetteville city boundaries (Figure 14).
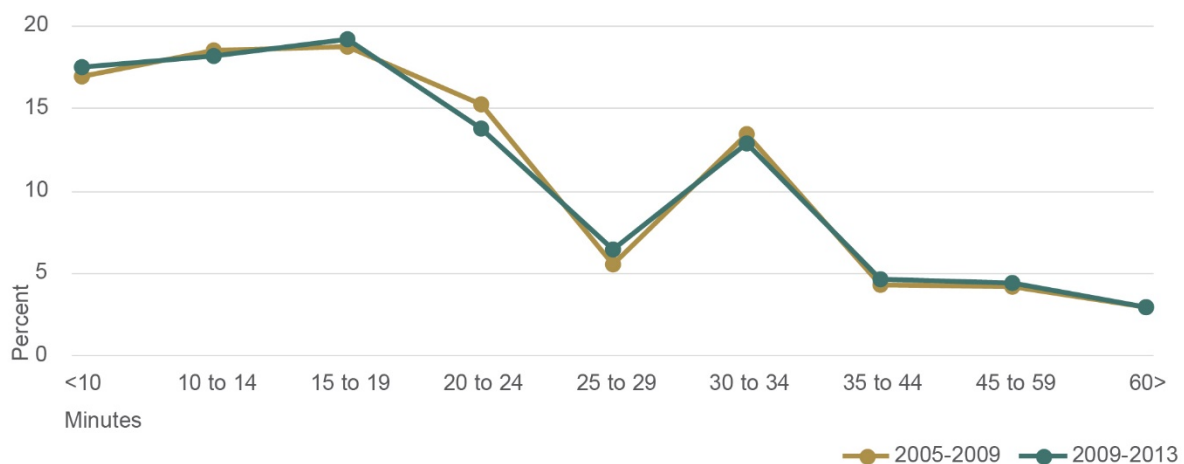


Figure 9: Travel Time to Work, Washington County. (Derived from NWARPC 2015
Source: American Community Survey)

The assessments of the roads of the region as well as a more detailed look at the streets within

Fayetteville are meant to describe the setting that people find themselves experiencing this city.

As Lynch so emphatically described, that paths hold the highest degree of exposure to

experiencing a city.  In of Fayetteville, AR, roads are the primary mode of mobility and therefore

the streets and routes of the city become the site for elaborating on Lynch's methods for the

quantification of a city's "image".  The following methods are specifically sited using the GIS

street data of the Fayetteville municipal boundary.
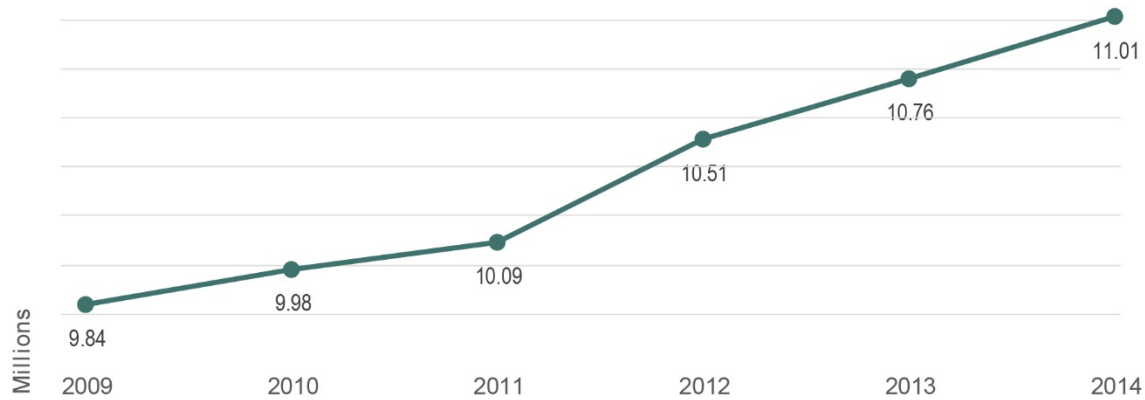


Figure 10: Daily Vehicle Miles Traveled, Washington and Benton Counties (Source: NWARPC)
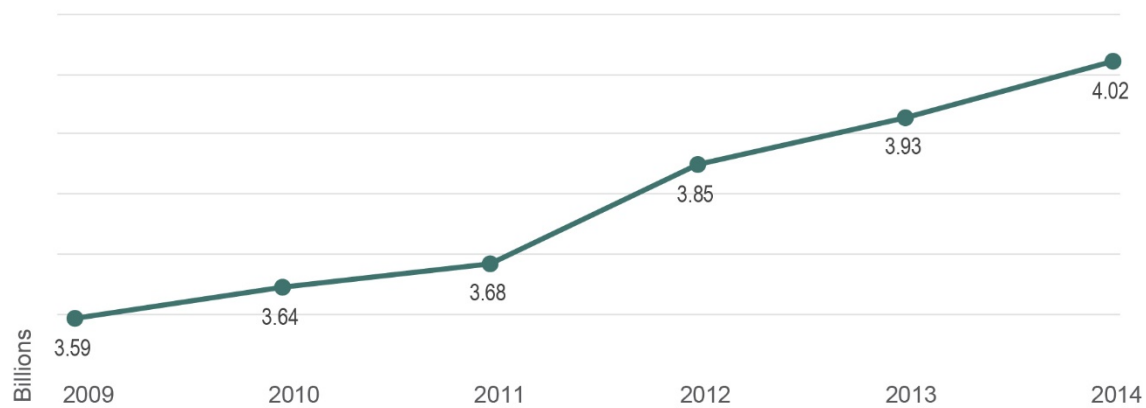


Figure 11: Annual Vehicle Miles Traveled, Washington and Benton Counties (Source: NWARPC)
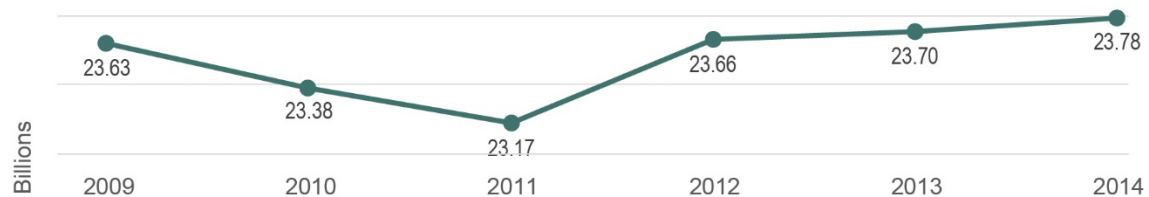


Figure 12: Daily Vehicle Miles Traveled per capita, Washington and Benton Counties. (Source: NWARPC)
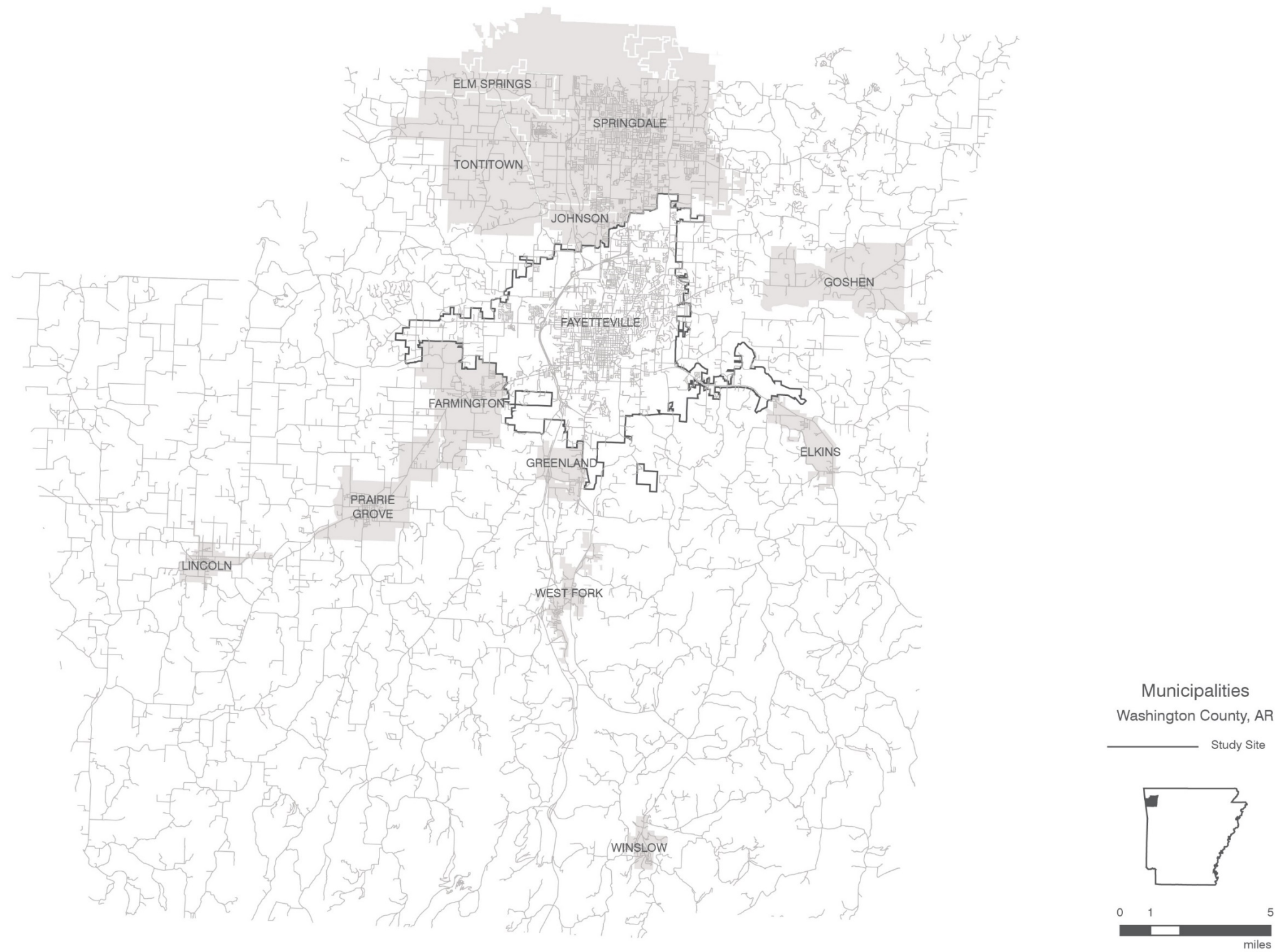
Figure 13 Municipalities, Washing County, AR
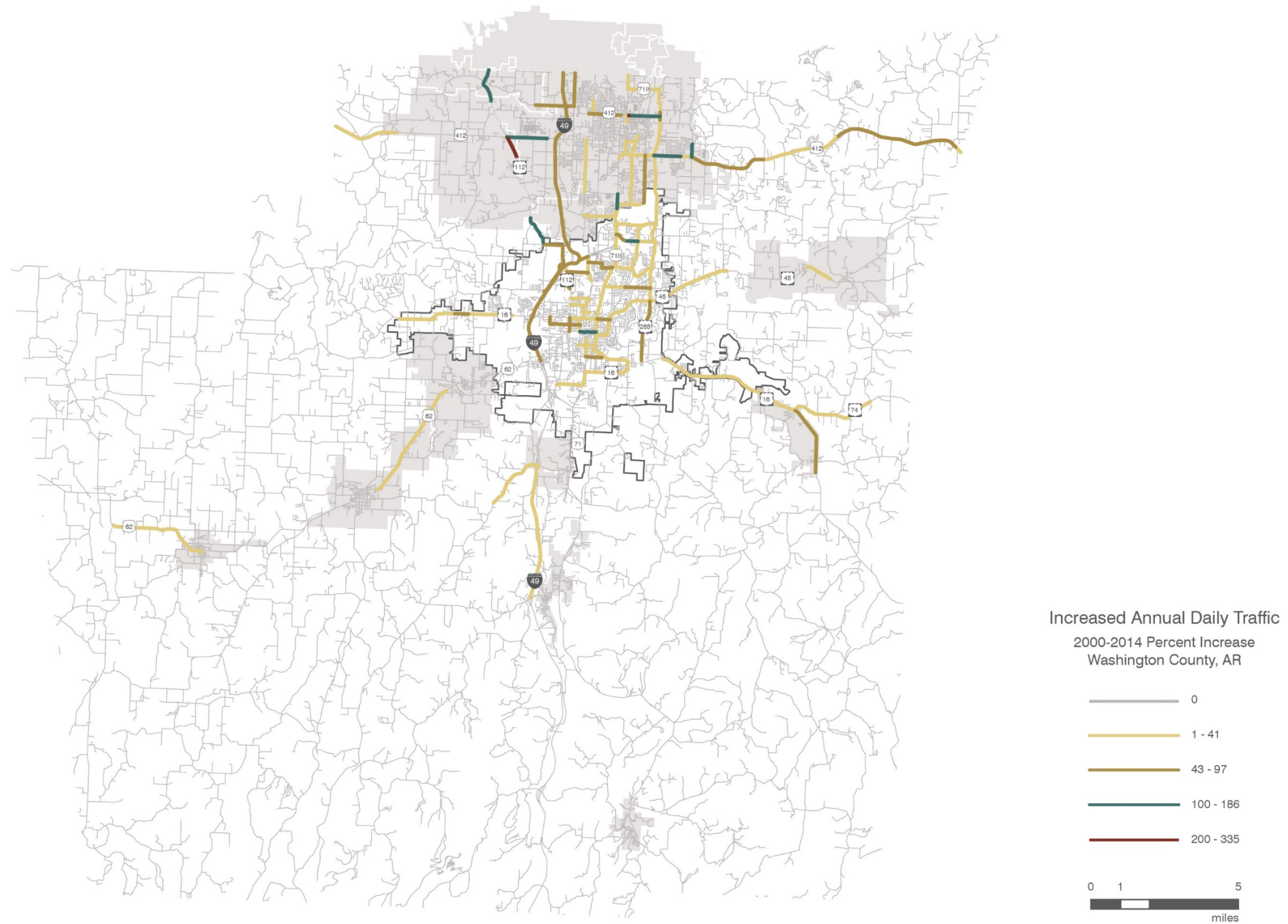
Figure 14 Percent Increase in Annual Daily Traffic, 2000-2014, Washington County, AR (Adapted from map by NWARPC)
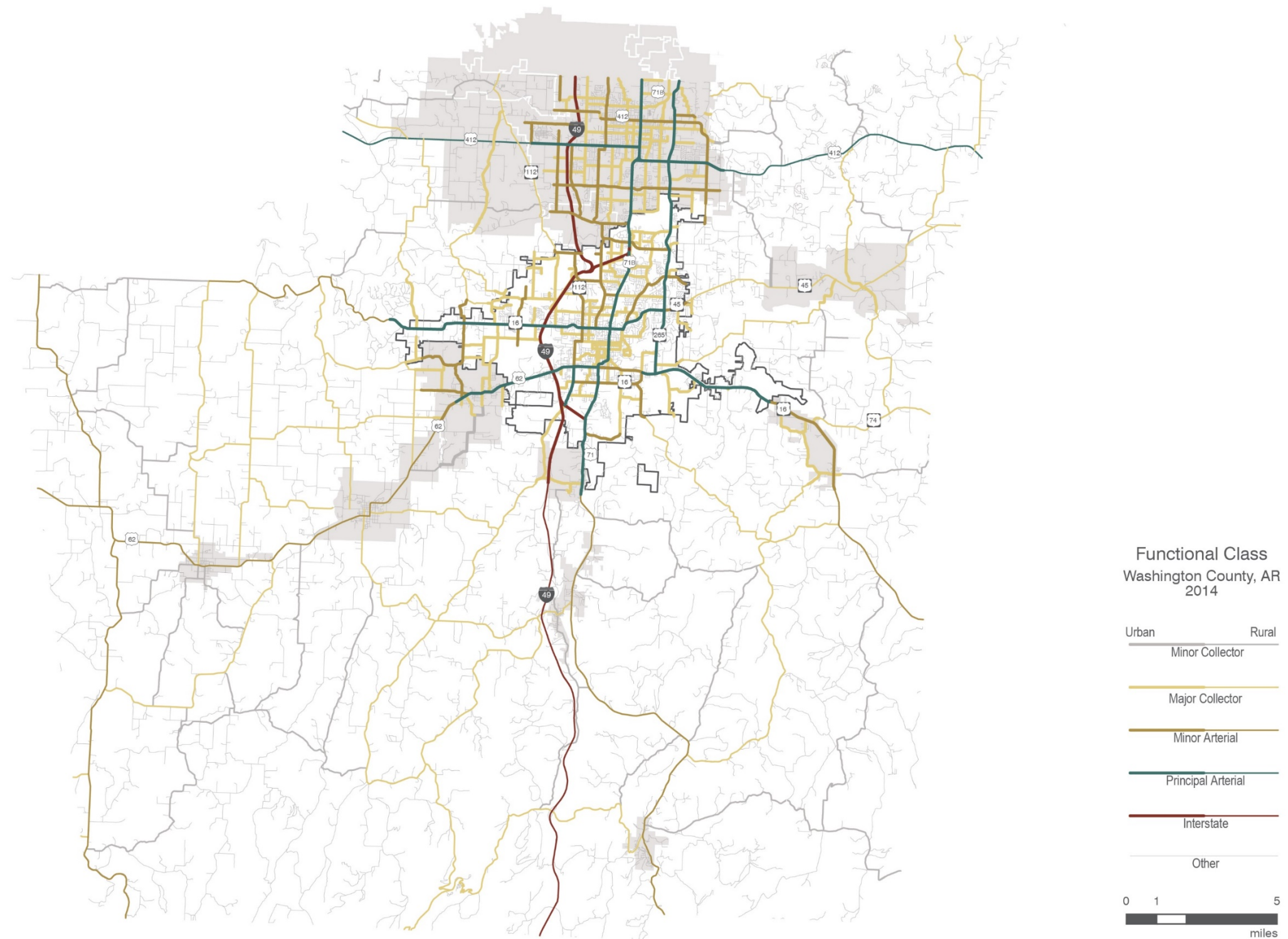
Figure 15 Roads by Functional Class, Washington County, 2014

**Methodology**

Lynch, and others that have emulated his approach, developed methods within a humanistic geography to describe the readings, or legibility, of a city's *image*. In efforts to align with the scientific process, the elements of the *image* became variables to measure and compare between themselves and other urban environments. While some rigor of scientific method was applied with Lynch and his contemporaries, as previously mentioned, methods were limited by lack of computational power and not always empirically sound nor fully considerate of cognitive theory.

While still presenting as a Lynchian model, the methods presented assume that quantification and articulation of perceived phenomena of a city in cartographic form is not only possible but made more empirically accurate by the ability to spatially analyze urban data within GIS. The proposed methods do not, however, argue to be able to fully articulate perception of a single person or a whole city's population in a cartographic artifact. The following methods only aim to describe an approach to classify data for a neural network knowledge base by defining an analysis of a phenomenon that is present while traveling through a city on a vehicular path. This approach updates the humanistic methods employed by Lynch and fellow researchers in the development of early behavioral and human geography.

The purpose of using a neural network to categorize data based on perception (images as data in this case) is to be able to use machine learning tools that have been and are being improved to simulate human cognitive patterns. Using machine learning as a part of behavioral geography methods increases the connection to cognitive theories. However, the learning part of a neural network is only as good as the training it receives. The methods outlined propose that a neural network be trained to recognize a particular phenomenon based on a knowledge base of images that have been classified by pairing fundamental techniques of observation, as in Lynch's

*The View from the Road*, with spatial analysis techniques in GIS to describe that particular

phenomenon. The steps to a classify a phenomenon from a view from the road is discussed as

follows:

1. Define a phenomenon in the city of Fayetteville that can be quantified both

perceptually and physically.

2. Quantify the phenomenon along vehicular routes.

3. Process the quantification statistically based in perception theories.

4. Group and map values in GIS database for future use classifying images, or views,

along the same vehicular routes for a neural network knowledge base.

What part of human experience can be measured both based in perception and in its

tangible state? Phenomena are the specific elements that are observed through the senses. A city

has many possible elements in which to characterize like color or sound, or other more subjective

terms like "scenic". The proposed methods use density of built structures as a perceptible

phenomenon that could be measured along a route. Commonly based on population, density for

this analysis is based on density of the built environment because it is a critical element of what

delineates a city. As described by Lynch, the built environment is defined by edges, districts,

nodes, and landmarks, all aspects of a city's *image* legibility.

To physically define density of built structures along roads, each footprint of all

structures in Fayetteville were mapped (Figure 18). Vision is the most important sense used to

perceive buildings and therefore, the human visual field is a vital component of calculating the

perception of building density along a road. The normal range of a human visual field is

indicated in Figure 16. There are several variables present in a city that would affect what can be

seen in a driver's field of view. Because of limitations of available surface and elevation model

data, only a two-dimensional aerial representation of the field of view is used.  Elements like vegetation, building elevations, and topographic elevations are not included in the data presented.  This is problematic because actual field of view is determined in three-dimensional space and not two-dimensional space.  Future adaptation of these methods to include the other relevant parameters that occur in the field of view is needed.  For the purposes of establishing procedures to categorize segments of road based on building density and not functional class, only two-dimensional representations of buildings and an unarticulated topography of Fayetteville is used.
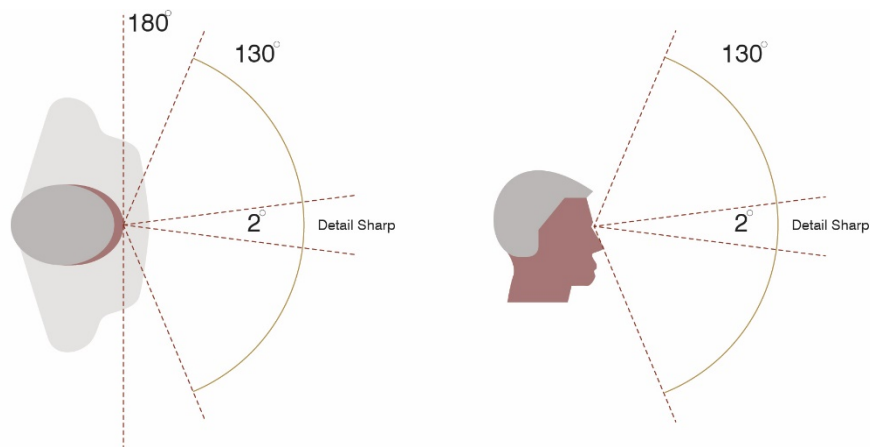


Figure 16 Normal range of visual field. (Derived from diagram
by (Sugden and Reid 2006)

To quantify the density along each road, each interstate, arterial, and collector road in Fayetteville was mapped along with the building footprints in GIS.  The ARDOT classifications of each road by functional class was identified and shown in Figure 15.  Figure 17 isolates a segment of road and building footprints, showing an example of the following steps. Simulation of a driver's visual field from each of these routes was represented at points along each route. To do so, each of the 62 routes were divided by evenly distributed points determined at one second at 50 miles per hour speed, or about every 73 feet. Maximum speeds do vary along the

routes; however, the same speed was assumed across all routes. How speed influences what is

perceived in the field of view could be a variable to consider in future investigations.

Using GIS spatial geoprocessing, a buffer with diameter of 100 yards was built around

each point.  In the same way that 50 miles per hour was assumed for each point along the routes,

a 100-yard diameter buffer was chosen heuristically to describe the field of view of a driver at

each point.  Changing the size of the field of view buffer as well as using a three-dimensional

representation of the field of view could be used in future studies to better simulate other

parameters of actual human sight.  Quantification of the building density along each route was

calculated at each point by dividing the square footage of the 100-yard buffer by the square

footage of any building that the buffer intersected.  All buildings that are experienced along the

roads within 100-yards is mapped in Figure 20.  A more detailed view of the intersections of

Interstate 49, MLK Jr. Blvd., and Razorback Rd is depicted in Figure 21 along with each

component required to calculate the building density along roads in Fayetteville.



Figure 17 Road divisions and 100-yard visual field buffer.

Building a knowledge base for training a neural network to identify building densities

along routes requires that the training images are also categorized based on accurate descriptions

of human perception.  To quantify density along the road based in perception, modeling the

nonlinear nature of human perception is needed.  In this case, two processes were applied to the

raw density data to best model human perception.  Researchers have determined that for a

human, the relationship between sensory stimulus and perception is logarithmic (Varshney 2013). The first step to defining density of built structures based on human perception was to calculate the logarithmic density. The second process was taking the logarithmic density and process a local regression that would give each point a weighted average of experience to simulate the act of driving along a road. A bandwidth of 500 yards, or 250 yards forward and backward from each point was used in a loess, or locally weighted regressing, smoothing function. A regression of this type is appropriate as it reveals the behavior of a multivariate sample (Cleveland and Devlin 1988). Varying bandwidth size and weight forward and backward would be possible future study considerations to compare with the perception of a built environment weighted by experiential variables like speed of travel.

     Besides the opportunities for comparison that these methods provide, the final steps in the methods would be to categorize images, or views, collected along the routes. While it is not the goals of this process to collect the images along each route, example categorized images are provided in the results. Categorized images of views along each road would be used to build a neural network knowledge base. Further discussion of this final process is discussed in the conclusion.
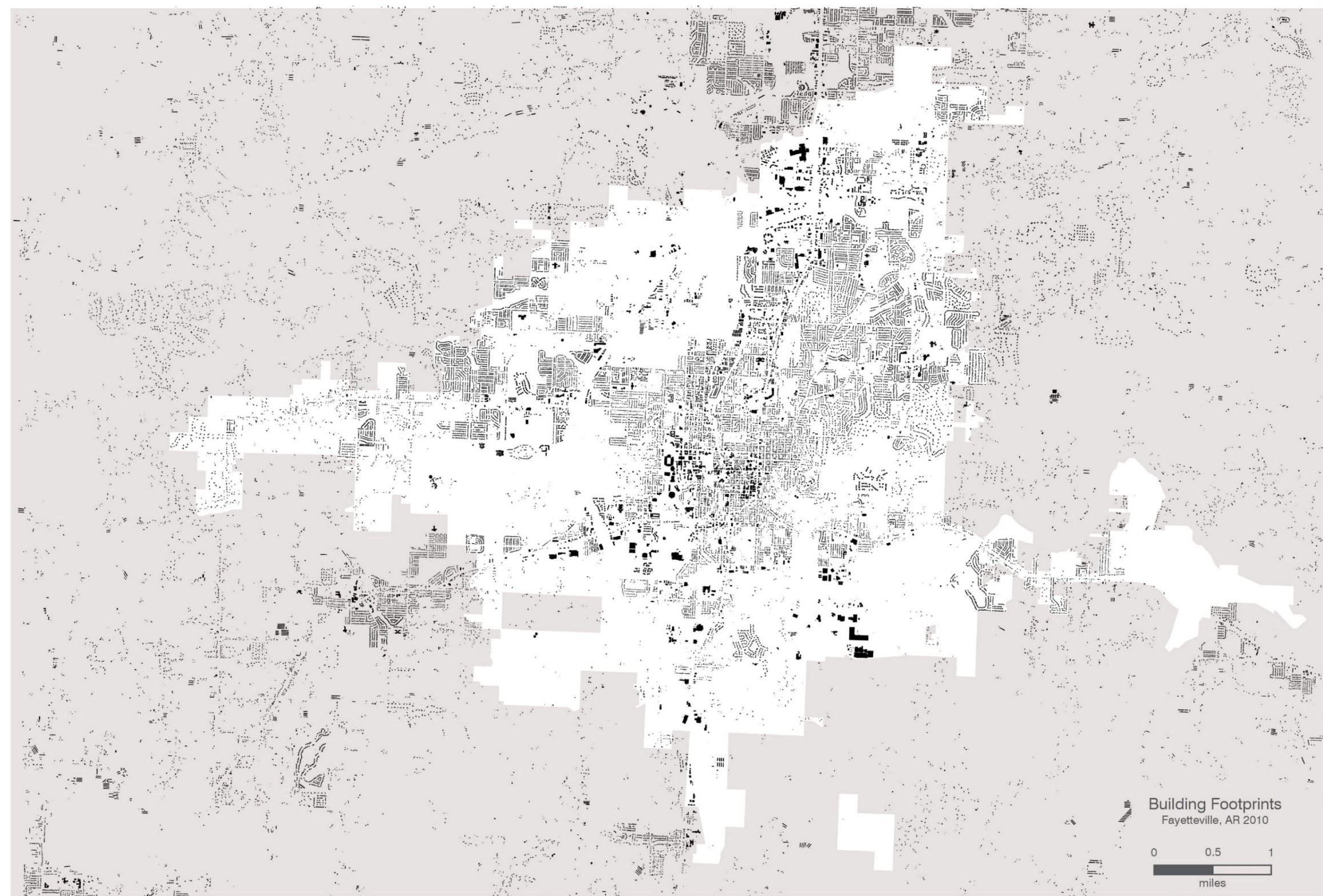
Figure 18 Building Footprints in Fayetteville, AR 2010
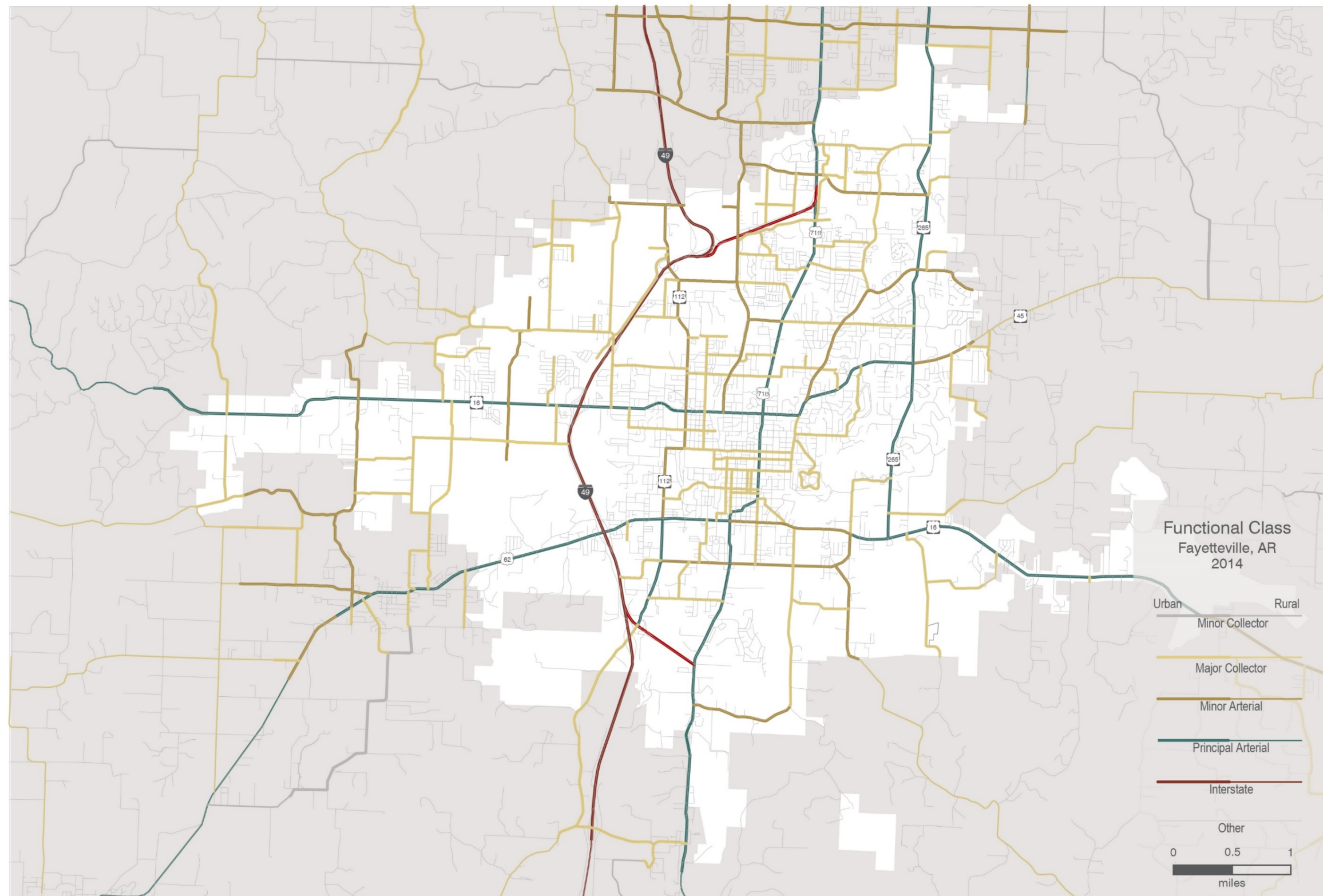
Figure 19 Functional Class in Fayetteville, AR including urban and rural distinctions

Building Footprints
100 yards by Functional Class
Fayetteville, AR
2014

Minor Collector
Major Collector
Minor Arterial
Principal Arterial
Interstate
Other

0    0.5    1
miles
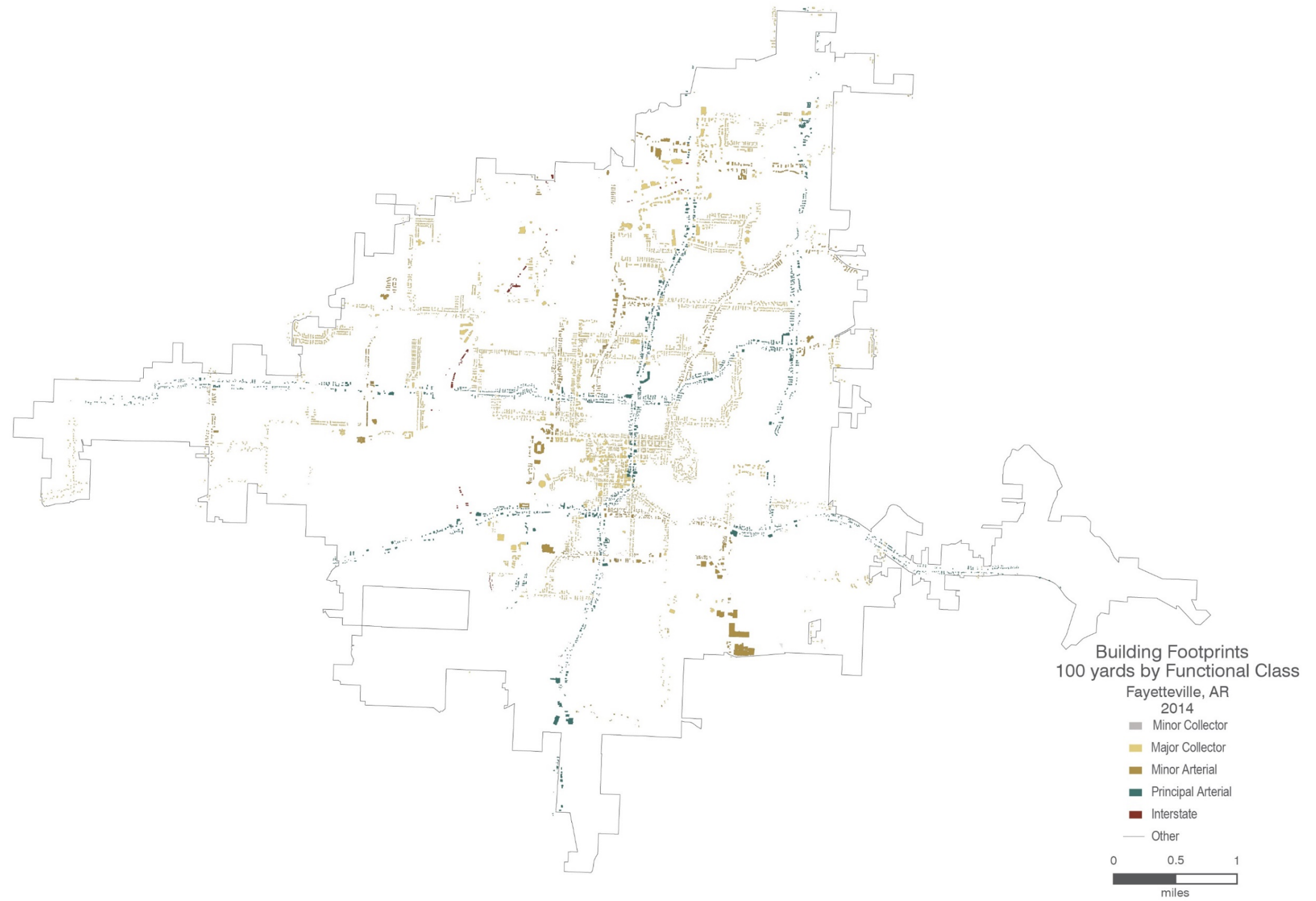
Figure 20 Building footprints that intersect 100-yard buffer coded by route functional class
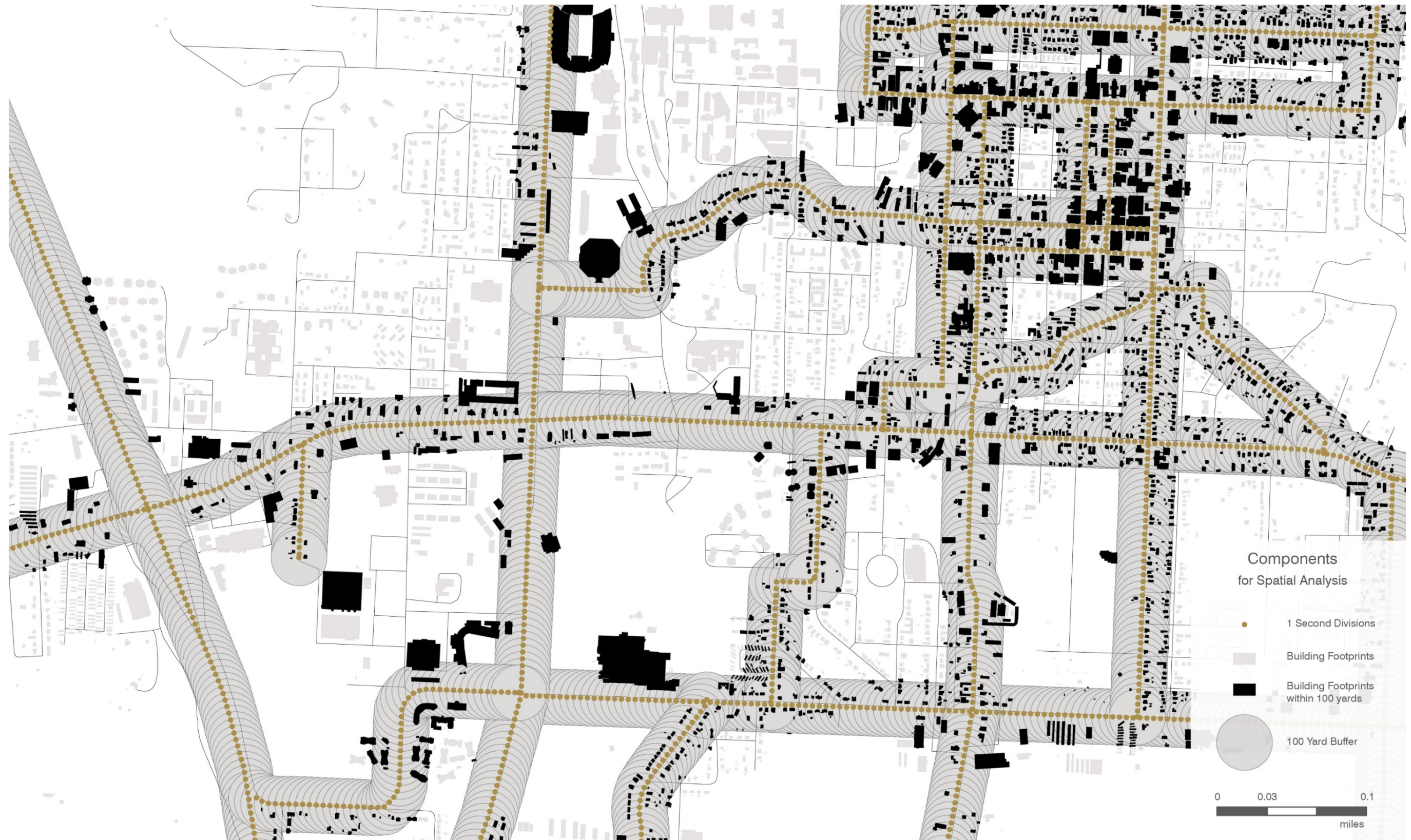
Figure 21 Components for Spatial Analysis

**Results**

The methods previously outlined result in an information rich database that can be used for further classification of images taken along the same segments of road for a neural network knowledge base.  The data also offers opportunity for comparison and discussion about current road classification systems.  Using Fayetteville, AR as a sample city, the following results present the building density and weighted average building density along the varying road functional classes.

Results are presented in cartographic and graph form as tools for comparison.  The results will first depict building density by functional class and will then isolate street examples from each functional class for comparing the linear building density data to the smoothed weighted average building density data.  The selected streets will also indicate street intersection points along the route.  Finally, images taken along a sample road, Highway 71, are classified and presented as an example of how the next steps of the proposed methods might start the categorization process of a neural network knowledge base.

There are 62 routes categorized as "Interstate", "Arterial", or "Collector" in the Fayetteville municipal boundary.  Functional class "Minor Collector" or sometimes referred to as "Locals" was not quantified in these results.  Weighted average building density of each street is presented in groups based on the street's ADOT Functional Class.  In cartographic form, the weighted average is grouped into 4 classes, weak to strong.  Using the Lynch's definition of a city's *image* as a guiding principle, the proposed methods also use a nominal scale for distributing the legibility of a city's image.  Here, weak to strong then refers to the strength of Fayetteville's building density *image*, or phenomenological density from the road.
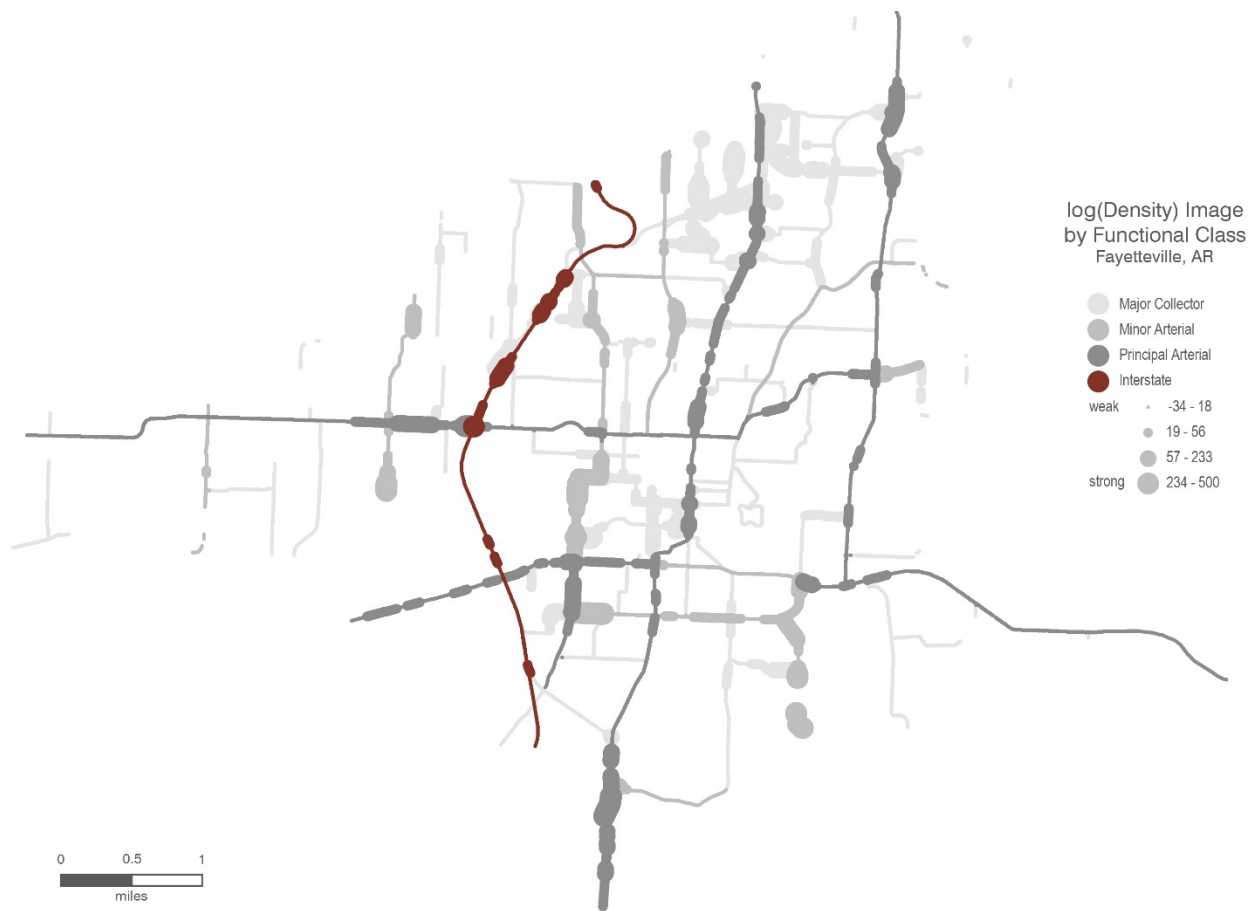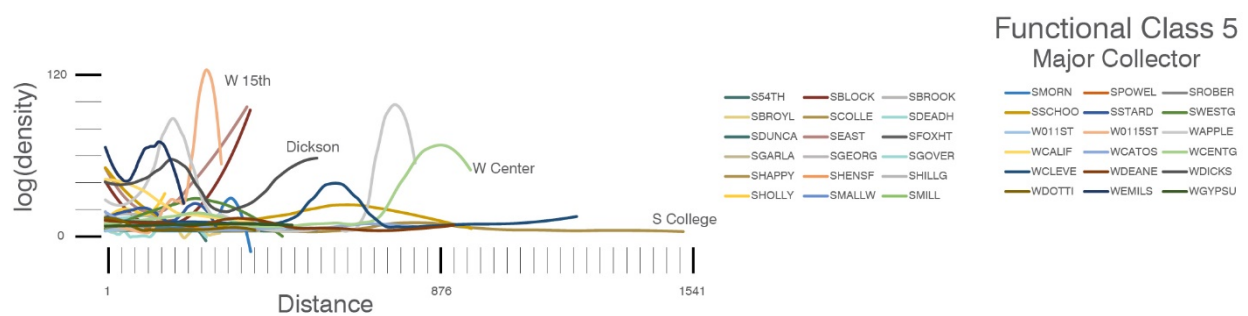
Figure 22 Image Map Log(Density) with loess regression of Fayetteville grouped by Functional Class - Interstate
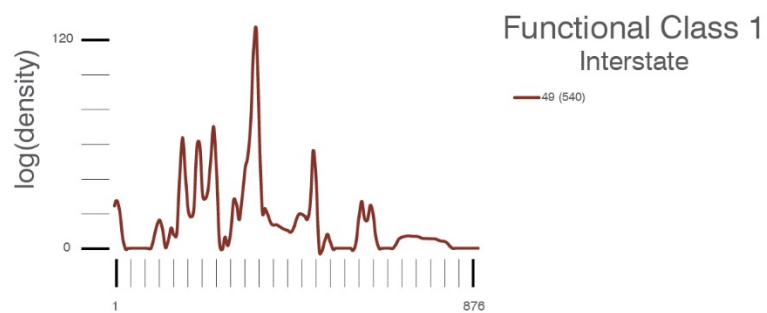


Figure 23 Log(Density) with loess regression of Fayetteville routes grouped by Functional Class - Interstate

Functional class one, interstates, includes one route, Interstate 49 (I-49 or I-540 at the time of source data creation) and is shown in Figures 22 and 23.  The length of the interstate is shorter through the actual Fayetteville city limits than other routes, like functional class three, principal arterials that are longer distances.  Along the length of I-49, the density is highly variable, indicating that singular larger buildings or groups of smaller buildings are located at long intervals.  Stretches between the higher density peaks might also indicate that larger building footprints are not as close in proximity to the interstate.  In terms of the strength of the phenomenological density, the density would be perceived as weak with about 5 peaks of medium to strong density along this route.

Routes of functional class three, principal arterials (Figures 24 and 25) contain eight roads and is the functional class with roads of the longest distances.  The most similar characteristics of this functional class is that this type maintains a medium to strong phenomenological density for long periods along the path.  Variability between weak and strong phenomenological density does exist for the roads.  For instance, Highways 71, 16, and 265 have steep peaks indicated in their density graphs, representing brief moments of again, either large buildings or large clusters of buildings.  The graph and mapping of Highway 71 shows a consistently higher rate of density along the entirety of the road, indicating a more robust structural development along the length of this corridor than the other principal arterials like Highway 265.  Looking at the Density Image map for this functional class, a visible increase in density seems to occur where the principal arterials intersect minor arterials, major collectors, or the interstate.
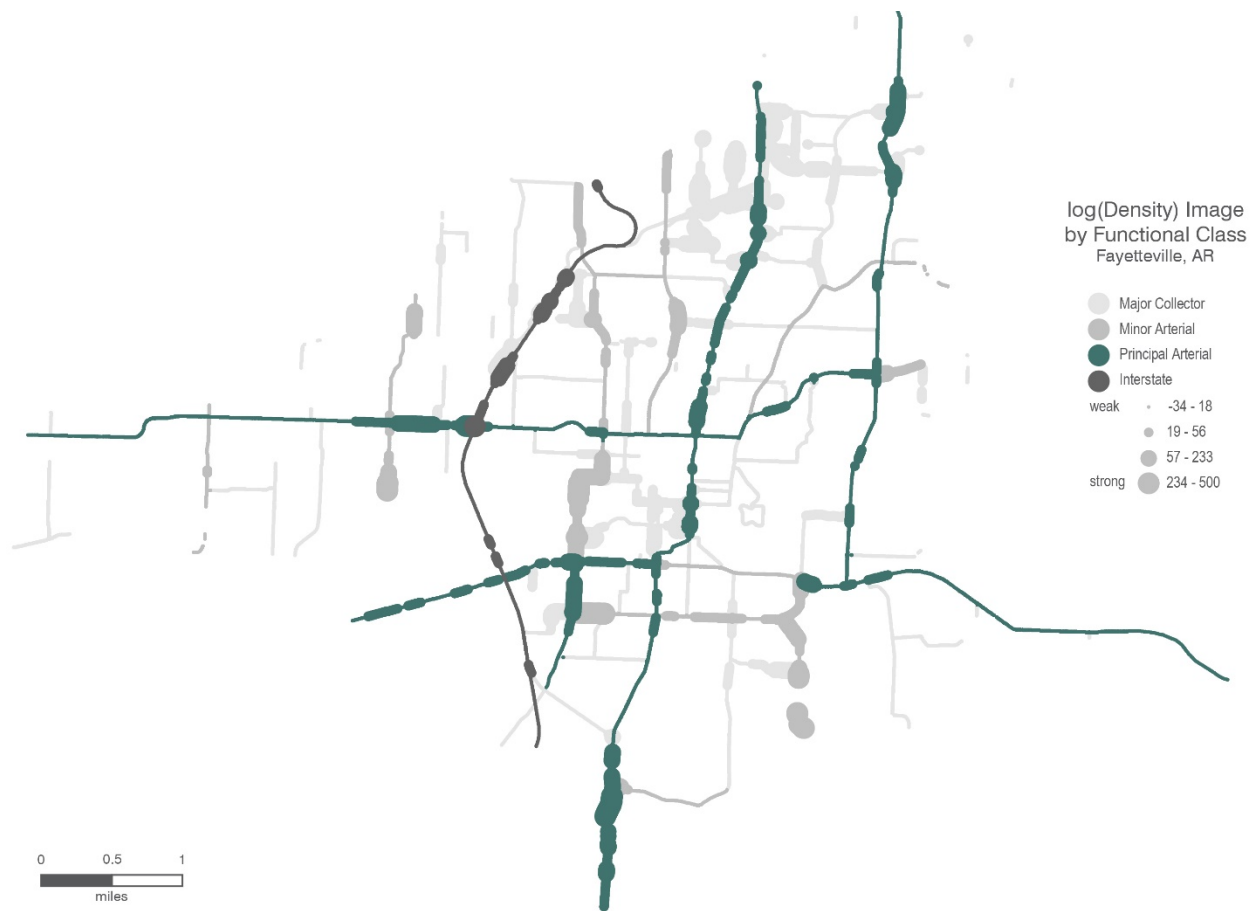
Figure 24 Image Map of Log(Density) with loess regression of Fayetteville grouped by Functional Class – Principal Arterial
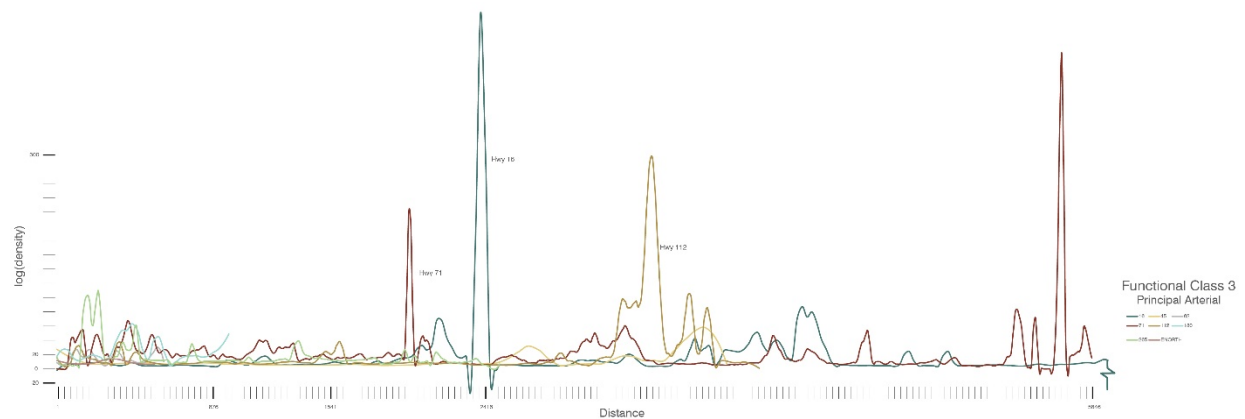


Figure 25 Log(Density) with loess regression of Fayetteville routes grouped by Functional Class – Principal Arterial
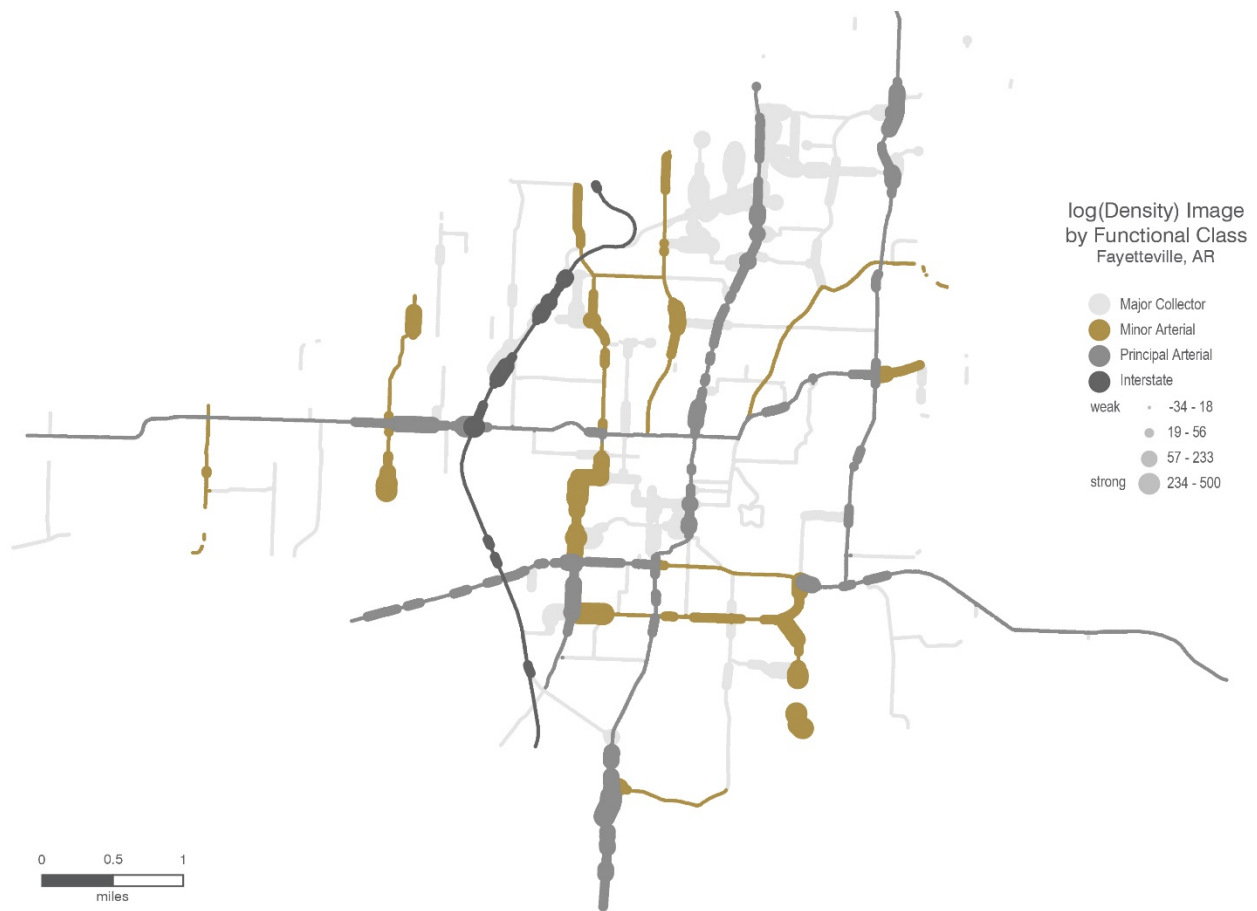
Figure 26 Image Map of Log(Density) with loess regression of Fayetteville grouped by Functional Class – Minor Arterial
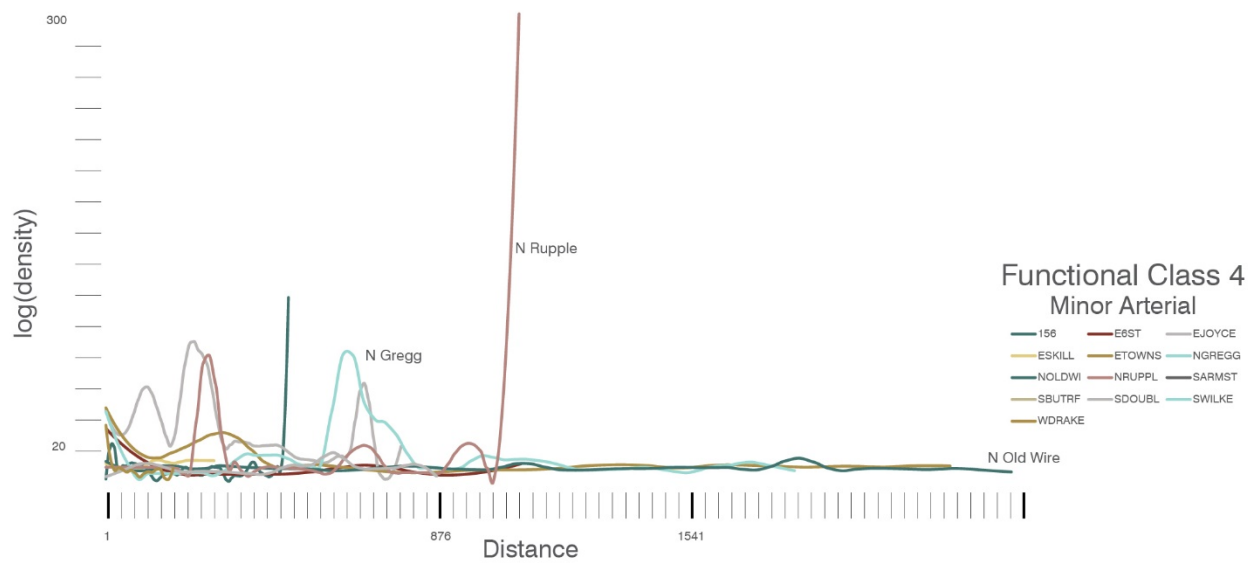


Figure 27 Log(Density) with loess regression of Fayetteville routes grouped by Functional Class – Minor Arterial

Functional class four, minor arterial (Figures 26 and 27) has a building density generally higher along the length of the route than the interstate class. The lengths of the thirteen routes are shorter than principal arterials and typically only contain one or two peak densities, but the peak interval is long. An example of being relatively unchanged then peaking for a long interval is Gregg Avenue (NGREGG). These long intervals indicate that dense structures are built near the road, as is the case of Highway 112. The strongest phenomenological density on Highway 112 occurs around the University of Arkansas campus where large recreational and residential buildings are located. If the other minor arterial routes do not peak one or two times along its length, then it seems as though the routes maintain a relative even density as in North Old Wire (NOLDWI).

The highest number of routes is in the group of functional class five, major collector (Figures 28 and 29). The thirty-six routes are also the shortest in length. A higher density along the entire length is shown in most of the routes such as Dickson Street (WDICKS). Where the collectors have high phenomenological density, residential and older and denser commercial districts are prevalent. Low or weak phenomenological dense collectors are often streets at the edges of less dense single-family residential neighborhoods.

The loess locally weighted average of building density along each route is represented in a compilation chart in Figure 30. The charts of each route described thus far could be useful tools in describing the density types along a route but locating them geographically would also aid in learning more characteristics of the routes. Figure 31 uses such a cartographic tool by depicting the smoothed weighted average structural density at every point. In this format, clusters of density throughout the city can now be understood more holistically.

Figure 28 Image Map of Log(Density) with loess regression of Fayetteville grouped by Functional Class – Major Collector



Figure 29 Log(Density) with loess regression of Fayetteville routes grouped by Functional Class – Major Collector
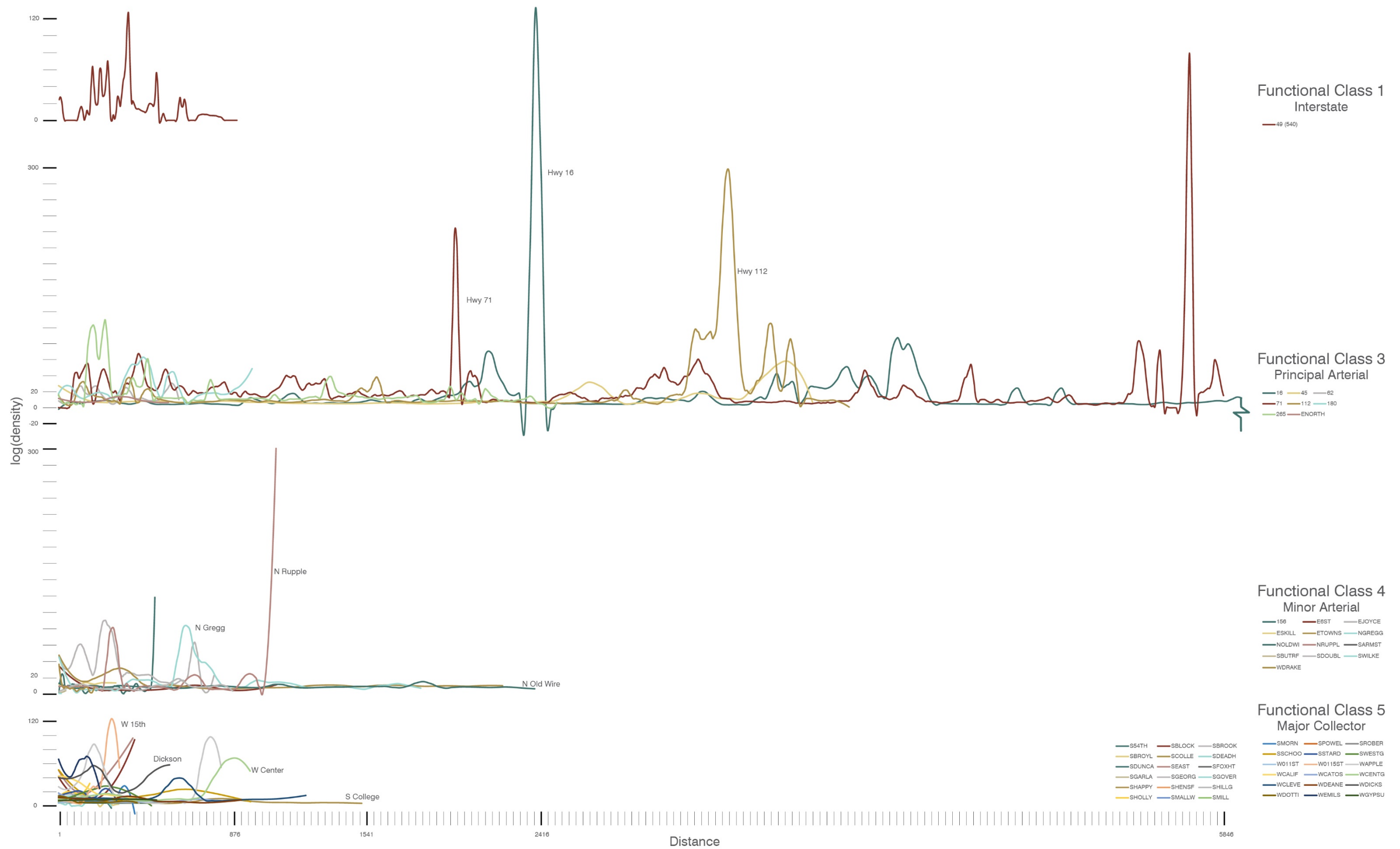
Figure 30 Log(Density) with loess regression of Fayetteville routes grouped by Functional Class
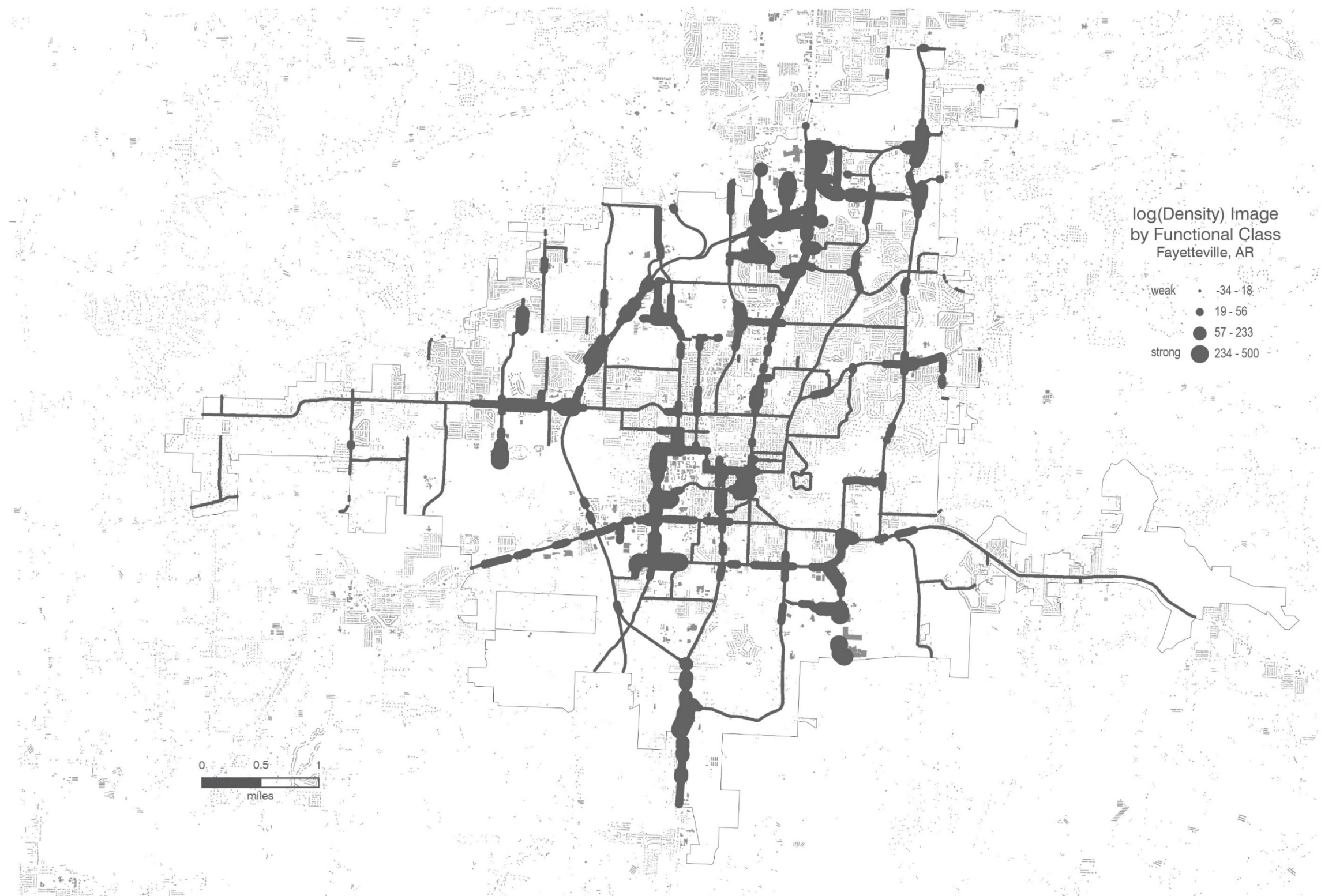
Figure 31 Image Map of Log(Density) with loess regression, Fayetteville

How street intersections might influence density was investigated along Interstate 49, Highway 71, Highway 265, Gregg Avenue, and Dickson Street (Figures 28-32) by charting the intersections and their functional class along each path. Both the smoothed weighted average of structural density and the linear density plot is included in the graphs. Because Highway 71 is a principal arterial route that traverses most the municipalities in Washington County, there are a significant number of intersections along its length. Questions about how structural density increase or decrease at an intersection are comparable by isolating routes. Do intersections of one specific functional class differ from the intersections of another functional class? Layering other data information along the routes creates possibilities of asking and answering these questions. The following discussion uses the example of Highway 71 and its twenty-one intersections to describe the data layers indicated in the graphs.

Along Highway 71 (Figure 29), the area of the intersections of Maple through W Rock describes an area that has multiple intersections in a short length and has a high structural density throughout. This indicates a characteristic of a downtown area, where the proximity of dense buildings to the road is increased. Other areas like Joyce, shows a direct increase of building density leading up to and at the intersection. This could possibly indicate buildings at the adjacent corners of the immediate intersection, as the peak rapidly declines as travel departs the intersection. Clusters of density can also be perceived along the length of Highway 71. Similar density types exist between Joyce and Rolling Hills, E Drake and North, Maple and W Rock. The lengths between School and beyond Cato Springs starts to develop a pattern of long segments with low density and extreme peaks of high density, mapping a much different density typology than the earlier clusters. Similar typological comparisons can be made for the other isolated streets.
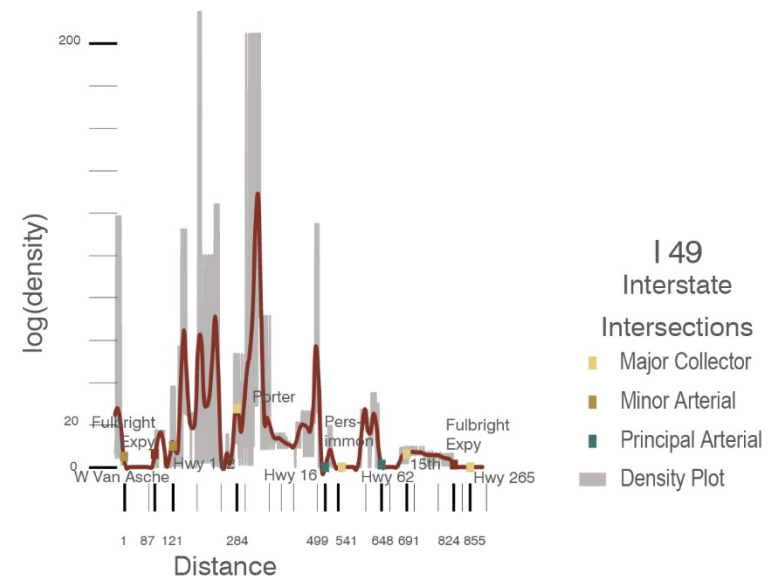
Figure 32 Density, Log(Density) with loess regression, and
Intersections – Interstate 49
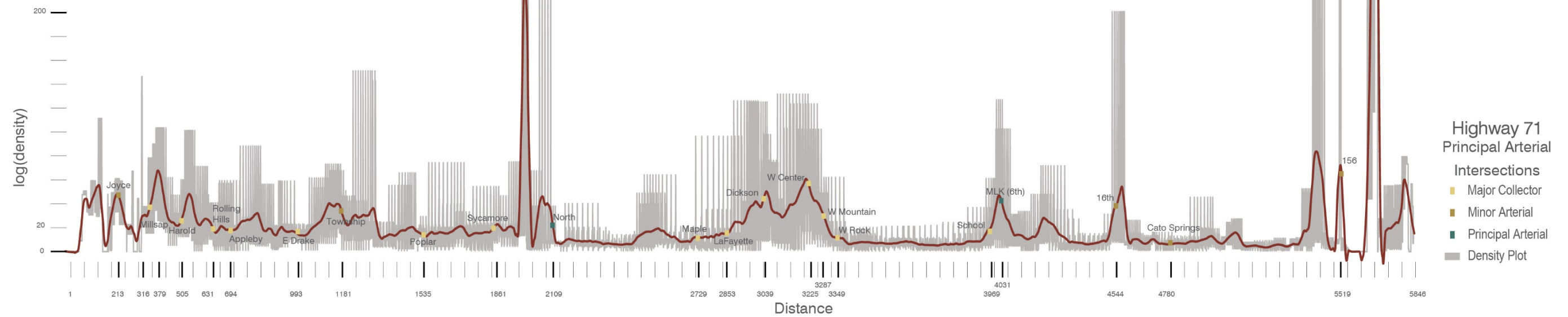


Figure 33 Density, Log(Density)with loess regression, and Intersections – Highway 71
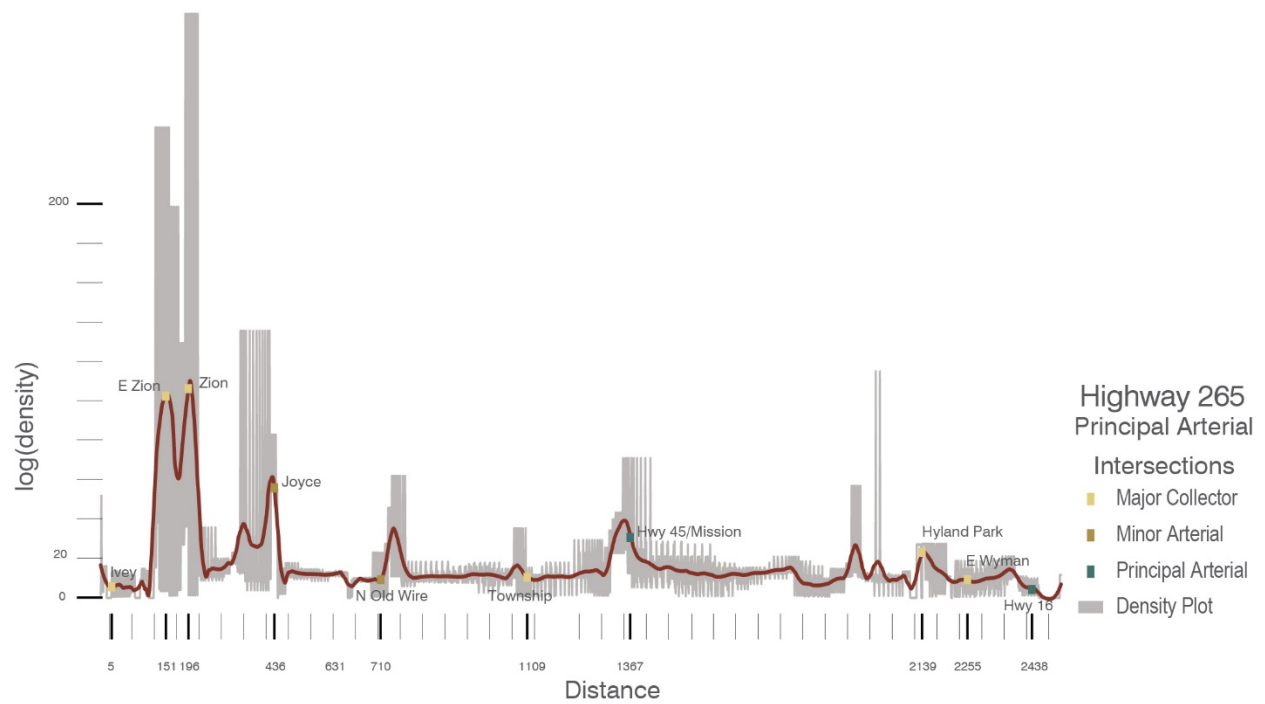
Figure 34 Density, Log(Density) with loess regression, and Intersections – Highway 265
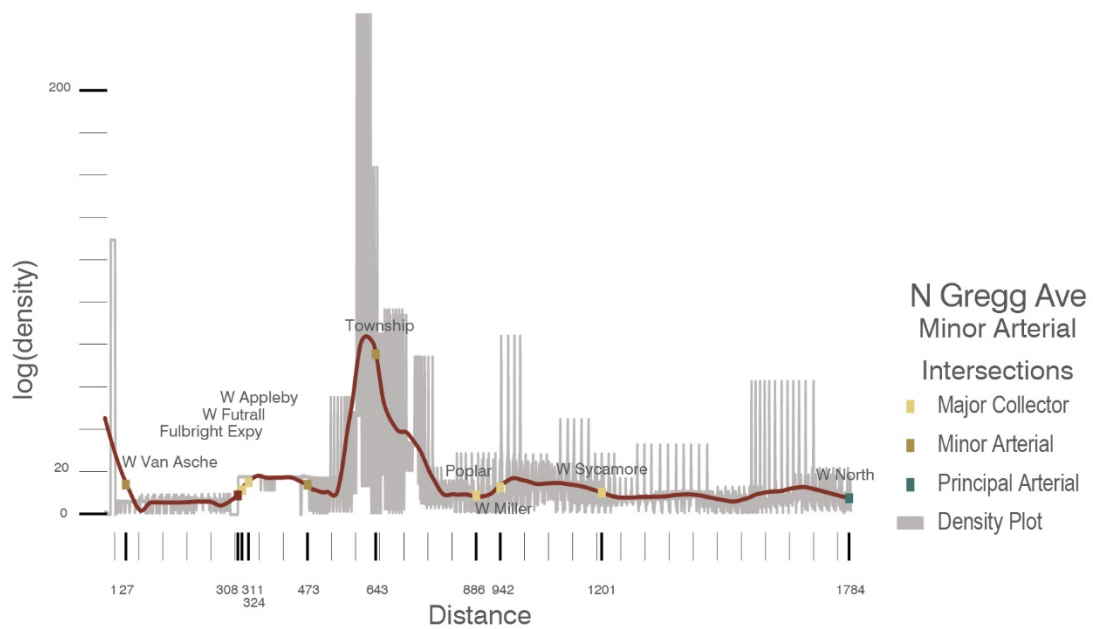


Figure 35 Density, Log(Density) with loess regression, and Intersections – N Gregg
Avenue
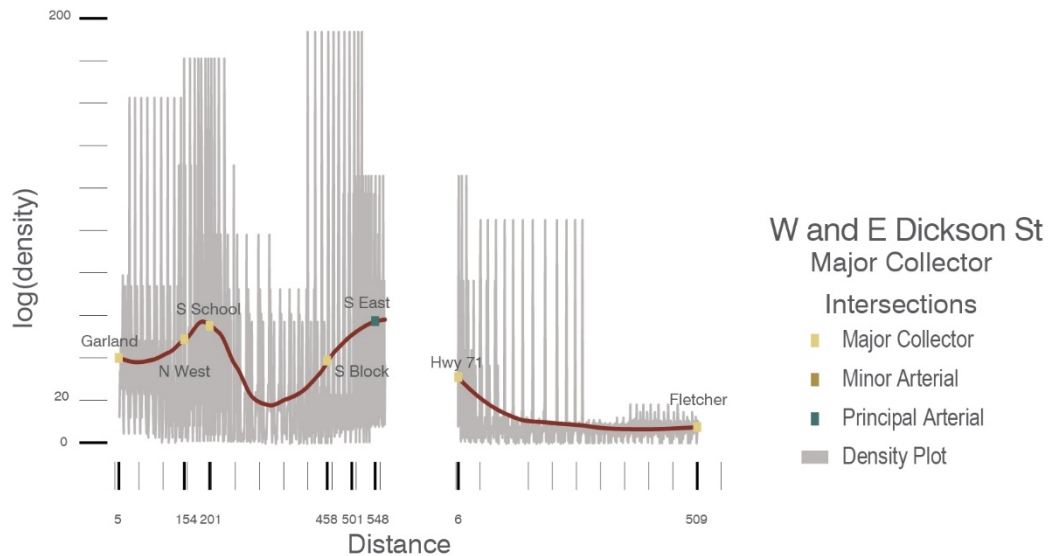
Figure 36 Density, Log(Density) with loess regression, and Intersections – Dickson Street

Highway 71 is used again as an example to demonstrate the results of classifying points along a road to then classify an image knowledge base for a neural network. The following images were captured by camera at one second intervals from a vehicle traveling Highway 71 and include views from the front and sides. The images were geotagged and compiled in the GIS database. The four intervals that determined the weak to strong phenomenological density was used to classify the images. Figure 33 depicts the original density collection points at approximately 1 second divisions traveling 55 miles per hour, or 73 feet, and the relative positions of the geotagged images collected along the route. Images included in Table 3 are taken at each of the 21 intersections on Highway 71.
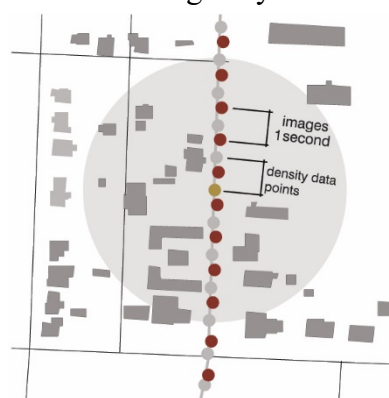


Figure 37 Density vs Image data collection points

Table 3 Photographs of Intersections along Highway 71 labeled by Log(Density)
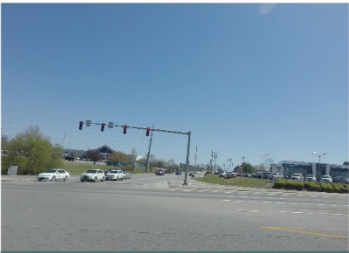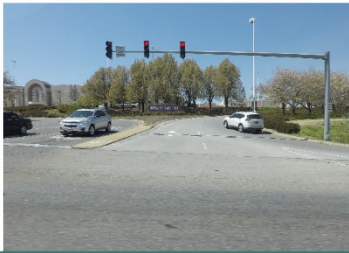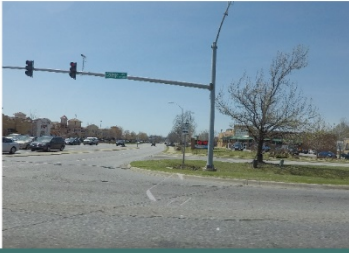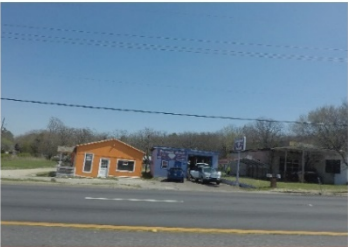
Table 3 continued

Table 3 continued

Table 3 continued
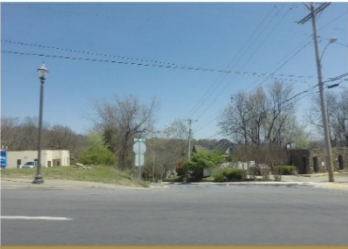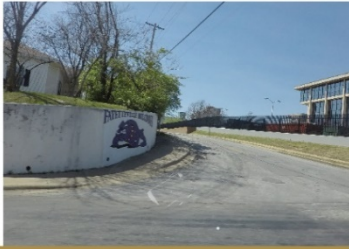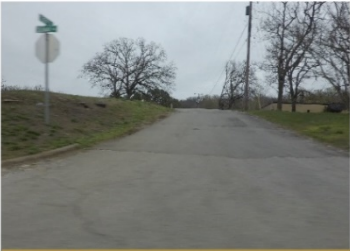


East                    South                    West

Mountain
HIGH

Roack/School
LOW

S School
LOW

MLK/6th
MED

Hwy 16
LOW

Table 3 continued

## Conclusions

Because contemporary lifestyles include a heavy reliance on mobility, inhabitants of any rural or urban environment, experience the landscape, the city, and the region not only from inside a vehicle, but along predetermined infrastructure.  The amount and type of exposure an inhabitant has with the infrastructure can affect, at a basic level, the knowledge one has about a city.  Quantifying the phenomenological can begin to provide knowledge about a city's perceived legibility from where people experience a vast majority of the city.  By using Lynch's early behavioral geography methods as a guideline, the methods proposed have articulated a contemporary process for quantifying the phenomenological.

The smoothed weighted average density data has merit producing results in cartographic form that can be used in a variety of ways to describe unseen relationships of phenomenological building density.  More importantly, this road classification process is fundamental in building a knowledge base for a neural network that can be used to even further articulate human cognition about a city.  The closer the classification of the knowledge base can be to realistic conditions, the closer the neural network can simulate human perception of phenomenological conditions experienced from a road in a city.  Even though the human brain is more complex than even the most thoughtful neural network structure, neural networks can "approximate the structure of the human brain," allowing for the potential to more accurately describe perception of urban environments (Bhatia 2018).  Including machine learning is critical in building a process driven behavioral geography.

Classification of urban descriptors, like density, nodes, landmarks, or in other words, phenomena, could all be inputs into a neural network to begin to identify these urban structures from any image of a city from a route.  Other considerations to describe phenomena from a route

have been discussed throughout, but generally, including any other three-dimensional factor into the methodology would improve the empirical quality of quantification. A three-dimensional field of view that considered visual distortion due to peripheral vision, building and surface elevations, and vegetation type and coverage would increase the quality of quantification of what building structures could be perceived from a road.

Multiple strategies of data generation and analysis could also be applied to the types of phenomena that might make up the *image* of a city from the road. For example, phenomena that perceivable from the visual field or other senses like distinctive colors, smells, sounds would each require specified strategies that address cognitive theory in each relative field. Cities are experienced from other paths that are not vehicular roadways. Further investigation could include walking and biking paths through a city, which would affect the weighted average based on the speed in which these paths are experienced.

Characterizing a city through the lens of the phenomenological allows for an understanding related to human experience. Traffic data is used in traffic models to forecast where the transportation network expansion might occur relative to forecasted land use and other trends (NWARPC 2015). One purpose of the proposed process is to include urban mapping of phenomenon as another metric to consider in a forecasted planning model. By including data from perceived phenomenological elements, planners and designers could not only evaluate the impact of changes in land use and development, but also begin to understand how other information about how humans behave, and experience cities are affected by the design of transportation networks and other built infrastructure. The Federal Highway Administration has made recent statements that roadway performance measures must be requalified to include measures of "character and context of the environment" (Federal Highway Administration 2013).

The relevancy of road classification by "Arterial", "Collector", and "Local" has declined and a need for alternative categorizations of roads is beginning to occur.  Quantification of a behavioral geography through the proposed process offers a tool for this evolution.

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**Appendix**

**Roads All (line)**



LOCATION: Arkansas

PUBLISHER: Arkansas Highway and Transportation Department

PUBLISH DATE: 29-AUG-2006

TITLE: TRANSP.DBO.ROADS_ALL_AHTD

DESCRIPTION: This file contains location information for all Roads in the State of Arkansas. These locations were extracted from the Arkansas Highway and Transportation Department county mapping files. The data provides all Road information for the state of Arkansas. The database provides location information for use in local and regional cartographic and spatial analysis applications.

DATUM: North American Datum of 1983

PROJECTION: NAD_1983_UTM_ZONE_15N

TABLE COLUMNS: Gid – internal feature number | Road_type – string | describes what type of road i.e. "city_street", "county_road" | Shape_stle | Geom

**County Boundary (polygon)**



LOCATION: Arkansas

PUBLISHER: Arkansas Highway and Transportation Department

PUBLISH DATE: 13-DEC-2013

TITLE: COUNTIES_AHTD

ABSTRACT: This file contains location information for County Boundaries in the state of Arkansas. These locations were extracted from the Arkansas Highway and Transportation Department county mapping files for the year 2000.  The data provides County Boundaries information for the state of Arkansas. The database provides location information for use in local and regional cartographic and spatial analysis applications. It is the intention of the Arkansas State Land Information Board to facilitate dissemination of public data.

DATUM: North American Datum of 1983

PROJECTION: NAD_1983_UTM_ZONE_15N

TABLE COLUMNS: gid – Internal Feature Number | id-  ID number | district – district number | mapid – map id | mslink, Pop_1990 – population 1990 | Pop_2000 – population 2000 | Sq_mi_land – land area in square miles | Id1 – id 1, county_nam – County Name | county_num – County number | fhwa_numbe | land_densi | sq_mi_tota | sq_mi_wate – square miles of water | pop_2010 | shape_area | shape_len | geom

**Average Daily Traffic Count (line)**



LOCATION: Arkansas

ORIGIN: Arkansas Highway and Transportation Department

PUBLISH DATE: 10-SEPT-2006

TITLE: TRANSP.AVG_DAY_TRAFFIC_AHTD

ABSTRACT: ADT is the dataset holding all of the Average Daily Traffic data available for the State Highway System for the year intended. Not all of the State Highway routes have ADT recorded for every year. Some years, only portions of the state had recorded data. ADT is an accurate, attributed dataset used to graphically represent the Average Daily Traffic data that AHTD collects annually.

DATUM: North American Datum of 1983

PROJECTION: NAD_1983_UTM_ZONE_15N

TABLE COLUMNS: gid – Internal Feature Number | county – County number | station – Location name where traffic is counted | route – Designation of highway | beginlm – Beginning log mile of the segment the traffic count covers | endlm – End log mile of the segment the traffic count covers | total_adt – Calculation of number of vehicles | adt_year – Year Average Daily Traffic was recorded | id2 | id1| shape_stle | geom

**Municipal Boundaries (polygon)**
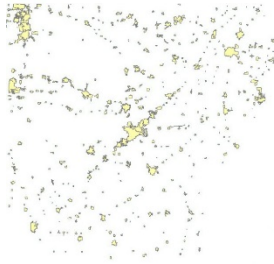


LOCATION: Arkansas

ORIGIN: Arkansas Geographic Information Systems Office.

PUBLISH DATE: 10-JULY-2017

TITLE: Municipal Boundaries (POLYGON)

ABSTRACT: The municipal boundary is a publication of polygons of all incorporated cities in Arkansas. The Arkansas GIS Office maintains this file in coordination with the municipalities of the State. It represents the contemporary boundary of the city. Data developed with coordinate geometry (COGO) from legal descriptions were used. When necessary the data were adjusted to conform to known physical features. This dataset does not represent exact legal boundaries as per surveyed description, but, rather a set of boundaries used for the administrative purposes that conforms to logical & administrative rules.

DATUM: North American Datum of 1983

PROJECTION: NAD_1983_UTM_ZONE_15N

TABLE COLUMNS: FID | Shape | city_name | city_fips | population | effective_ | revised_da | revision_t | squaremile | acres | shape_STAr | shape_STLe | Shape_Length | Shape_Area

**Functional Class - ARDOT**



LOCATION: Arkansas

PUBLISHER: Arkansas Highway and Transportation Department

PUBLISH DATE: 13-FEB-12

TITLE: Functional_Class_AHTD

DESCRIPTION: This data set contains Functional Classification roads for the State of Arkansas per the Arkansas Department of Transportation (ARDOT). This file should only be used as a graphical representation and for general reporting. Field verification and source contact should always occur prior to financial planning taking place. Functional classification is the process by which streets and highways are grouped into classes, or systems, according to the character of service they are intended to provide. Basic to this process is the recognition that individual roads and streets do not serve travel independently in any major way. Rather, most travel involves movement through a network of roads. It becomes necessary then to determine how this travel can be channelized within the network in a logical and efficient manner. Functional classification defines the nature of this channelization process by defining the part that any particular road or street should play in serving the flow of trips through a highway network.
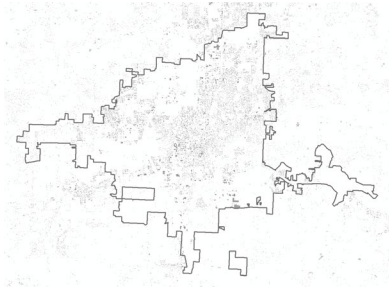
DATUM: North American Datum of 1983

PROJECTION: NAD_1983_UTM_ZONE_15N

TABLE COLUMNS: FID | Shape | ID | COUNTY | COUNTYNAME | ROUTE | SECTN |

LOGMILE | RURALURBAN | FUNCCLASS | ROUTESIGN | ROADLENGTH |

ENDLOGMILE | ROADID | ID1 | Shape_Length

- OBJECTID *( type: esriFieldTypeOID , alias: OBJECTID , editable: false , nullable: false )*
- AH_RoadID *( type: esriFieldTypeString , alias: AH_RoadID , editable: true , nullable: true , length: 150 )*
- AH_District *( type: esriFieldTypeString , alias: AH_District , editable: true , nullable: true , length: 2 )*
- FunctionalClass *( type: esriFieldTypeSmallInteger , alias: FunctionalClass , editable: true , nullable: true , Coded Values: [1: Interstate] , [2: Other Freeways & Expressways] , [3: Other Principal Arterials] , ...4 more... )*
- MIN_AH_BLM *( type: esriFieldTypeDouble , alias: AH_BLM , editable: true , nullable: true )*
- MAX_AH_ELM *( type: esriFieldTypeDouble , alias: AH_ELM , editable: true , nullable: true )*
- AH_County *( type: esriFieldTypeInteger , alias: AH_County , editable: true , nullable: true , Coded Values: [1: Arkansas] , [2: Ashley] , [3: Baxter] , ...72 more... )*
- AH_Route *( type: esriFieldTypeString , alias: AH_Route , editable: true , nullable: true , length: 150 )*
- AH_Section *( type: esriFieldTypeString , alias: AH_Section , editable: true , nullable: true , length: 50 )*
- AH_Direction *( type: esriFieldTypeString , alias: AH_Direction , editable: true , nullable: true , length: 10 , Coded Values: [A: Log] , [B: Anti-Log] )*
- Length_Miles *( type: esriFieldTypeDouble , alias: Length_Miles , editable: true , nullable: true )*
- created_user *( type: esriFieldTypeString , alias: created_user , editable: true , nullable: true , length: 255 )*
- created_date *( type: esriFieldTypeDate , alias: created_date , editable: true , nullable: true , length: 8 )*
- last_edited_user *( type: esriFieldTypeString , alias: last_edited_user , editable: true , nullable: true , length: 255 )*
- last_edited_date *( type: esriFieldTypeDate , alias: last_edited_date , editable: true , nullable: true , length: 8 )*

**Building Footprints - 2010**



LOCATION: Fayetteville, Arkansas

PUBLISHER:

PUBLISH DATE:

TITLE: Building_Footprints_2010

DESCRPTION:

DATUM: North American Datum of 1983

PROJECTION: NAD_1983_UTM_ZONE_15N

TABLE COLUMNS: FID | Shape | OBJECTID_1 | OBJECTID | STATUS | PIN | X | Y | AREA |

PREV_AREA | PCT_CHANGE | COMMENT | Shape_Leng | Shape_Area