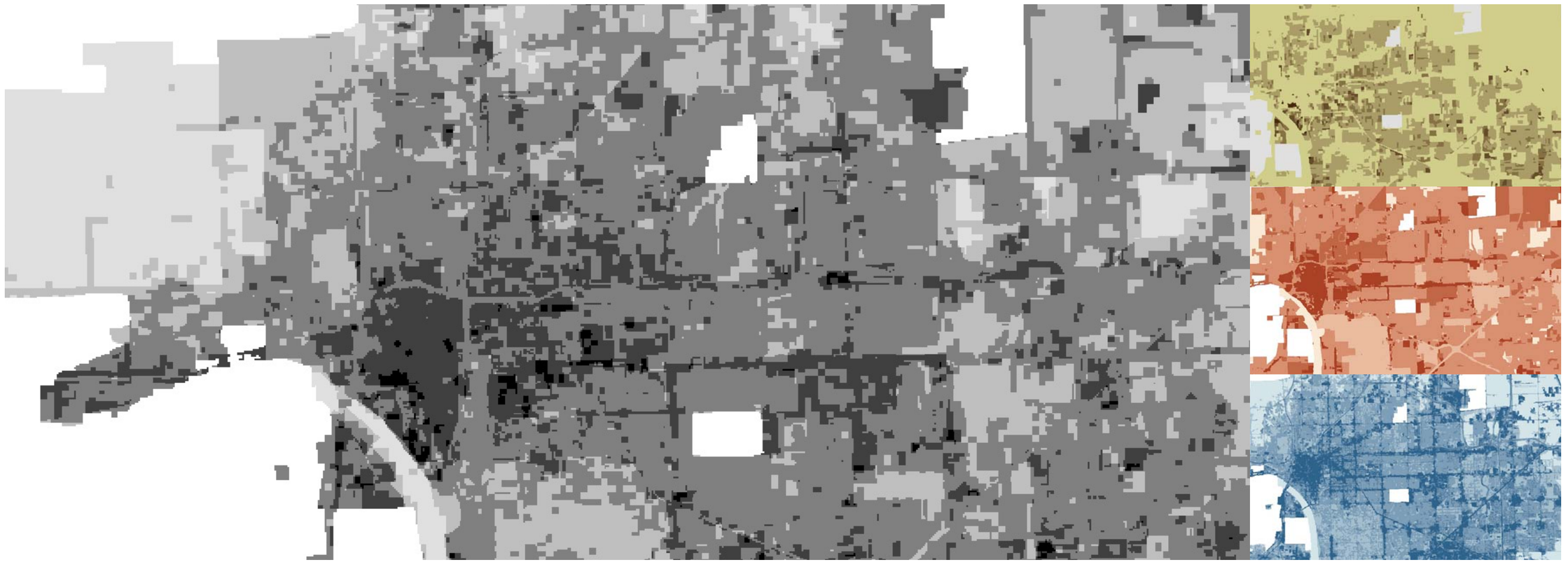
Measuring Urban Development Intensity:
Is it possible to get an X-Ray of our cities?
Case study: Tulsa, OK



Heloisa Ceccato Mendes

Professional Project – Spring 2008
Master of Science in Architectural Urban Studies
Advisor: Shawn Schaefer

The University of Oklahoma Urban Design Studio

The University of Oklahoma
Graduate College

Measuring Urban Development Intensity: Is it possible to get an X-Ray of our Cities?

A Professional Project
Submitted to the Graduate Faculty
in partial fulfillment of the requirements for the
degree of
Master of Science in Architectural Urban Studies

By

Heloisa Ceccato Mendes
Tulsa, Oklahoma
2008

A Professional Project approved for the
College of Architecture
Urban Design Studio

By

Shawn Michael Schaefer, Chair
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a) During a workshop presented by the Urban Design Studio at the 5th Okalhoma Sustainability Network Conference, in September 2006 (part of a Special Studies Course)
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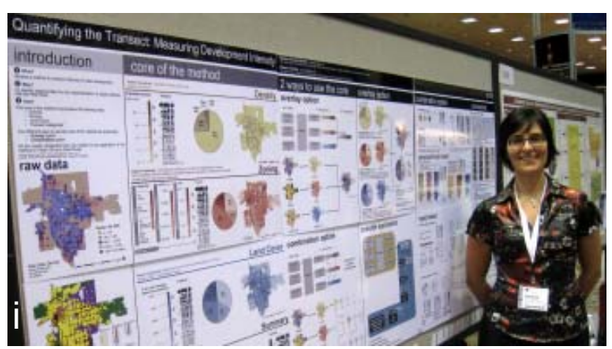
d) In Skiatook with project team mates Anna Grider and Craig Longacre and town administrator Martin Tucker.

2008 - Graduation:
e) With Francisco after Graduation
f) With Francisco after the final defense
g) With Professor Shawn Schaefer after Graduation



2008 APA National Conference - Las Vegas
h) Picture posted at APA's website
i) Presenting my poster

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Finally, I would like to thank my husband for sharing this and many other journeys with me. *Francisco*, this project is dedicated to you and to everything that is about to come in our future.

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Introduction and Goals

This project aims to develop a method that could be used by cities to:
- Measure intensity of development within city limits
- Identify opportunities for the implementation of public policies that can help cities to get the most out of its existing infrastructure.

The method presented in this project is based on the following general steps:
1 - Establish criteria to quantify the categories of the Transect concept
2 - Apply the criteria to Density, Zoning and Land Cover data having Tulsa, Oklahoma as a case study

After going through these general steps, two different ways of using the data are presented in this project. The first one is based on the *overlay* of the preliminary results, while the second one is based on the *combination* of the same preliminary results. Possibilities of application are presented for both options. More details are available on the sections of this report that are related specifically to each option.

This project intends to contribute to a debate that has been taking place all over the United States. Cities throughout America have been trying to find ways to control sprawl and this is certainly one of the main topics being discussed by planners in the US currently.

Due to the complexity of this topic, it is anticipated that this project will not be able to completely answer this question. However, this project intends to contribute to this debate by focusing on one of the main aspects that are closely related to this issue: underutilization of land within city limits.

Even though sprawl has become a very popular pattern of land development in America since the mid 1940s, that does not mean this is the only possible model of development. Americans often associate their life style with low density suburbs and tend to think higher density developments located in urban environments can not offer the same level of comfort and quality of life offered by the suburbs. Part of this project is dedicated to demystify that assumption and show some benefits of living in higher density developments and more compact cities.

The goals of this project are:

1. **Develop research to investigate:**

- The benefits of having compact and higher density cities

- The relationship between density and other aspects of urban life

2. **Develop a method that can be applied on cities to:**

- Measure intensity of development within city limits considering Density, Zoning and Land Cover Data

- Identify opportunities for the implementation of public policies that can help cities to get the most out of its existing infrastructure

3. **Develop and apply the method having Tulsa, Oklahoma as a Case Study**

4. **Develop recommendations for the application of the method**

1. Introduction and Goals

2. Research

3. Methodology

4. Results
   - Core
   - Overlay Option
   - Combination Option

5. Conclusions

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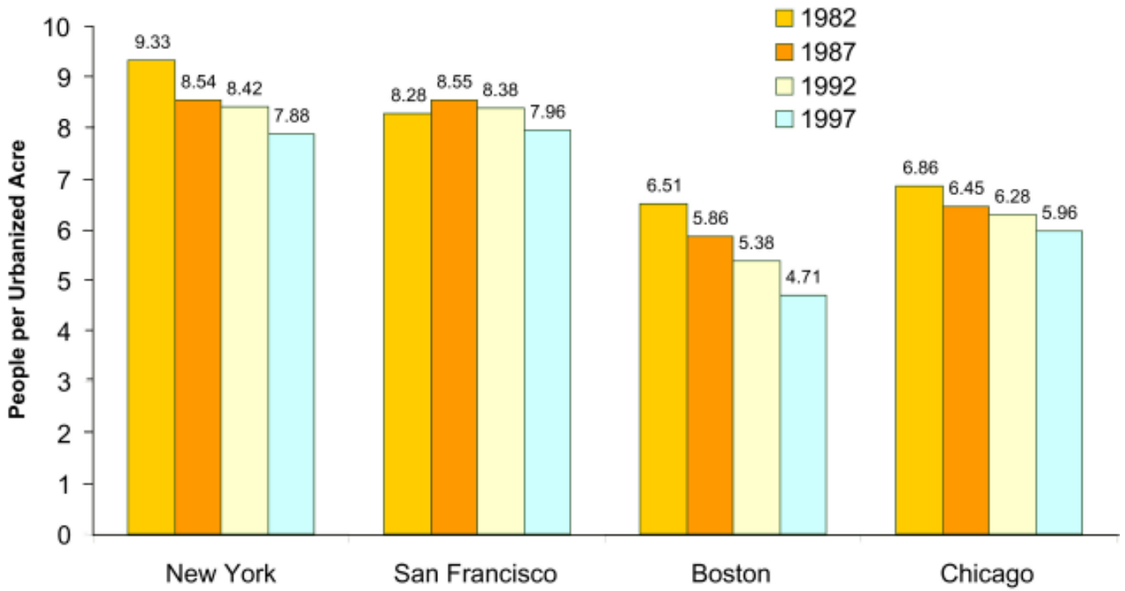
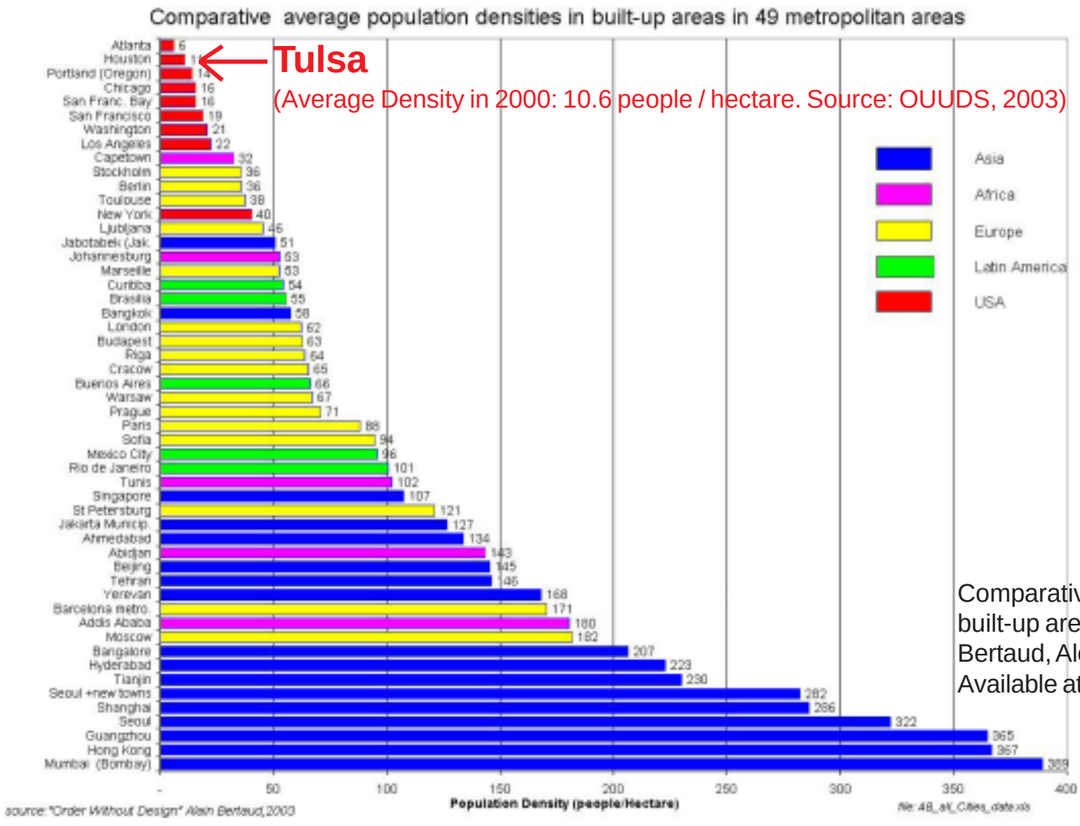
7. Bibliography



Evolution of Density (People / Urbanized Acre) in some American Cities. Source: Fulton et al. (2003) "Who Sprawls Most? How Growth Patterns Differ Across the U.S.". Brookings Institution, July 2001 by Lyu, Ami.



Comparative Average Population Densities in built-up areas in 48 metropolitan cities. Source: Bertaud, Alen (2003). "Order without Design" . Available at: http://alain-bertaud.com/

Research

Sprawl in America

The graphic located on the top of this page shows the evolution of density in some American Cities from 1982 to 1997. It is noticeable that densities have diminished in Boston, New York and Chicago and went up and then down in San Francisco. In general, we notice that density in 1997 is lower than it was in 1982 in all cities presented in this graphic, which is a possible indication of sprawl.

The graph located on the bottom of this page shows average demographic densities (people / hectare) of cities located all over the world. Asian cities are represented in blue, African cities in magenta, European cities in yellow, Latin American cities in green and American Cities in red. The graph shows that the lower end of the spectrum is mainly represented by American cities, while the higher end of the spectrum is represented mainly by Asian cities. European, African and Latin American cities are distributed in the mid range.

In order to understand the big picture and establish some comparisons, I placed Tulsa (the city used as a Case Study in this project) on the graph. According to the "Urban Mapping Study of the Tulsa Region", developed by the University of Oklahoma Urban Design Studio in 2003, Tulsa's average density in 2000 was 2,752 people per square mile. If we convert this number to the unit used in this graph (people per hectare) we will get to 10.6 people per hectare, which places Tulsa in the lower end of the spectrum, between Atlanta (6 people per hectare) and Houston (11 people per hectare).

The list of cities presented on this grap is not extensive, but it is representative. It is also important to highlight that the way cities are built to accommodate urban growth in different countries is closely related to aspects such as availability of resources and cultural aspects. However, it is not the intent of this project to analyze those topics. On the other hand, it is important to have an overview of the possible ways urban growth can be accommodated to open our minds to other possible models of urban development. This graph shows how the density of cities across the world varies and where American cities stand in comparison to other cities. It is important to highlight that density is a consequence of the adopted pattern of development. This is, of course, closely related to the model of urban development that has been adopted in different regions and the intent of presenting this graph is to show where American cities stand in comparison to other cities in the world.


LOCAL

Family dinner

PAVED WITH PROMISES

Growth pains felt on streets

19th

184th

10 miles

29th

3,000

2 million

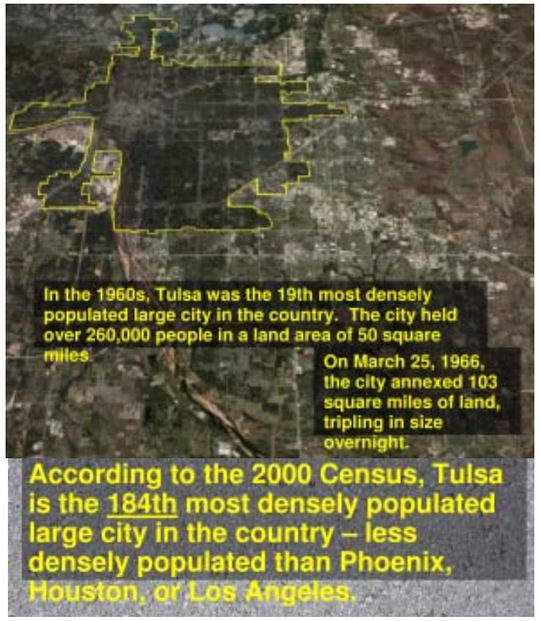
Online

In the 1960s:

19th most densely populated large city in the country

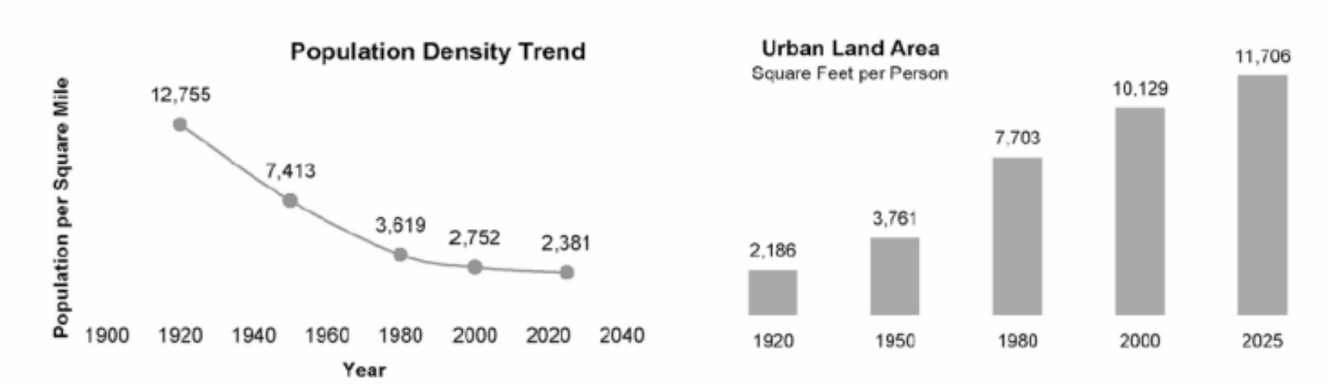
Today:

184th most densely populated large city in the country



Source : http://www.tulsaworld.com/tulsastreets

Adapted from Newspaper article published in the Tulsa World (local newspaper) in October 27th, 2007.
Available at: http://www.tulsaworld.comarchivestwo.htm
Source of the data cited in this article: http://www.tulsaworld.com/tulsastreets (see original figures to the right)



Graph showing the evolution of Density and Urban Land Area/ Source: Schaefer *et al.* (2003) Urban Mapping Study of the Tulsa Region. Available at: http://tulsagrad.ou.edu/studio/archives

Research

Sprawl in Tulsa

Sprawl is happening all over the United States. In Tulsa things are not different. However, in Tulsa sprawl seems to be even more intense than in the US in general.

The article published in the Tulsa World (local newspaper, shown on top of the page) on 10/24/2007 shows that Tulsa used to be the 19th most densely populated city in the US in the 1960s and it has dropped enormously in the same rank, standing today at 184th place. This is closely related to the way cities have grown in the period. What this data show is that Tulsa has grown spreading out over the territory and implementing low density developments in a even more extreme way than American cities in general. Even though sprawl is ocurring and densities are going down all over the US, sprawl in Tulsa between the 1960s and today has been even more intense than in America in general.

It is important to highlight that this is not related to city growth itself, but to the model that is being used to accommodate growth. In other words: it is not about growth, it is about *how we are growing*. Many cities in America are growing, and at least most of them are spreading out over the territory with low density developments. But the fact that Tulsa has dropped form 19 to 184 in the mentioned rank shows that Tulsa has been growing like that too, but in an even more intensive way. The questions to be answered are: *"Do we want to keep growing this way? Can we afford it or sustain it? Or should we rethink the way we are growing?"*

The graph on the bottom of this page shows how urban land area has been growing while Tulsa's density has been declining over the years *(1)*. There is a major increment on Urban Area between 1950 and 1980 and that can be explained by the annexation of 103 square miles to Tulsa's city limits in the 1960s *(source: City of Tulsa website: http://cityoftulsa.org/Community/Planning/CompPlan/documents/Dec11Demographicspresentation.pdf)*. Despite the fact that there was this major annexation to Tulsa's city limits, we can conclude from the graph that Tulsa has been growing based on a low density and a spread out model of development.

Note (1): The numbers for 2020, 2025 and 2040 are projections.

The Cost of Sprawl - some examples

- High cost to provide services and infrastructure (roads, sewer, water, etc.) to serve a dispersed population
- Automobile dependence
- Traffic congestion and pollution
- Loss of prime agricultural lands and open space
- Predominant single use in the suburbs (as opposed to mixed use, which provides vitality around the clock)
- Lack of character and absence of a “town center”
- No sense of location or “place” result in lack of sense of community

Research

Smart Growth Concepts

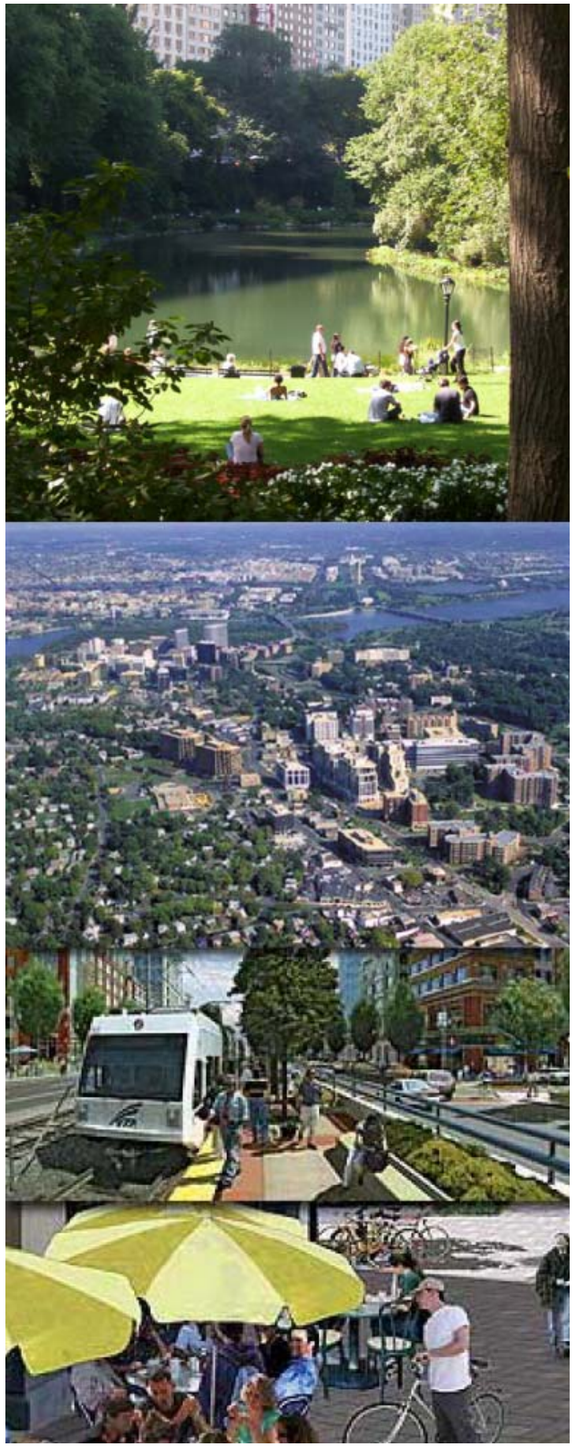
Smart Growth is an urban planning theory and movement that promotes urban growth close to existing urban areas as a way to better utilize existing infrastructure. It advocates that cities should be compact, walkable, bicycle-friendly, transit-oriented and should have mixed-use development with a range of housing choices.

Since Smart Growth is a broad concept that involves many topics, definitions of its principles are slightly different between texts produced by different authors. It is important to highlight that the various definitions tend to complement each other and that is why a list of Smart Growth principles according to different authors is presented following. The entire content of the following bullet points *(presented in Italic font)* was taken from the sources cited at the end of this document.

The items highlighted in red are the ones that are extremely related to possible applications of the method developed in this project. However, this does not mean the other items do not relate to the method presented in this project. There are many indirect benefits of using this method to encourage more efficient land use infill development of vacant land and having more compact cities that are pointed out on the items that are not highlighted.

According to De Grove (2005):

- *“Make efficient and effective use of land resources and existing infrastructure by encouraging development to areas with existing infrastructure or capacity to avoid costly duplication of services and costly use of land*
- *Provide mix of land uses to create a variety of housing choices and opportunities*
- *Make development decisions predictable, fair and cost-effective*
- *Provide a variety of transportation choices, including pedestrian friendly neighborhoods.*
- *Maintain a unique sense of place by respecting local culture and natural environment features.*
- *Conserve open space and farmland, and preserve critical environmental areas.*
- *Encourage stakeholder collaboration and community participation rather than a conflict*
- *Provide staged and managed growth in urban transition areas with compact development patterns*
- *Enhance access to equitable public and private resources for everyone.*
- *Promote the safety, livability and revitalization of existing urban and rural communities*



Research

Smart Growth Concepts (cont.)

According to the Urban Land Institute (2000), Smart Growth features:

- *Collaboration on Solutions*
- *Mixing Land Uses*
- *Encouraging Infill Development and Redevelopment*
- *Building Master-Planned Communities*
- *Conserving Open Space*
- *Providing Transportation Choices*
- *Providing Housing Opportunities*
- *Lowering Barriers to and providing Incentives for Smart Development*
- *Using High-Quality Design Techniques*

According to the Smart Growth Network (2007):

- *Create Range of Housing Opportunities and Choices*
- *Create Walkable Neighborhoods*
- *Encourage Community and Stakeholder Collaboration*
- *Foster Distinctive, Attractive Communities with a Strong Sense of Place*
- *Make Development Decisions Predictable, Fair and Cost Effective*
- *Mix Land Uses*
- *Preserve Open Space, Farmland, Natural Beauty and Critical Environmental Areas*
- *Provide a Variety of Transportation Choices*
- *Strengthen and Direct Development Towards Existing Communities*
- *Take Advantage of Compact Building Design*

According to Smart Growth America (2007), Smart growth is growth that helps to achieve these goals:

- *Neighborhood Livability: The central goal of any smart growth plan is the quality of the neighborhoods where we live. They should be safe, convenient, attractive, and affordable. Sprawl development too often forces trade-offs between these goals. Some neighborhoods are safe but not convenient. Others are convenient but not affordable. Too many affordable neighborhoods are not safe. Careful planning can help bring all these elements together.*

- *Better Access, Less Traffic: One of the major downfalls of sprawl is traffic. By putting jobs, homes and other destinations far apart and requiring a car for every trip, sprawl makes everyday tasks a chore. Smart growth's emphasis on mixing land uses, clustering development, and providing multiple transportation choices helps us manage congestion, pollute less and save energy. Those who want to drive can, but people who would rather not drive everywhere or don't own a car have other choices.*

- *Thriving Cities, Suburbs and Towns: Smart growth puts the needs of existing communities first. By guiding development to already built-up areas, money for investments in transportation, schools, libraries and other public services can go to the communities where people live today. This is especially important for neighborhoods that have inadequate public services and low levels of private investment. It is also critical for preserving what makes so many places special—attractive buildings, historic districts and cultural landmarks.*

- *Shared Benefits: Sprawl leaves too many people behind. Divisions by income and race have allowed some areas to prosper while others languish. As basic needs such as jobs, education and health care become less plentiful in some communities, residents have diminishing opportunities to participate in their regional economy. Smart growth enables all residents to be beneficiaries of prosperity.*

- *Lower Costs, Lower Taxes: Sprawl costs money. Opening up green space to new development means that the cost of new schools, roads, sewer lines, and water supplies will be borne by residents throughout metro areas. Sprawl also means families have to own more cars and drive them further. This has made transportation the second highest category of household spending, just behind shelter. Smart growth helps on both fronts. Taking advantage of existing infrastructure keeps taxes down. And where convenient transportation choices enable families to rely less on driving, there's more money left over for other things, like buying a home or saving for college.*

4 *Keeping Open Space Open: By focusing development in already built-up areas, smart growth preserves rapidly vanishing natural treasures. From forests and farms to wetlands and wildlife, smart growth lets us pass on to our children the landscapes we love. Communities are demanding more parks that are conveniently located and bring recreation within reach of more people. Also, protecting natural resources will provide healthier air and cleaner drinking water.*

1st Time:
The idea was to describe what would be a typical spread out development.

Spread out Development

Getting Around:
(x) Private auto (no transit available)
( ) Limited transit
a bus line runs near the site with buses arriving every hour or half hour
( ) Small town with a mixed-use commercial center within 1/2 mile
( ) Convenient transit
a subway, rail, light rail, bus route or routes within 1/4 mile with frequent service- 20 minutes or less

Shopping:
(x) Drive to a shopping center
( ) Walk to street-level shops

Recreation:
(x) Drive to recreation facilities and open space
( ) Convenient transit to recreation facilities or park
( ) Neighborhood facility such as pool, tennis courts, or nearby park

Outdoor Space:
(X) Large private yard
( ) Small private space such as a patio, deck or balcony
( ) Shared green space

2nd Time:
The idea was to describe what would be a typical compact development.

Compact Development

Getting Around:
( ) Private auto (no transit available)
( ) Limited transit
a bus line runs near the site with buses arriving every hour or half hour
( ) Small town with a mixed-use commercial center within 1/2 mile
(X) Convenient transit
a subway, rail, light rail, bus route or routes within 1/4 mile with frequent service- 20 minutes or less

Shopping:
( ) Drive to a shopping center
(X) Walk to street-level shops

Recreation:
( ) Drive to recreation facilities and open space
(X) Convenient transit to recreation facilities or park
( ) Neighborhood facility such as pool, tennis courts, or nearby park

Outdoor Space:
( ) Large private yard
( ) Small private space such as a patio, deck or balcony
(X) Shared green space

Elaborated based on data from the Lincoln Institute Website – Visualizing Density
Available at: http://www.lincolninst.edu/subcenters/VD/goodthings/index.aspx. Date of Research: 10/15/2007

Research

Density and other aspects of the urban environment

At this part of the project I intend to explore the relationship between urban form and other aspects of urban life. The content presented here was extracted from a quiz that is posted on the Lincoln Institute's website. We are using this as a source because it presents this subject in a very interactive and interesting way.

The quiz gives different options for the following topics: Getting Around, Shopping, Recreation and Outdoor Space:

Getting Around:
( ) Private auto (no transit available)
( ) Limited transit (a bus line runs near the site with buses arriving every hour or half hour)
( ) Small town with a mixed-use commercial center within 1/2 mile
( ) Convenient transit (a subway, rail, light rail, bus route or routes within 1/4 mile with frequent service- 20 minutes or less)
Shopping:
( ) Drive to a shopping center
( ) Walk to street-level shops
Recreation:
( ) Drive to recreation facilities and open space
( ) Convenient transit to recreation facilities or park
( ) Neighborhood facility such as pool, tennis courts, or nearby park
Outdoor Space:
( ) Large private yard
( ) Small private space such as a patio, deck or balcony
( ) Shared green space

It works basically like this: you pick the options for the different topics and it shows you examples of neighborhoods with that description when you click on "View Neighborhoods". The pictures that are shown here are some examples of the neighborhoods that are shown when you click on "View Neighborhoods".

We took the quiz twice and selected different options (extremes) to see what kind of neighborhood would be shown as an example of what we had just described. The graphics to the left show examples of the results we got for each description.

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Research

Density and other aspects of the urban environment

In this section of the report some questions and answers are shown. They exemplify the relationship between density and other aspects of urban life such as availability of services and transportation. The source of the data presented here is also the Lincoln Institute's website.

Pictures were added to illustrate the subject being discussed. For example, some of the pictures show examples of neighborhoods that present the density that is being mentioned.

We can see that the urban form has many implications in our everyday life. Activities such as going to work or school or going to the grocery store can be affected by the choices we make while managing urban growth. High density developments tend to occupy less area than low density developments. Low density and spread out developments tend to be car dependant while in high density developments travel distances are shorter, which makes walking and riding more likely. Instead of driving to work, people have the option of walking to work in a high density development. These are some examples of benefits of higher density developments. The information on the following sheet will help us understand other benefits of living in High Density and compact cities.

What is the minimum number of households needed to support a 50,000 sq. ft. supermarket ?

500

As with transit services, retail depends on adequate population to be viable. Where population densities are low, supermarkets must draw from a larger area.

Low Density: big box development and big parking lots, car scale. Drive to the supermarket is the only option.

High Density: vitality at street level and pedestrian scale. People have the option of shopping for groceries on foot.

At what density level does bus service (every 30 minutes) become feasible?

7 units per acre

Bus service is possible at any density level, depending on the fares charged or subsidies offered. To be economically feasible however, a density of 7 units per acre is necessary. At 4 - 6 units / acre bus service is often less frequent (1 bus per hour) and more heavily subsidized.

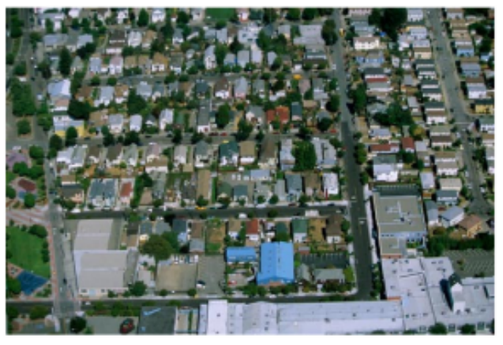
Given a pleasant walking environment, what is the density level at which people are usually willing to walk or take transit?

6 units per acre

Transit use and walking begins to rise at a level of 6 units / acre and increase with greater density.

Why?

Trip lengths become shorter and more convenient by bus or on foot. This helps explain why vehicle trips are reduced by 40% every time density doubles.



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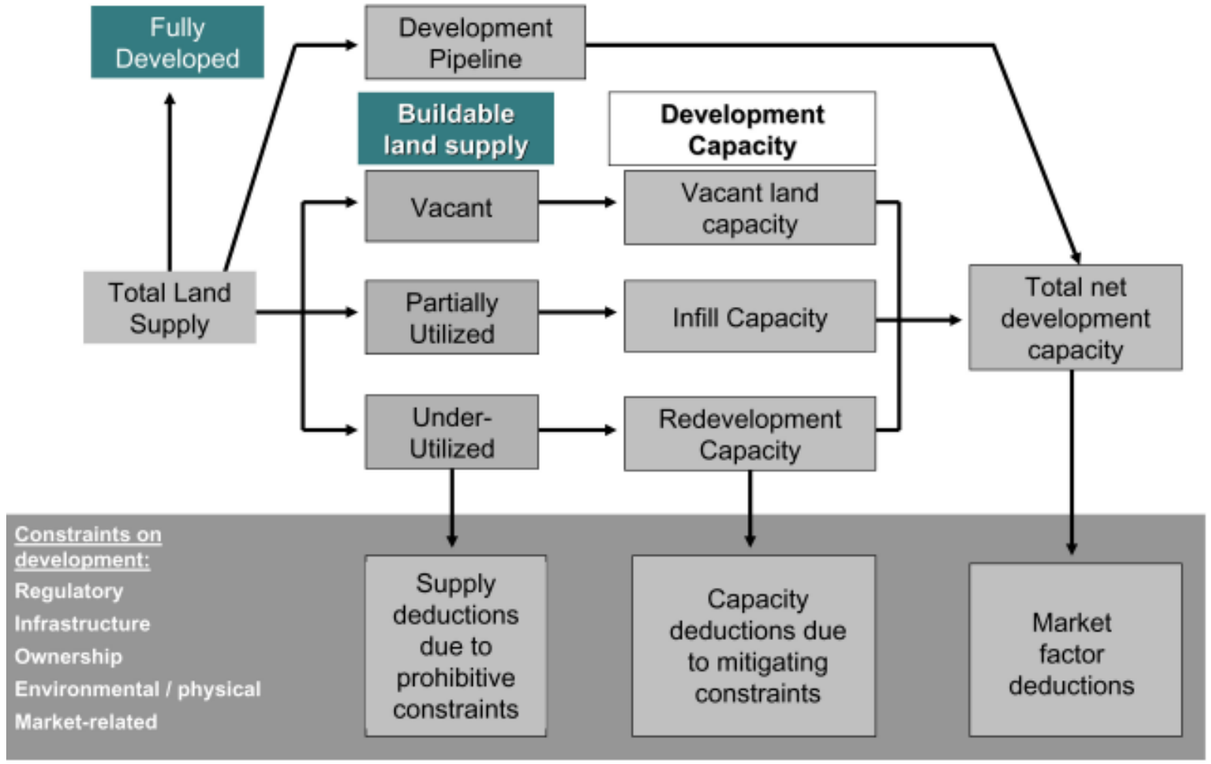

Information for Plan Making and Implementation
Source: Adapted from Moudon, A. V. , Hubner, M. (2000). Monitoring Land Supply with GIS: Theory, Practice and Parcel-Based Approaches.

Research

Land Capacity Monitoring

This flowchart was reproduced and adapted from Moudon *et. al. (2000)* and it shows how Land Supply and Capacity Monitoring (LSCM) works. It shows the Information for Plan Making and Plan Implementation and the relationship between its elements. It is important to notice that it classifies the Total Land Supply under two categories:
- Fully Developed Land
- Buildable Land Supply (highlighted in blue in the adapted flowchart)

The aspects presented here about the LSCM will be presented again later in this project with a different approach, in the section that presents possible applications of the method.

With this we finish the research section of this project, which was done with the intent to provide information about some aspects that are closely related to possible applications of the method developed and presented in this project.

A general summary of the research part of this project is presented following. It consists basically of mentioning that this project is generally based on the following premises:

URBAN GROWTH:
- There are alternatives to sprawl
- Development of Buildable Land Supply within city limits is one of them

AVAILABILITY OF BUILDABLE LAND SUPPLY:
- The first step to discuss what can be done with existing buildable land within city limits is to have an inventory
- Cities very rarely have records about buildable land supply because this is difficult to survey and has to be constantly updated
- It is important to use a method to build an inventory in a reasonable amount of time so next steps can be undertaken
- After having an inventory of buildable land supply, public policies and plans can be developed and implemented to actually use this land so cities can get the most out of its infrastructure

DEVELOPMENT CAPACITY:
- Encouraging measures such as Infill Development, which will help develop land to its full capacity, is one of the Smart Growth principles that can help cities to use environmental resources in a more efficient way.
- Measures that encourage efficient land use can help to create more compact and higher density cities.

HIGHER DENSITY CITIES:
- There are benefits of living in higher density developments within City limits as opposed to living in low-density suburbs
- Help on creating more vibrant and dynamic cities
- Support amenities such as transit and retail
- Are more likely to have pedestrian friendly environments.

1. Introduction and Goals

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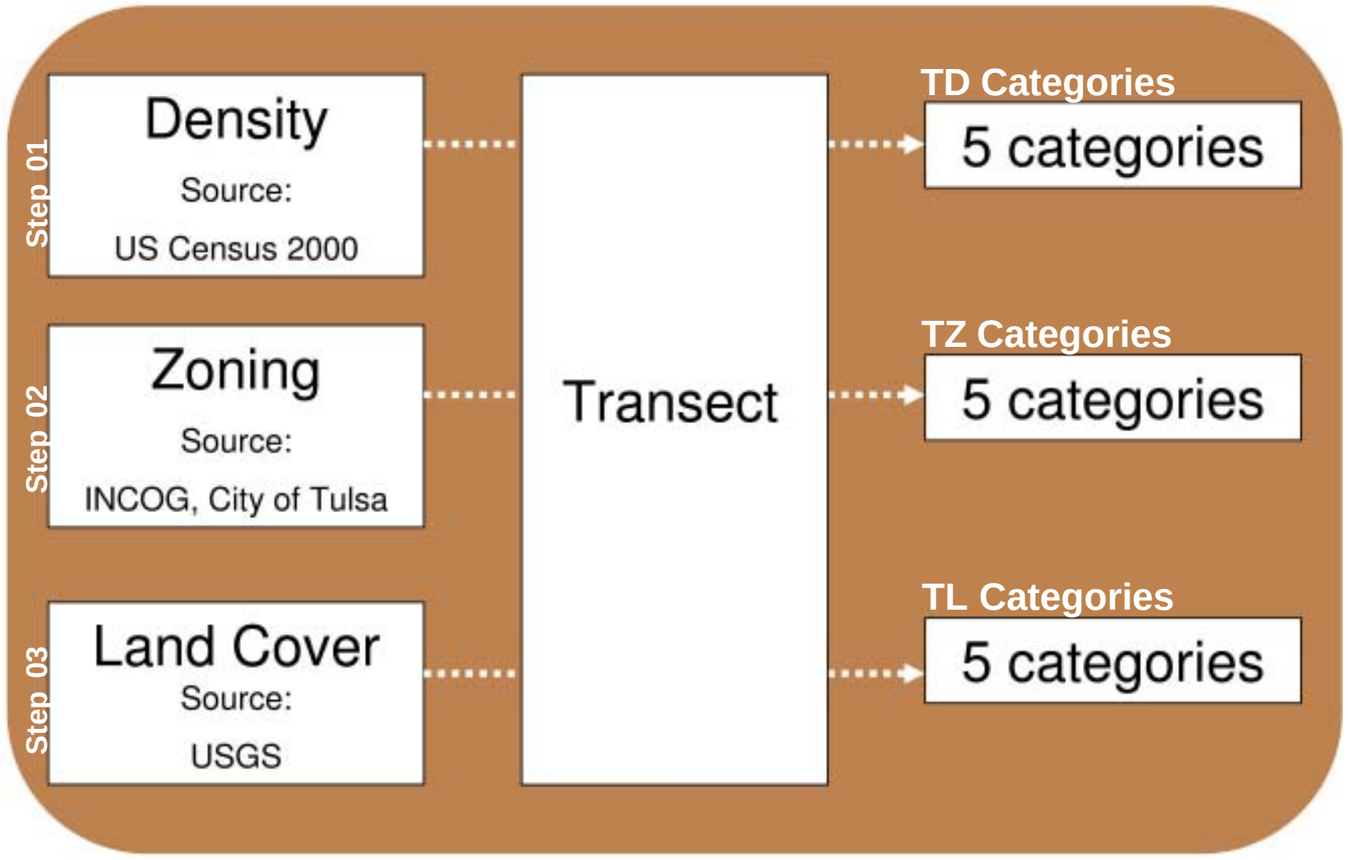
8. Appendices



Flowchart showing the core of the method

Methodology

The core of the method: relationship between its elements

This method is based on the premisse that is more valuable to have several variables than just one to describe the urban environment. It incorporates three main aspects of development intensity (Density, Zoning and Land Use Land Cover Data) and it is designed to correct the limitations of the individual data sets.

Besides that, the method also uses the Transect concept (Duany *et al.*, 2002) as the element that will connect all these three aspects in a rating system. On the next page there is a brief explanation of each one of these aspects and how they will be analyzed on this project.

The following Flow Chart shows an overview of the core of the project and the relationship between its elements.

Step 01 – Establish 5 Categories for Density (TD Categories):

- Elaborate a density map for Tulsa based on US Census data;
- Analyze Density Map;
- Establish 5 TD Categories: Density categories associated with the 5 Transect categories *(1)*
- Classify the areas within Tulsa City Limits in these categories.

Step 02 – Establish 5 Categories for Zoning (TZ Categories):

- Elaborate a zoning map for Tulsa based on INCOG (Indian Nations Council of Governments) and City of Tulsa data;
- Analyze Zoning Ordinances with special attention to what is allowed to be built on each zone;
- Establish 5 TZ Categories: Zoning categories associated with the 5 Transect categories *(1)*
- Classify the areas within Tulsa City Limits in these categories.

Step 03 – Establish 5 Categories for Land Use Land Cover Data (TL Categories):

- Use USGS (United States Geological Survey) data;
- Analyze categories established by the USGS for Land Cover Data;
- Establish 5 TL Categories: Land Coverage categories associated with the 5 Transect categories *(1)*
- Classify the areas within Tulsa City Limits in these categories.

The following pages present more information about each component of the core of the method.

Methodology

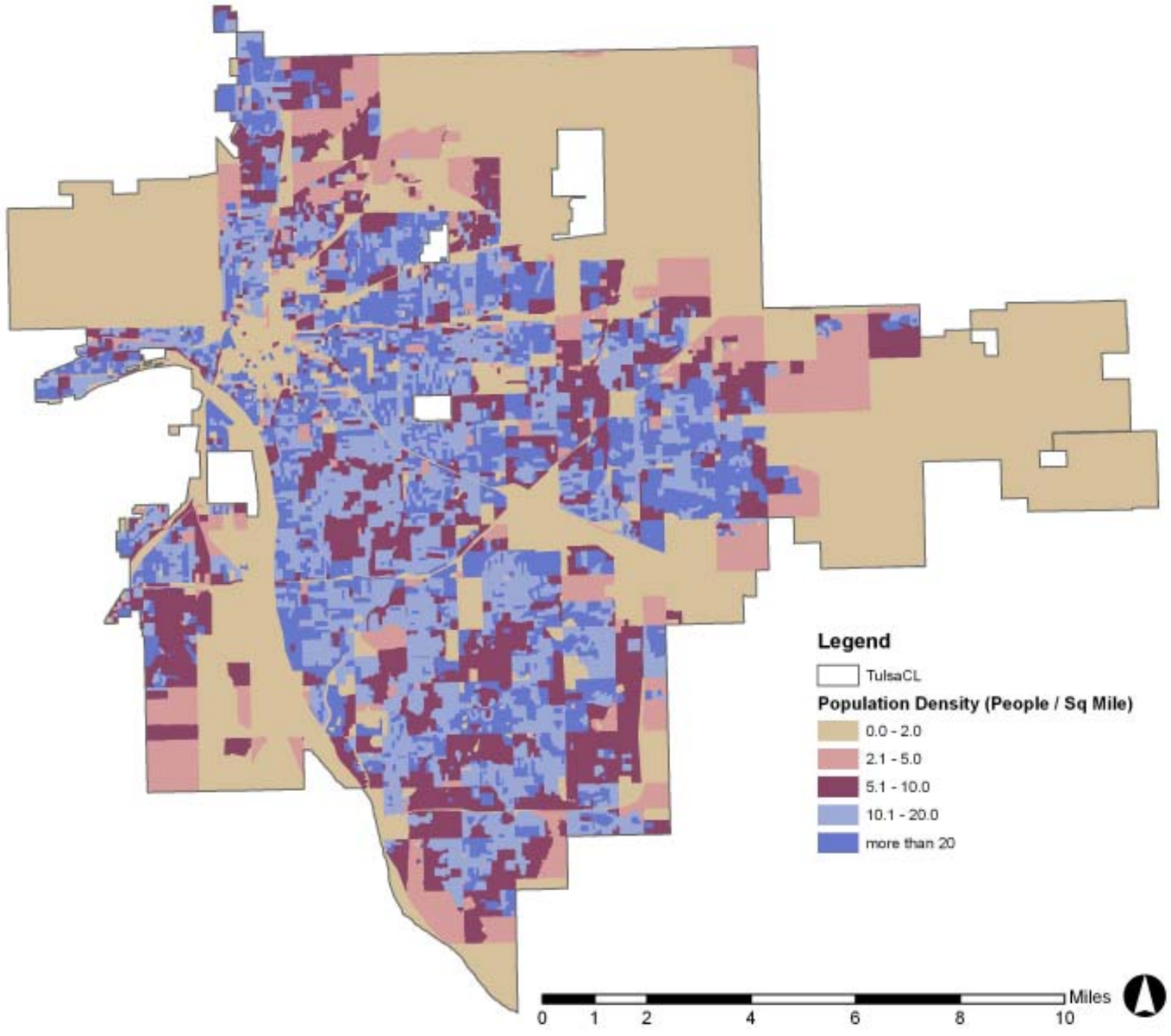
Density - Raw Data

Density is here represented as Population Density (people/ square mile). *(See Note 01)*

The main data source for this component of the core of the method was the ESRI (Environmental Systems Research Institute) website, which provides free download of Census 2000 Data in a very well organized way. Some of the limitations of the data are definitions of US Census Data and time.

Further information about US Census Data can be found on the following link:

US Census 2000 Data available at:
http://www.esri.com/data/download/census2000_tigerline/index.html



Density - Raw Data. Source of data : US Census 2000

Note:
01) Density (raw data) is being presented here in *people / square mile*. However, density will be later presented in this report in *units / acre* (for TD Categories, see p. 19 for details). That was done to:

1. Differentiate the map that shows raw data for density and the map that shows TD categories.
2. To be consistent with the main source used in this project to establish the scales for density (Campoli; MacLean, 2007). The density catalog published by the mentioned authors was adopted as one of the main sources of this project because it provides a good overview of density in American cities. Since *units / acre* is the unit used in this catalog, that was also adopted in this project for the TD categories so we could understand Tulsa's density in the context of American cities.

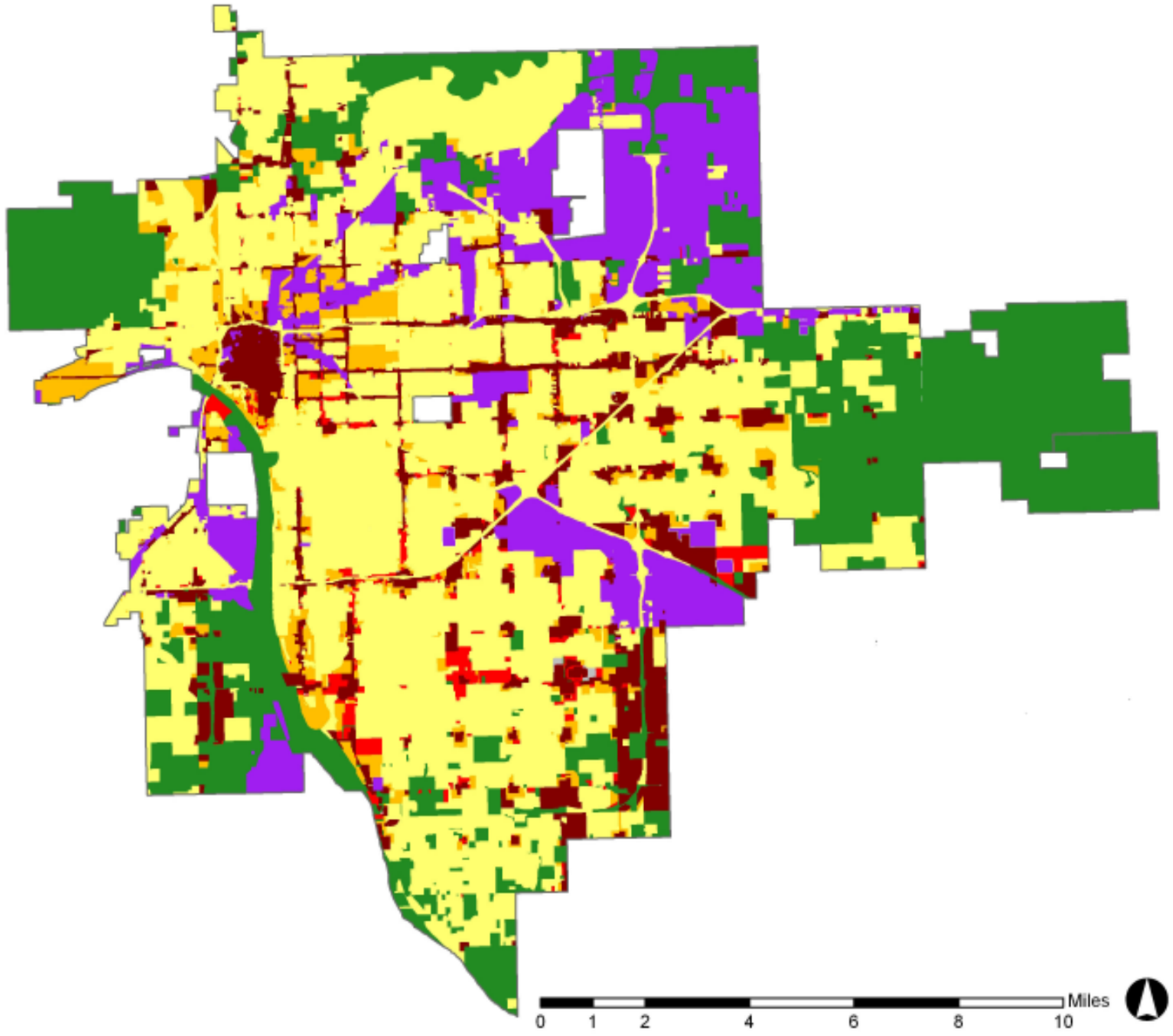
Methodology

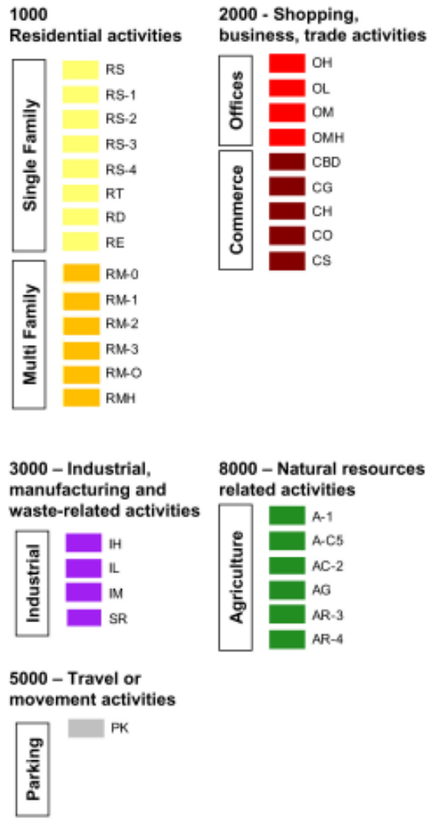
Zoning - Raw Data

Zoning will be analyzed considering property restrictions and maximum levels of construction allowed for each zone.

The main data source for this component of the core of the method was INCOG and City of Tulsa. ArcGIS files (shapefiles) were obtained from INCOG and other information about Zoning Ordinances was obtained from City of Tulsa website. A limitation of the data is the fact that Zoning is a regulatory tool, and some times it may not reflect the reality of the city being studied. For example, it is possible to find cities that are not built to the maximum capactity allowed by zoning.

City of Tulsa Zoning Ordinances available at:
http://www.cityoftulsa.org/ourcity/ordinances/Title42.asp





Zoning - Raw Data. Source of data : INCOG, City of Tulsa

Methodology

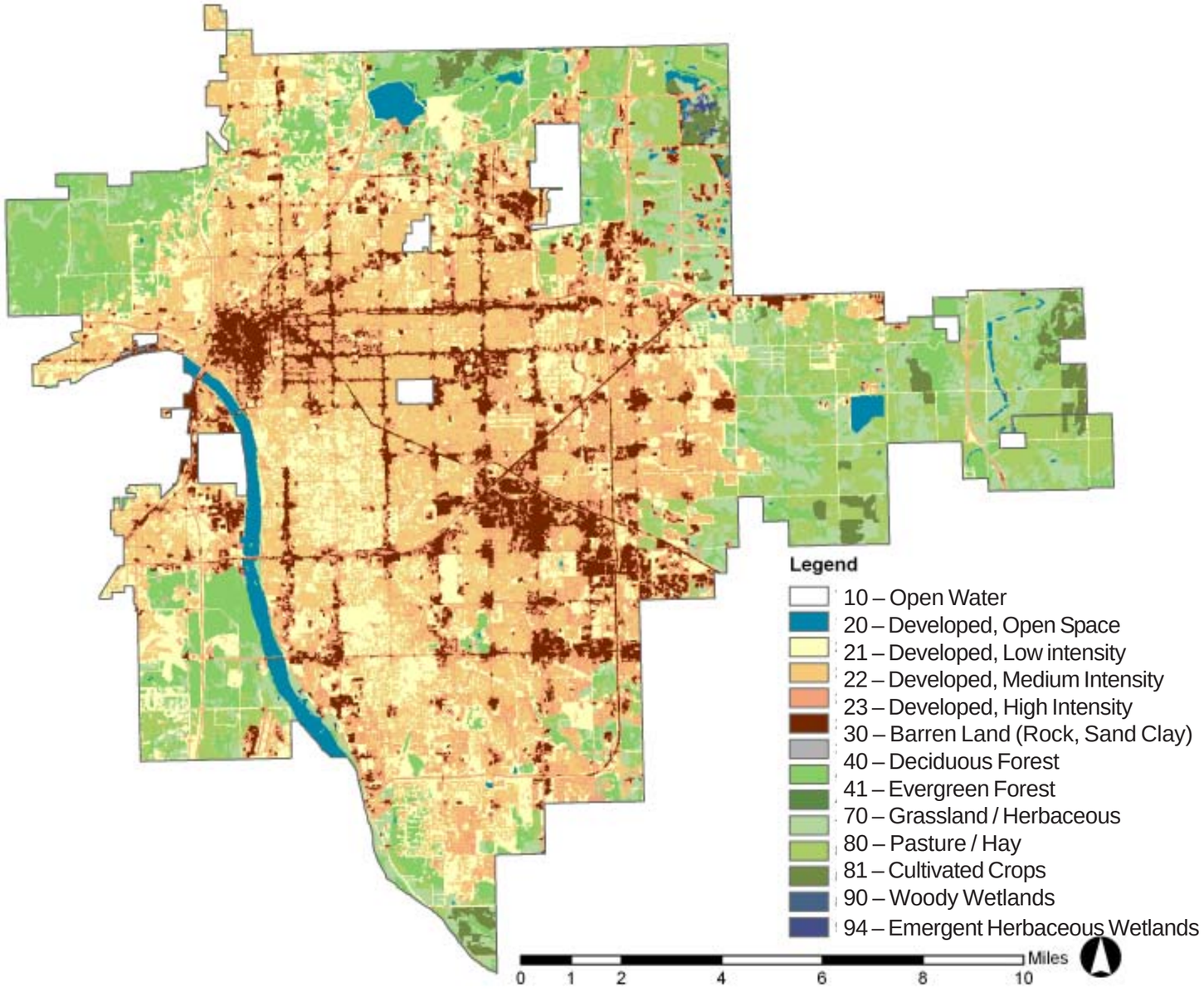
Land Cover - Raw Data

Land Cover data is based on infrared which show different levels of impervious surface coverage or hardscaping. Heat island effect is an urban characteristic that can be shown by Land Cover data. The more hardscaped the area, the more heat it reflects.

Land Cover Data will be analyzed considering the categories established by the MRLC (Multi Resolution Land Characteristics Consortium) . The main source of data for this aspect was the USGS website which provides free download of Land Cover Data . A limitation of the data is the fact that Land Cover data does not change with verticalization.

The precision of the data is given by the size of each pixel, which in this case is 150 feet by 150 feet. Because of that, this is the pixel size that was adopted in this project.

See Appendix 01 for 2001 NLCD (National Land Cover Data) Land Cover Class Definitions.
Available at: http://www.mrlc.gov/nlcd_definitions.asp

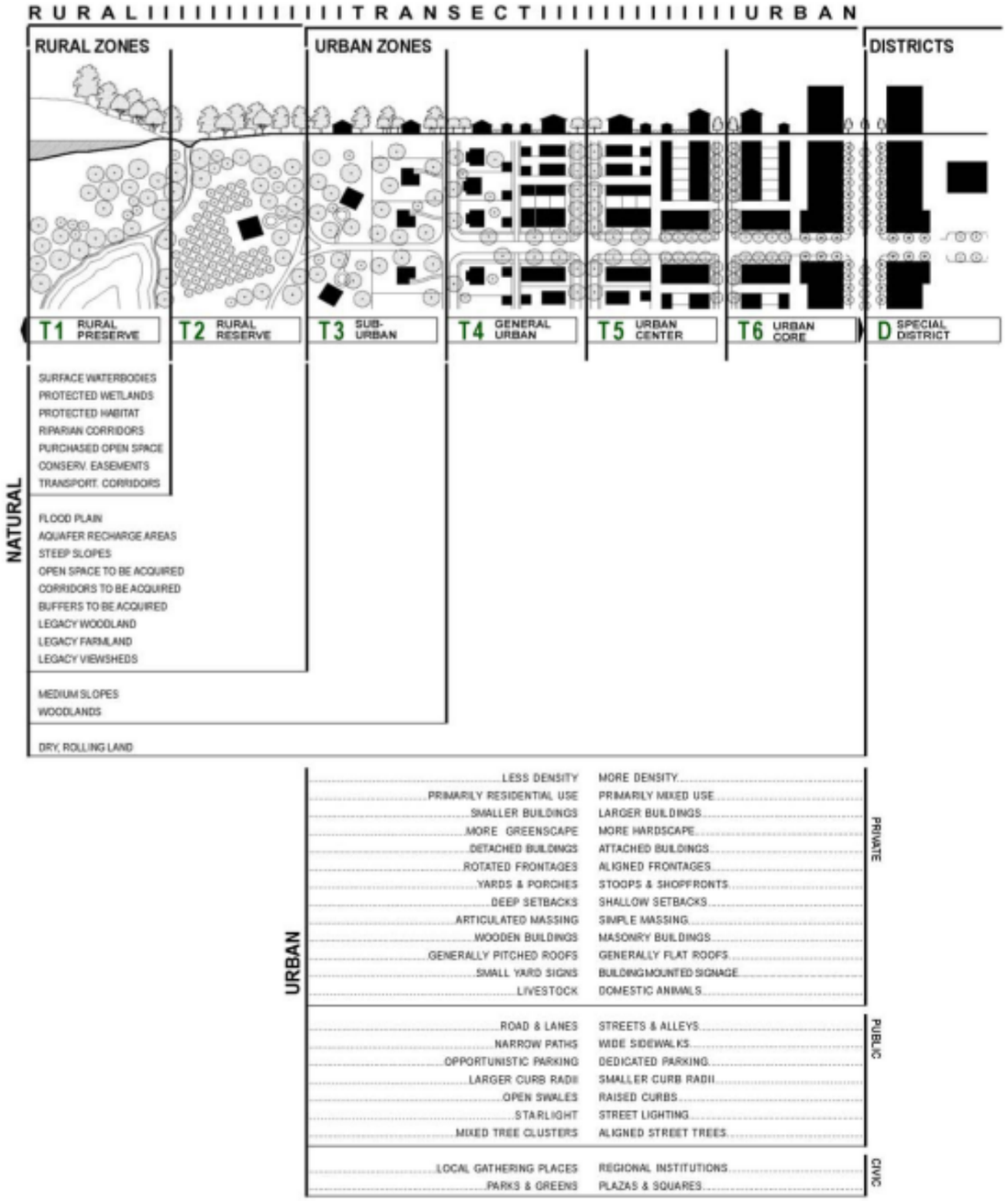


Land cover map - Raw Data. Source of data : USGS

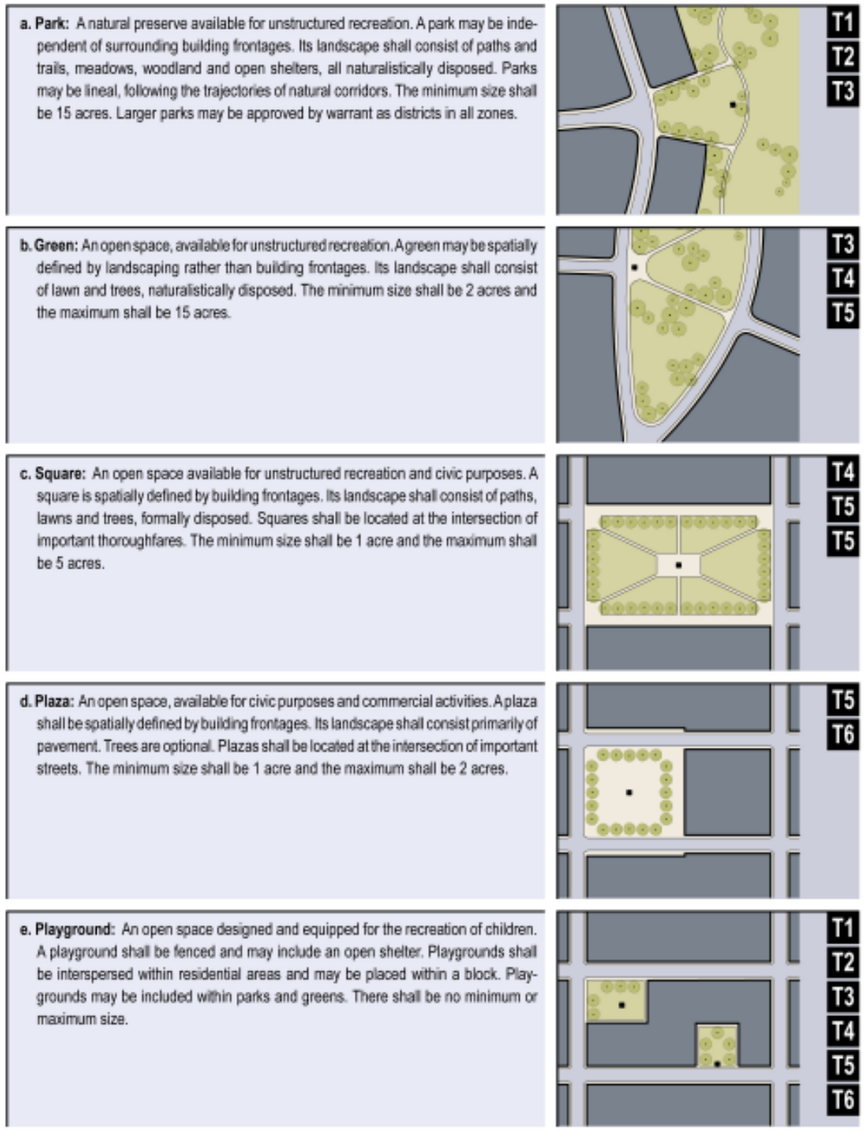
Methodology

The Transect and The Smart Code

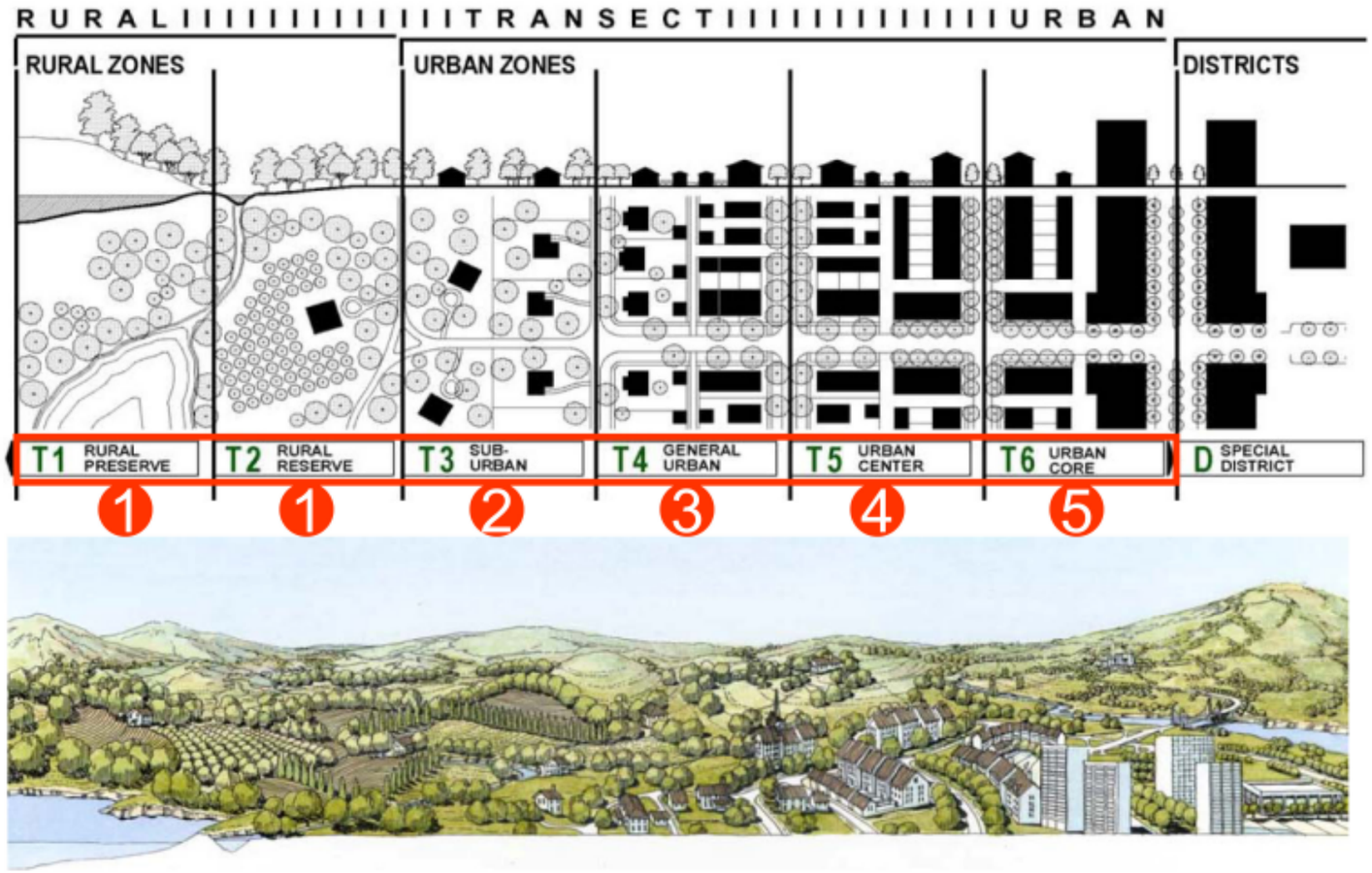
The Transect concept (Duany; Talen, 2002) defines a series of categories of development between sparse rural areas and dense urban cores. There are 7 categories: Rural Preserve (T1), Rural Reserve (T2), Sub-Urban (T3), General Urban (T4), Urban Center (T5), Urban Core (T6) and Special District (D). The graphics presented here show more details about the Transect concept and the characteristics of its categories.



Transect concept: descritpion of categories.
Source: Duany ; Talen (2002)



Transect concept:
description of categories.
Source: Duany *et al* (2007)



Numbers that will be assigned for zones in the rating system (in red). Source: Adapted from Duany *et al.* (2007)

(1) It is important to highlight that de data presented is this project does not consist only on a calibration of the quantitative aspects presented by the Smart Code. This will be discussed with more details later in this report, specifically in the sections Methodology / The scales - criteria used to establish the T Categories and Conclusions.

Methodology

The Transect and The Smart Code

The Smart Code is a Transect-based code that *"organizes the natural, rural, suburban, and urban landscape into categories of density, complexity and intensity"* (Duany *et al*., 2007). It is based on the principle that *"certain forms belong in certain environments; for example, an apartment builiding belongs in a more urban setting, and a ranch house belongs in a more rural setting"* (Duany *et al*., 2007). Following this principle, the Smart Code presents some quantitative aspects for each zone (T1, T2, T3, T4 , T5 and T6). The table on the next page shows a summary of the quantitative aspects for each zone. It is important to highlight that all aspects presented in this table are subject to calibration for local context and that in the suthor's words *"The SmartCode is a template for a community to design its own vision."*

The approach and concepts introduced by the Transect and the Smart Code form a conceptual basis for the classification of development intensity for the method presented in this project *(1)*. The data for the 3 components of the core of the method (Density, Zoning and Land Cover Data) will be classified in categories in accordance to 5 categories established by the Transect concept. The 5 categories to be used in this process are:

1. Rural Zone (Undeveloped, Very Low intensity):
   T1 – Rural Preserve plus T2 – Rural Reserve
2. Urban Zones (Low, Medium, High, Very High intensity):
   T3 – Sub-urban; T4 - General Urban; T5 – Urban Center; T6 – Urban Core

The graphic to the left was created by adapting graphics from Duany *et al*. (2002) to illustrate the Transect concept and how that translates into the physical level. It also highlights the categories that will be used in this method and the numbers that will be used in the rating system.

Methodology

The Transect and The Smart Code

Transect concept: description of categories. Source: Duany *et al.* (2007)

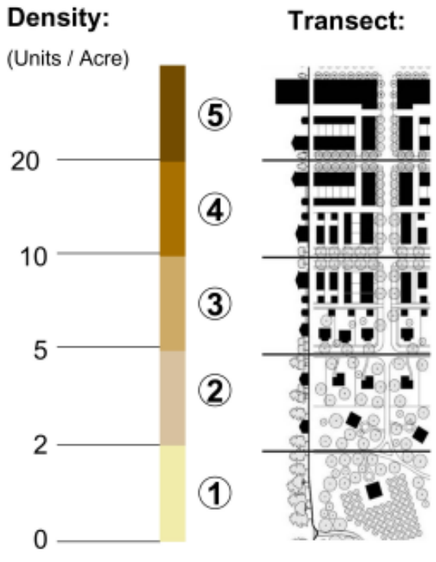
Methodology

The Scales - criteria used to establish the T Categories

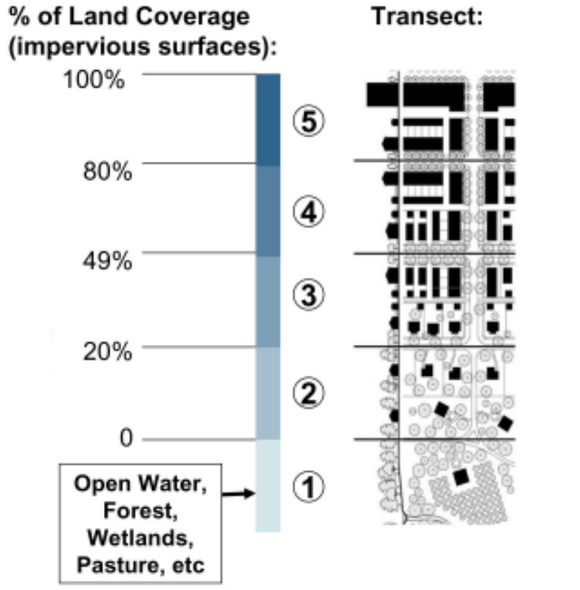
The following table shows a summary of the aspects that were considered to establish the 5 categories for Density, Zoning and Land Cover. The graphs show more details.

	Aspect Considered	Unit
Density		
	Population Density	Units / acre
Land Cover		
	% of Land Coverage	%
Zoning		
Agricultural	Description of category	NA
Residential and Corridor	Land Area / Dwelling Unit (LA/DU)	Min. Sq. Ft
Office and Scientific Research	Floor Area Ratio (FAR)	NA
Industrial	Description of category	NA

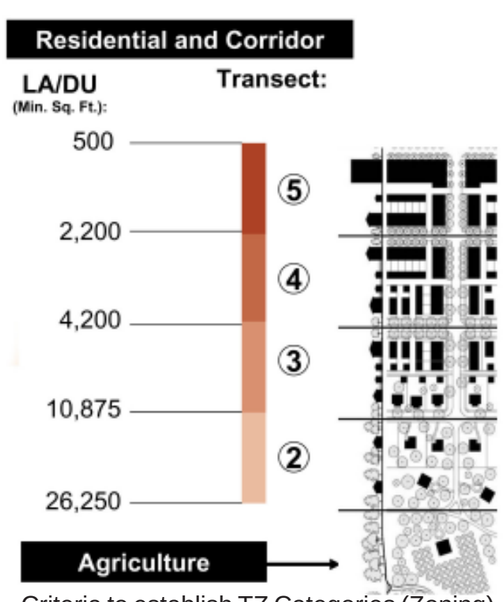
(See Appendix 02 for further explanation about Land Area per Dwelling Unit and Floor Area Ratio)



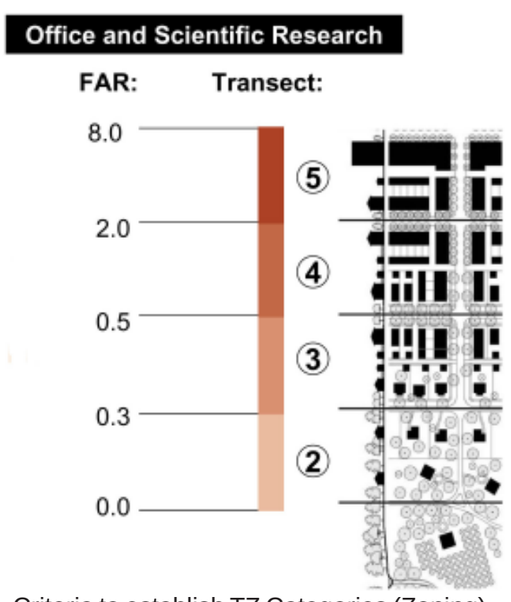
Criteria to establish TD Categories (Density)
Aspect Considered:
Population Density (units / acre)
(See Appendix 03 for Some Definitions of US Census Terms)



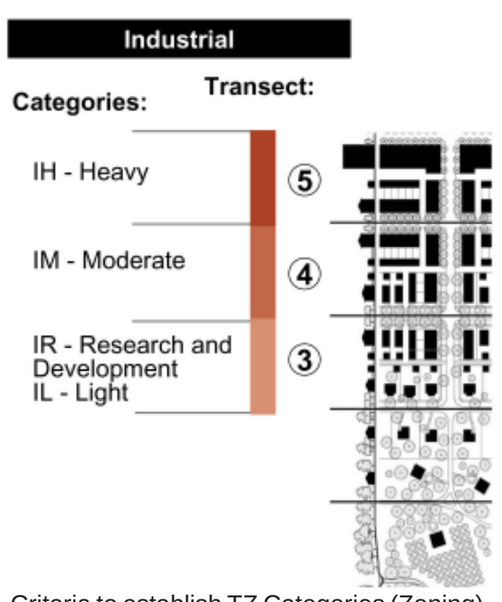
Criteria to establish TL Categories (Land Cover)
Aspect Considered:
Categories of Land Cover Data and Percentage of Land Coverage



Criteria to establish TZ Categories (Zoning)
Aspect Considered: Land Area per Dwelling Unit (LA/DU) for Residential and Corridor, Description of Category for Agricultural



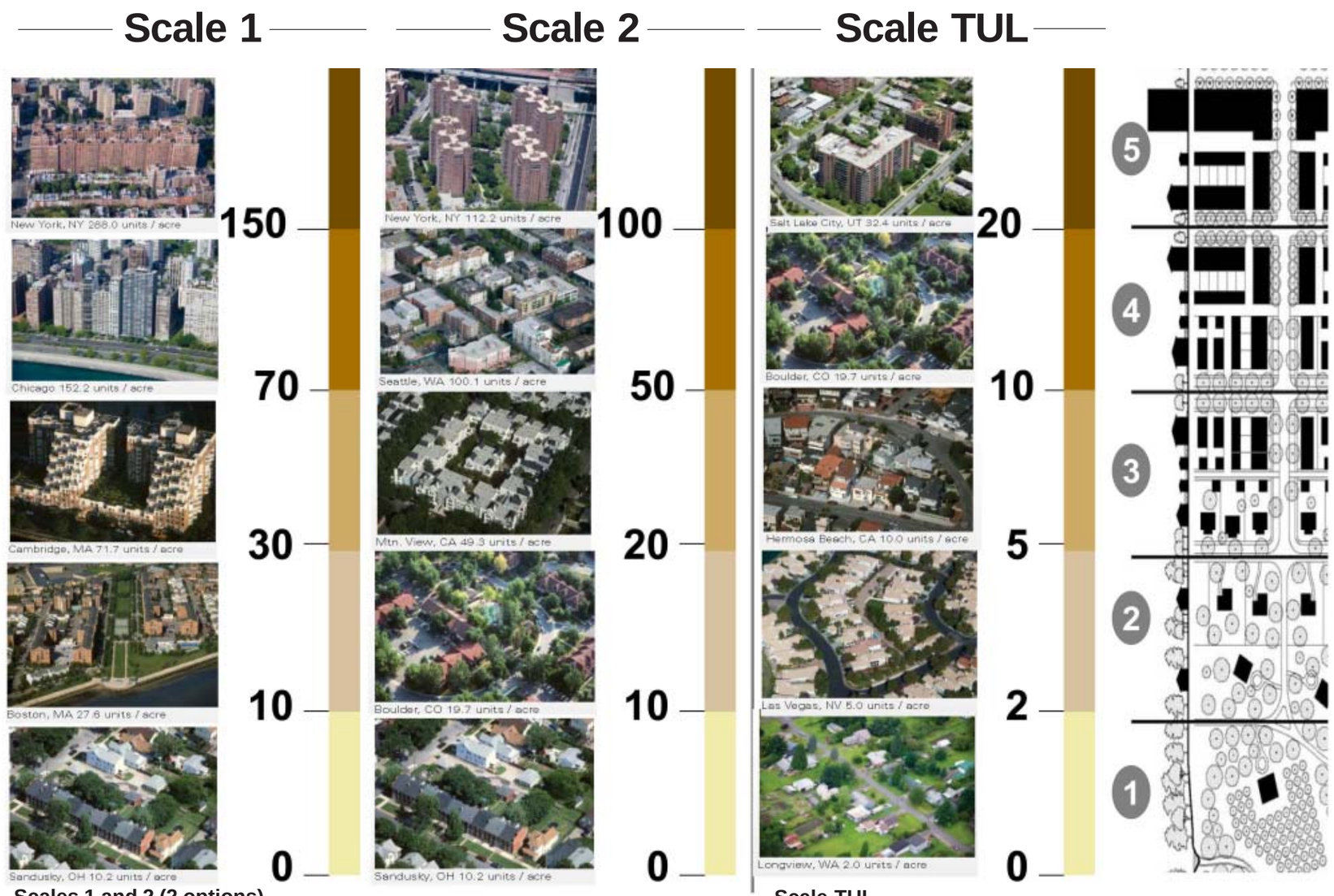
Criteria to establish TZ Categories (Zoning)
Aspect Considered: Floor Area Ratio (FAR) for Office and Scientific Research



Criteria to establish TZ Categories (Zoning)
Aspect Considered:
Descripiton of Industrial Categories

Methodology

The Scales - criteria used to establish the T Categories



Scales 1 and 2 (2 options)

- Using Campoli; MacLean (2007) as a reference
- "Universal" approach, Possible use: compare results of different cities

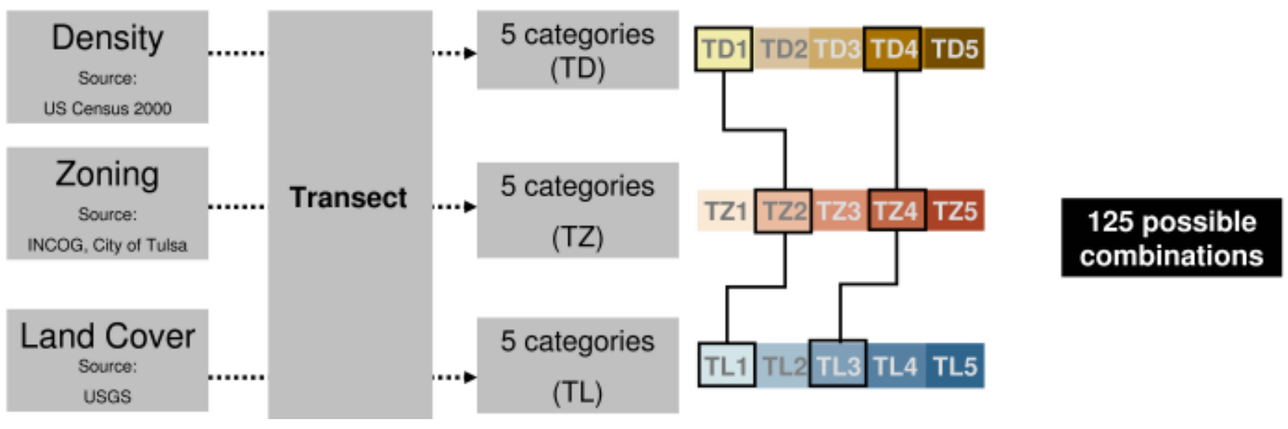
Scale TUL

- Adapted for Tulsa (low density)

About Density Scale:

The graphics located to the left show different density scales and pictures to illustrate them. Scales 1 and 2 were developed with the intent of establishing two options of scale that could be considered more universal, and could be applied to American cities in general. These scales could also be useful to compare results of the application of the method in different cities. Since Scales 1 and 2 were developed to provide a more universal approach, it was the intent of this project to use one of those scales to apply the method to Tulsa. The idea was to apply both scales to Tulsa and analyze the results to define which one of them should be adopted. However, after applying Scales 1 and 2 to Tulsa the map only showed categories TD1 and TD2. This showed how low density Tulsa is. Because of that, a different density scale was developed for Tulsa (see Scale TUL), which is the one described and used in this report.

Graphic illustrating the Overlay Option



Graphic illustrating the Combination Option

Methodology

Presenting two different ways to use the Core of the method

Two different ways to use the results obtained through the application of the core of the method are presented in this project: the Overlay option and the Combination option. This report shows results and outlines applications for both options.

Overlay Option:

With the Overlay option the T Categories are overlaid and the scores assigned to them are summed and displayed as the final result. The Results of the application of this option for Tulsa, OK, are in the section Results / Overlay Option.

.

Combination Option:

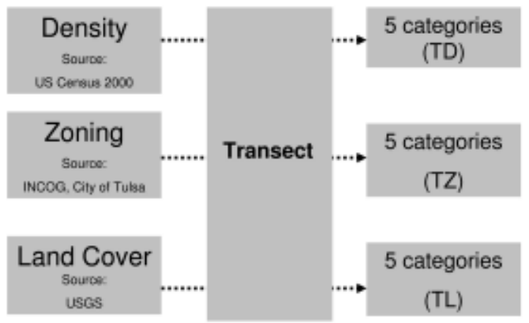
With the Combination option, the T categories are independent elements that can be combined however the user desires. There are at least 125 possible combinations that can be made with this option. It is important to highlight that the combinations should be made according to what the user wants to get out of that process. Some of the possible combinations are shown and analyzed in this report. The Results of the application of this option for Tulsa, OK, are presented in the section Results / Combination Option.

The Results of this project are presented following. They are divided intothree sections that contain specifically the results obtained through the application of:

a) Core (results of the application of the Core of the Method)

b) Overlay Option

c) Combination Option



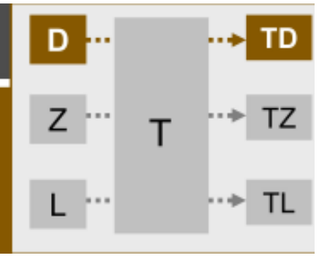
Results

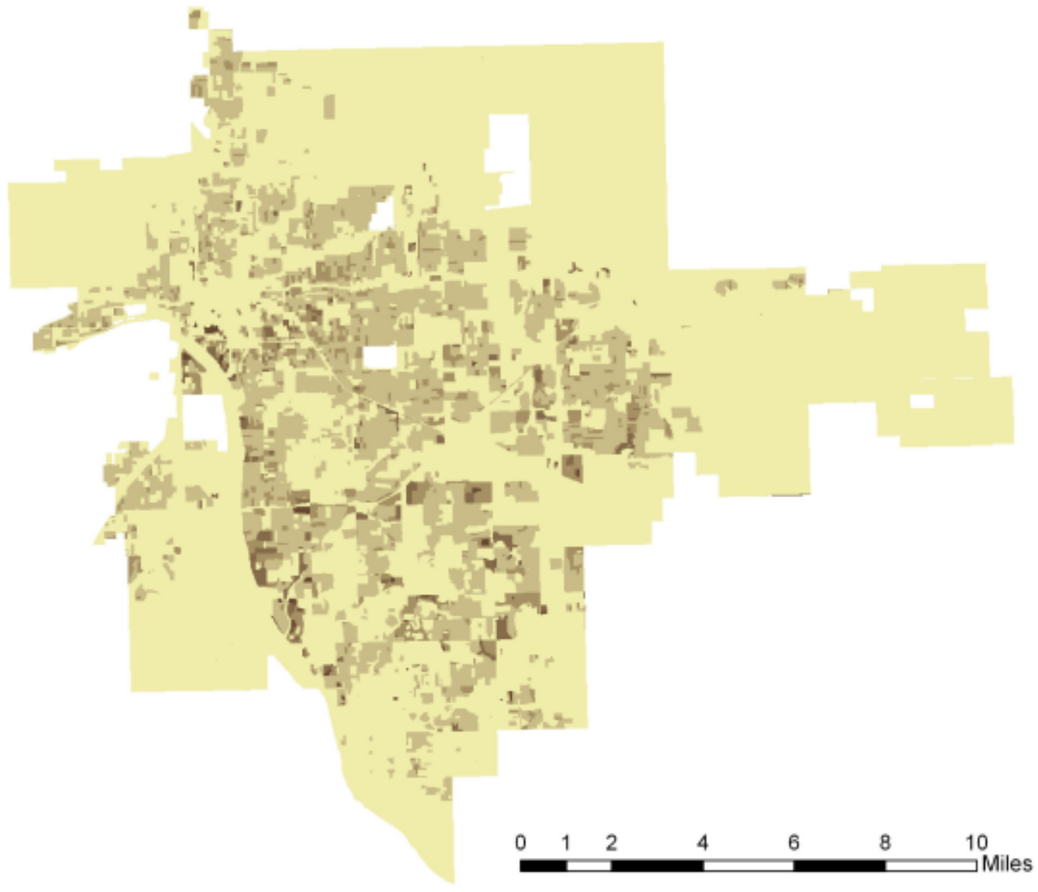
a) Core: TD Categories (Density)

Step 01 –Establish TD Categories

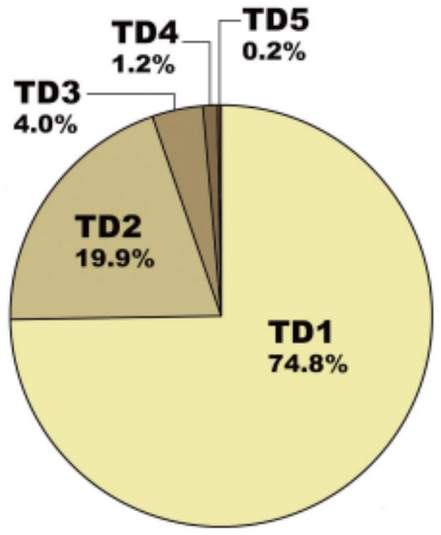
Aspect Considered:
• Density (units / acre) *

Source:
US Census

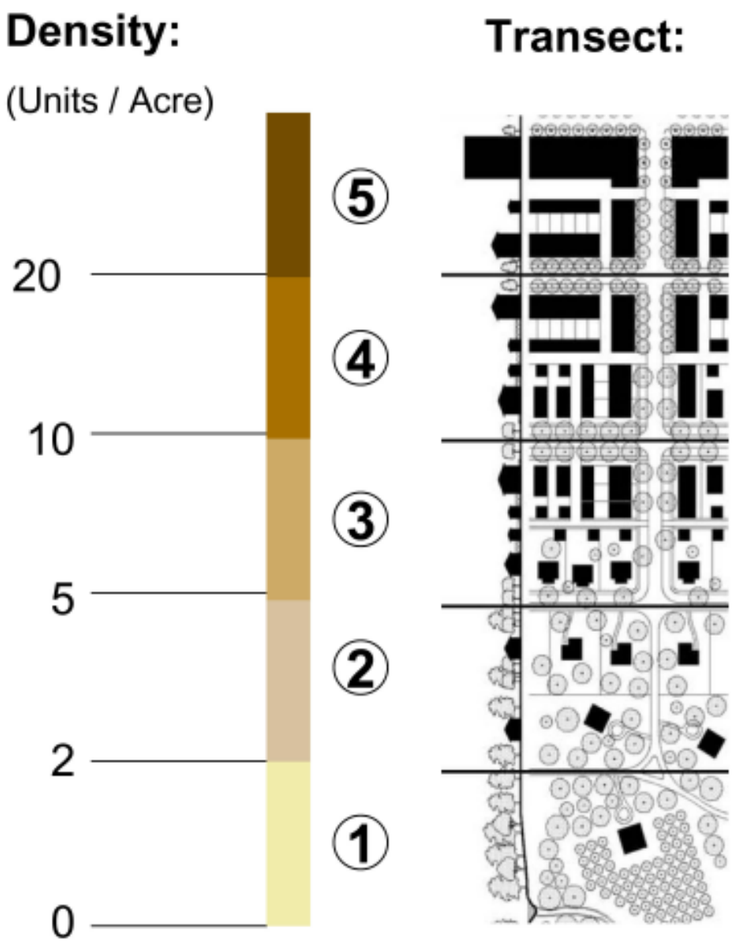




Map of Tulsa with TD categories
TD Categories: Transect categories for Density



TD categories within Tulsa City Limits
(percentage)



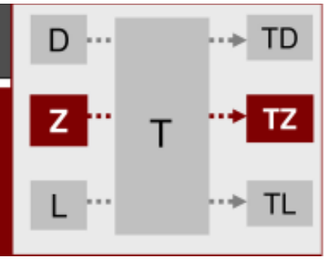
Criteria used to establish TD categories

* Housing Units - See Appendix 03 for Definitions of US Census Terms

Step 02 –Establish TZ Categories

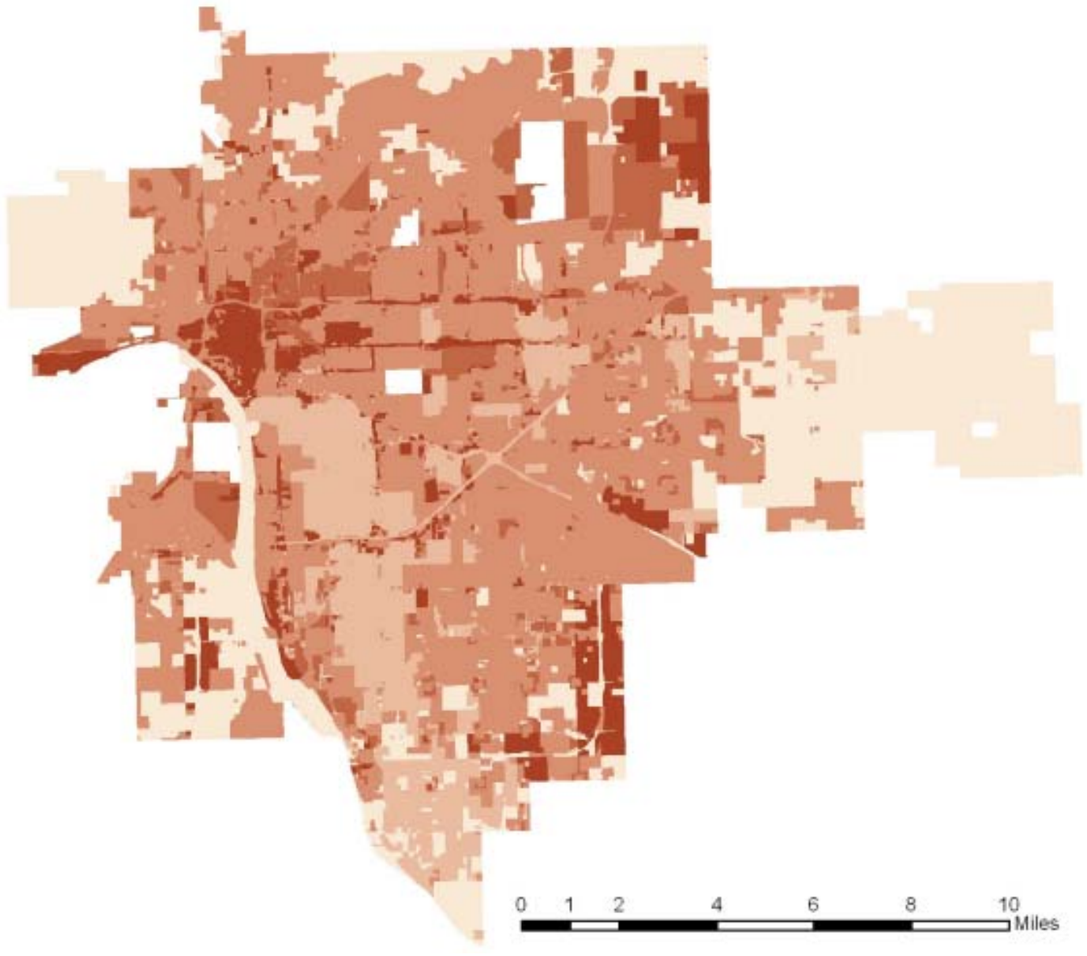
Aspect Considered:
- LA/DU for Residential and Corridor
- FAR for Office and Scientific Research
- Description of Categories for Industrial

Source:
City of Tulsa Zoning Ordinances

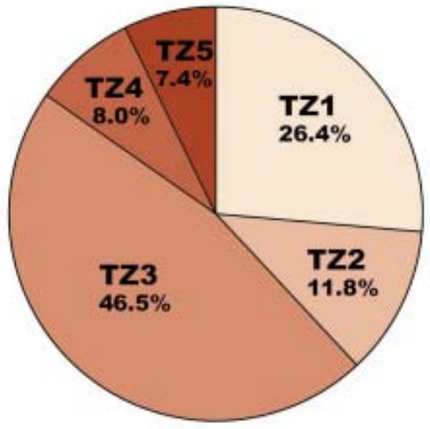


Results

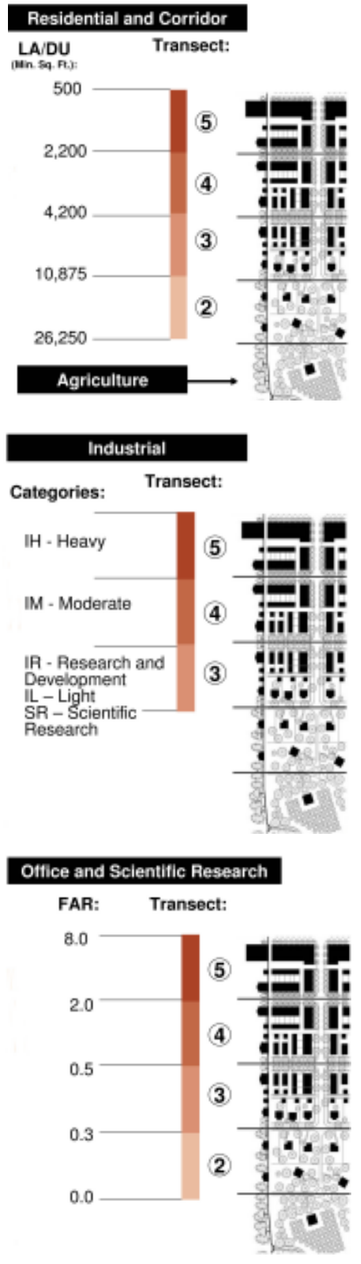
a) Core: TZ Categories (Zoning)



Map of Tulsa with TZ categories
TZ Categories: Transect categories for Zoning



TZ categories within Tulsa City Limits (percentage)



Criteria used to establish TZ categories

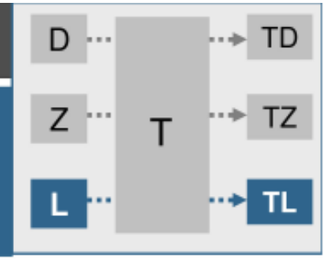
Results

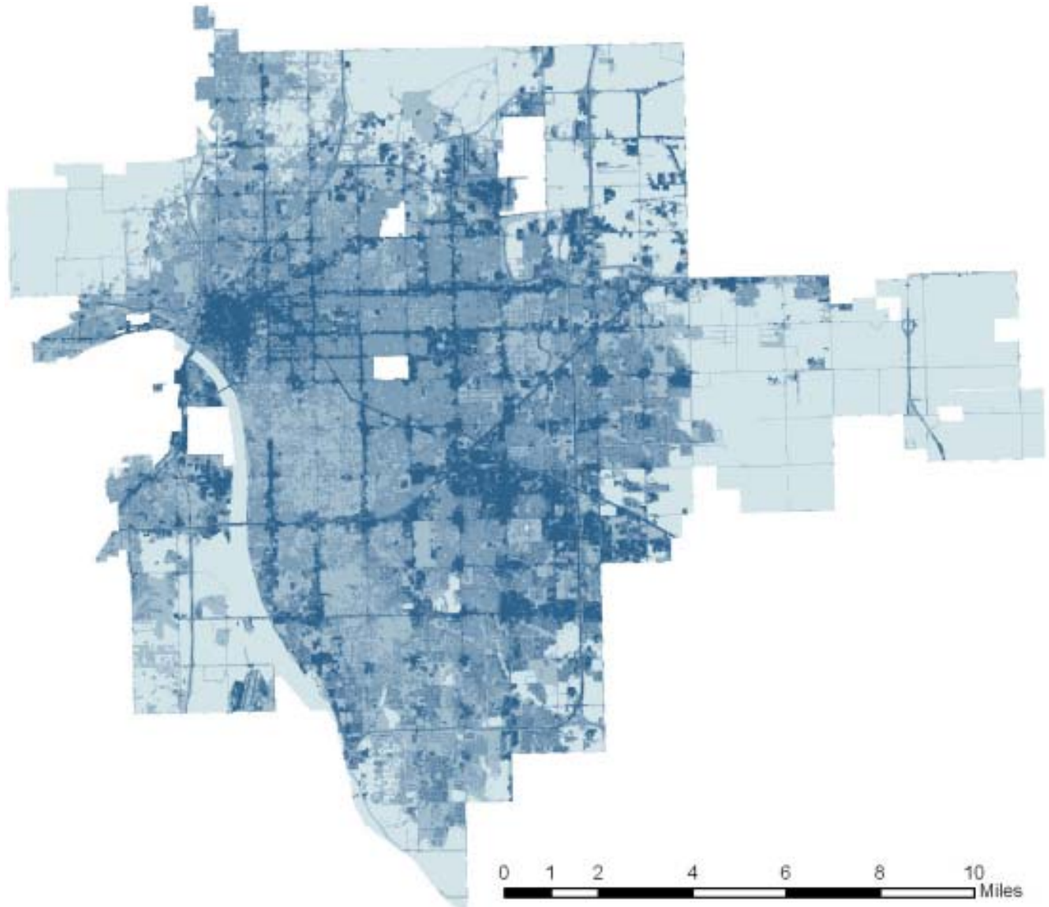
a) Core: TL Categories (Land Cover)

Step 03 –Establish TL Categories

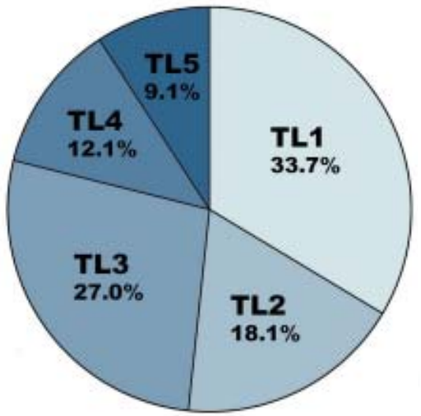
Aspect Considered:
- Categories of Land Cover Data
- Percentage of Land Cover

Source:
USGS – US Geological Survey

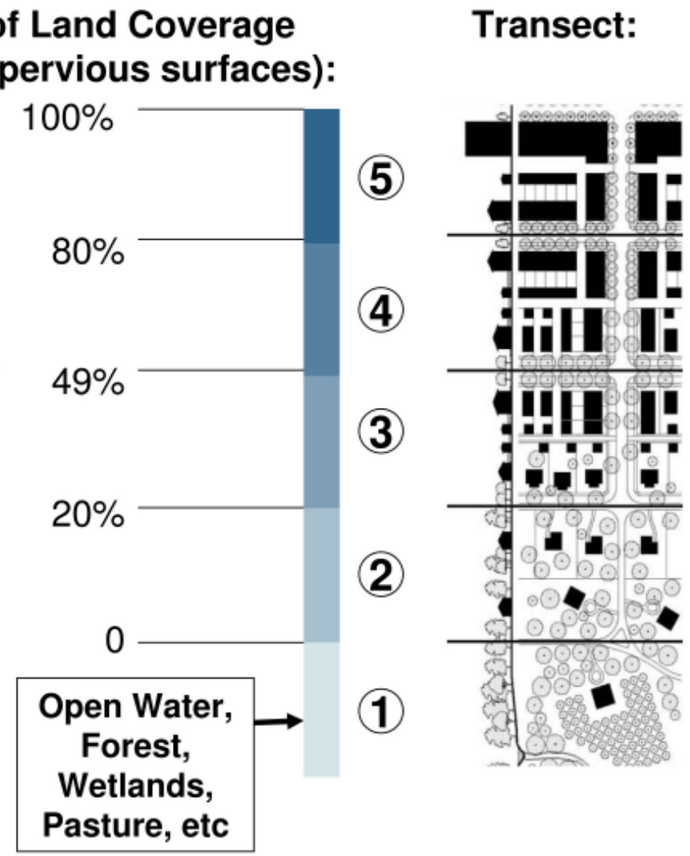




Map of Tulsa with TL categories
TL Categories: Transect categories for Land Cover



TL categories within Tulsa City Limits (percentage)



Criteria used to establish TL categories

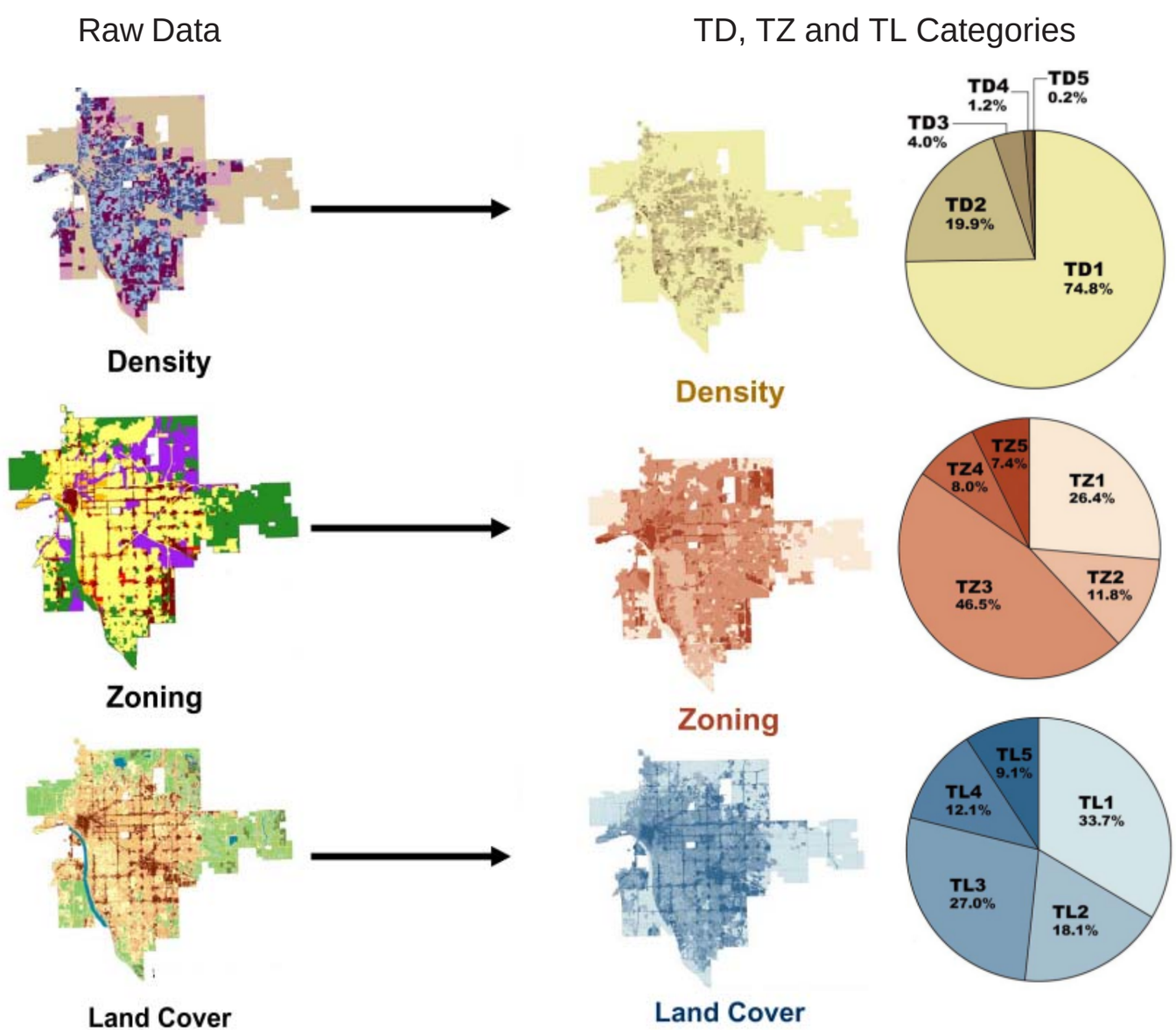


Diagram showing Summary of results of the application of the Core of the Method to Tulsa.
Graphs show areas of TD, TZ and TL categories within Tulsa City Limits (percentage)

Results

a) Core: Analysis of Results

The diagram to the left shows a summary of the results obtained thought the application of the core of the method to Tulsa. Following there is a brief analysis of the results obtained for each aspect. In order to make the analysis more reader friendly, it is presented in items that relate to groups of categories. For the purpose of this analysis, the categories were divided into "low and intermediate", and "high", as following:

- "Low and Intermediate": Categories 1, 2 and 3
- "High": Categories 4 and 5

Density:

Regarding Low and Intermediate Categories (TD1, TD2 and TD3):

The graph shows that 98.7 % of the area within Tulsa City Limit presents low or intermediate density (categories TD1, TD2 and TD3 combined), and TD1 really stands out with the highest percentage among all TD categories (74.8%).

Regarding High Categories (TD4 and TD5):

The categories TD4 and TD5 represent only 1.4 % of the area within City Limits, and TZ5 really stands out as the category with the lowest percentage (only 0.2%).

Highest Percentage: TD1, 74.8 % ; Lowest Percentage: TD5, 0.2%

Conclusion: This shows how low Tulsa's density is. This topic will be discussed with more details in the Conclusions of this report (see Conclusions / About Tulsa's Density).

Zoning:

Regarding Low and Intermediate Categories (TZ1, TZ2 and TZ3):

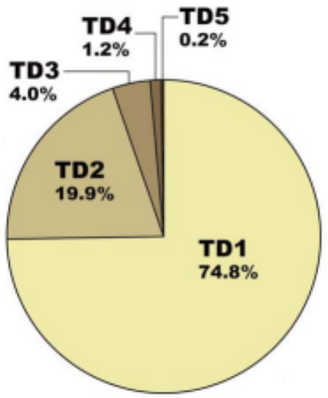
The graph shows that 84.7 % of the area within Tulsa City Limit is zoned for low or intermediate intensity of development (categories TZ1, TZ2 and TZ3 combined). TZ3 stands out with the highest percentage among all TZ categories (46.5%).

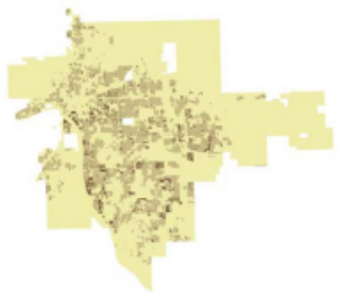
Regarding High Categories (TZ4 and TZ5):

On the other end of the spectrum, categories TZ4 and TZ5, which represent areas that are zoned for intense and high density development, represent only 15.4 % of the area within City Limits.

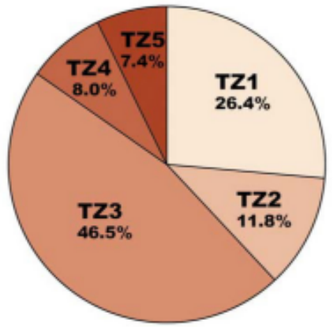
Highest Percentage: TZ3, 46.5 % ; Lowest Percentage: TZ5, 7.4%

Conclusion: This shows that the majority of the area within Tulsa's city limits (84.7%) is zoned to allow low or intermediate intensity of development. Few areas within the City Limits (15.4 %) are zoned for high intensity development. Thus, we should not be surprised with the fact that this is actually what we see as a reality in Tulsa: a pattern of development that implements low intensity of land use all over the city.

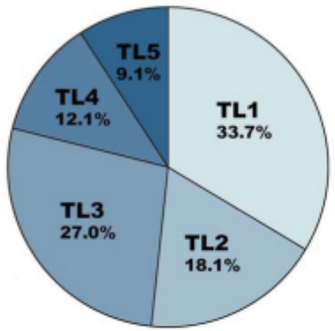


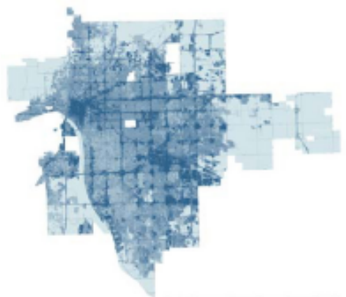


Density



Zoning





Land Cover

TD, TZ and TL Categories in Tulsa

Note:
1) We should be careful when analyzing Land Cover Data because low and intermediate scores on Land Cover don't necessarily mean the area is not developed or is developed in a low intensity. It just means that the area is just not highly hardscaped. For example, areas with parks and recreational areas will present low scores but that does not mean they are not developed or are develop in a low intensity pattern. The information about Land Cover should always be analyzed considering the other two aspects(Density and Zoning) too. The *section Results / Combination option / Topic Based* shows some examples of combinations that use firt Density and Zoning, and then incorporate the information about Land Cover Data.

Results

a) Core: Analysis of Results (cont.)

Land Cover:
Regarding Low and Intermediate Categories (TL1, TL2 and TL3):
The graph shows that 78.8 % of the area within Tulsa City Limit presents low or intermediate hardscaping (categories TL1, TL2 and TL3 combined), and TL1 stands out with the highest percentage among all TL categories (33.7%).

Regarding High Categories (TL4 and TL5):
The categories TD4 and TD5 represent 21.2 % of the area within City Limits, and TZ5 stands out as the category with the lowest percentage (9.1%).

Highest Percentage: TL1, 33.7 %; Lowest Percentage: TL5, 9.1%

Conclusion:
This shows that, in general terms, Tulsa is not highly hardscaped. There are just some areas in the city that present high hardscaping. Downtown is a major one among them. Another section of this report will focus on analyzing Downtown Tulsa (See Results / Combination Option / Geographically Based for more details). (See Note 1)

About Percentages of TD, TZ and TL Categories within Tulsa City Limits:
The Land Cover graph shows that this is the aspect with the least variance among the categories, while Density and Zoning graphs show more variance on the percentages for the different categories. In other words: the percentages are more evenly distributed for Land Cover than for Density and Zoning.

All three aspects show predominance of the low and intermediate categories. However, this predominance is stronger with Density and Zoning than with Land Cover. This can be observed with a general look on the pie charts, but also with a closer look on the categories that stand out as the ones with the highest percentages for each aspect:

• Density shows a very clear predominance of TD1 (with a remarkable 74.8%),
• Zoning shows some predominance of TZ3 (with also significant 46.5%)
• Land Cover shows a slight predominance of TL1 (with 33.7%, which is the lowest of the three numbers presented here).

If we analyze the 3 aspects (Density, Zoning and Land Cover) separately with regards to the categories that present the highest and the lowest percentages, we will notice that:

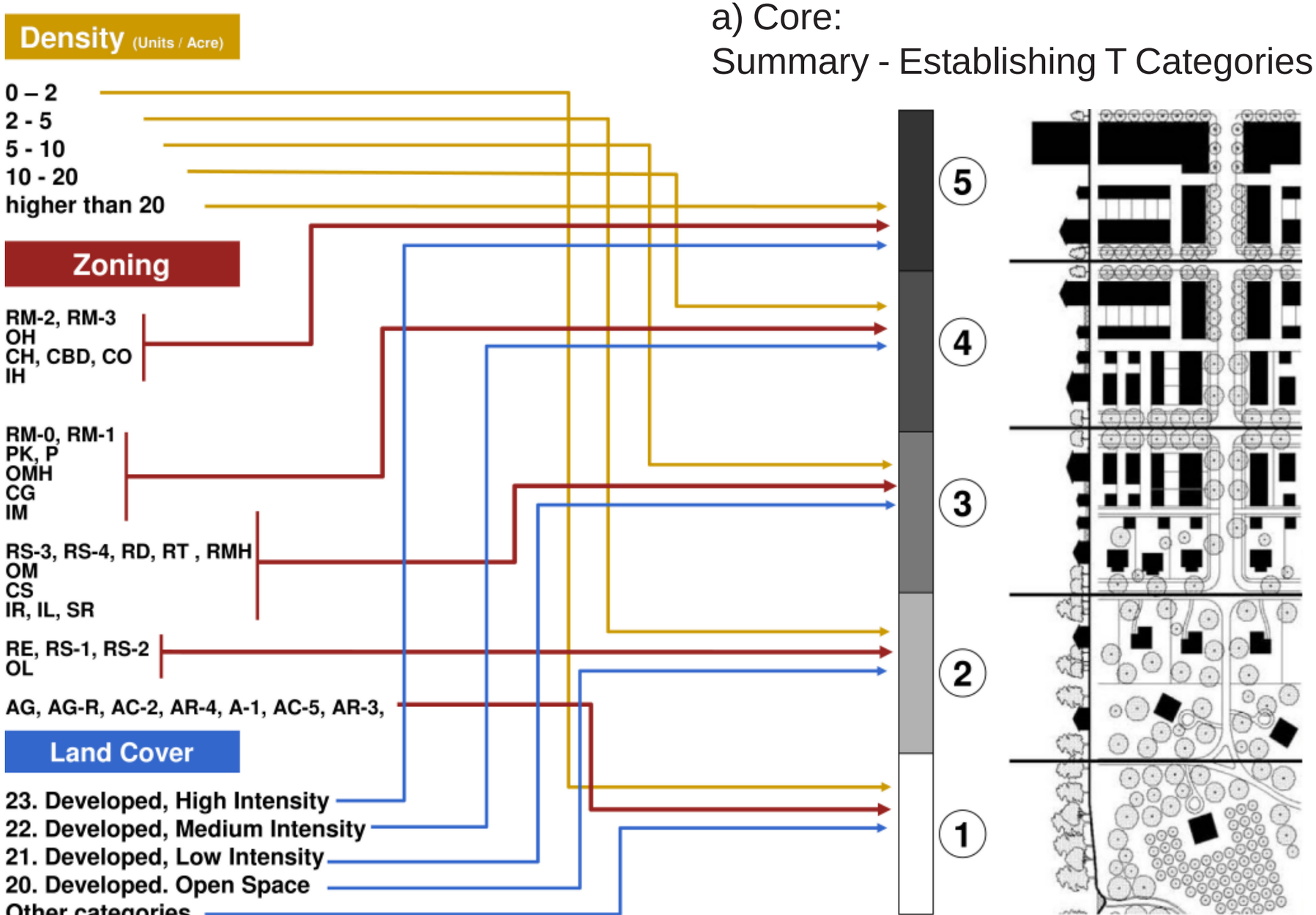
- The categories that present the **lowest** percentages are:
  - the **"High Categories" for all aspects** (TZ4, TZ5, TD4, TD5, TL4, TL5)

- The categories that present the **highest** percentages are:
  - the **"Low Categories" for Density and Land Cover** (TZ1, TL1)
  - the **"Intermediate Category" for Zoning** (TZ3).

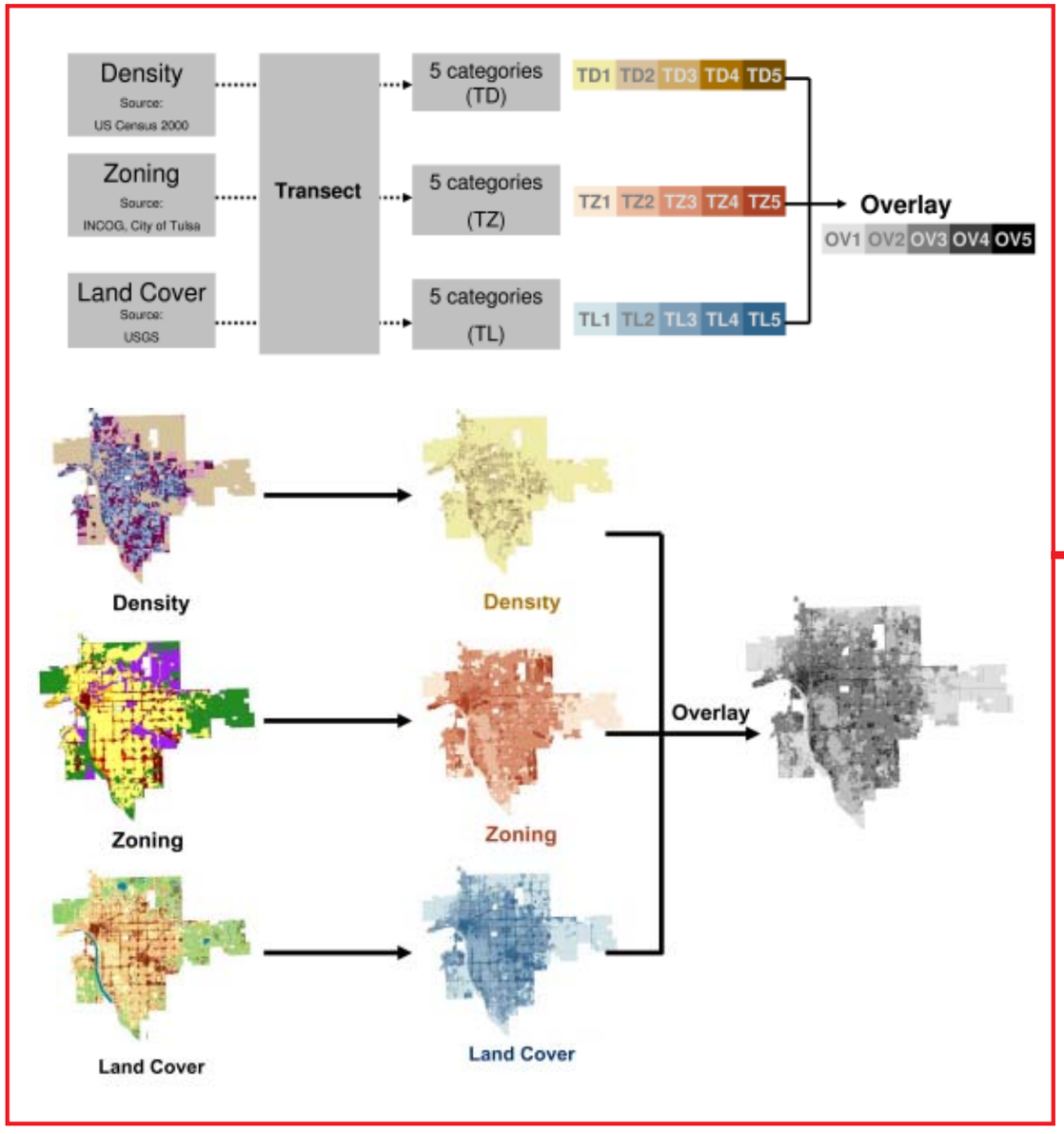
In other words, it is possible to say that, in general, the "High Categories" are the ones that have the lowest percentages, while the "Low Categories" are the ones that have the highest percentages in Tulsa. (See Results / Overlay Option for more details about this)

Results

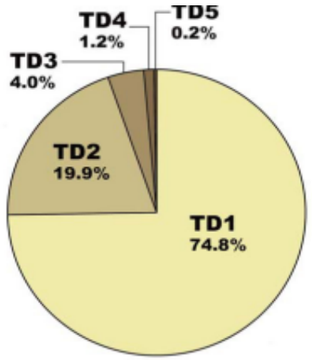
a) Core:
Summary - Establishing T Categories

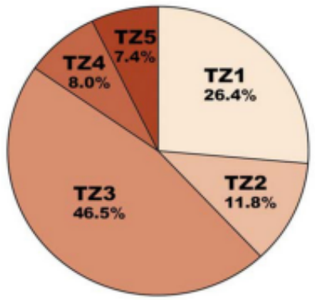


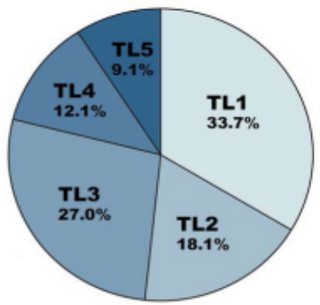
Graphic summarizing the establishment of the T Categories

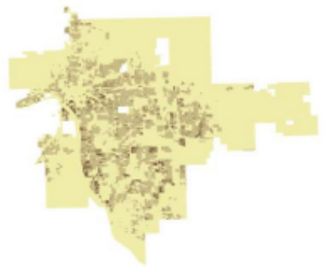


TD, TZ and TL Categories



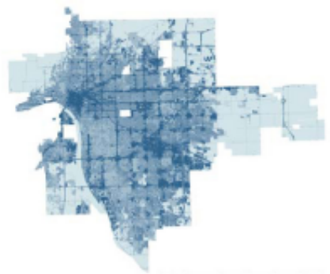






Density

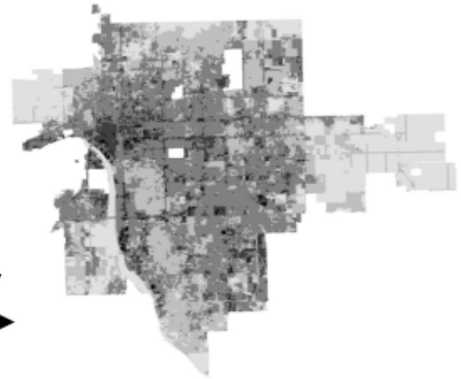
Zoning

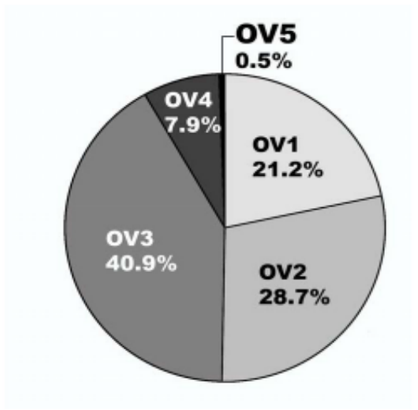


Land Cover

overlay

OV Categories





Results

b) Overlay Option

Regarding Weights:
In this project the Overlay Option was applied using equal weights for the three components of the core. Depending on what kind of analysis the user wants to do, different weights could be assigned to the variables when doing the overlay.

Regarding Low and Intermediate Categories (OV1, OV2 and OV3):
The graph shows that 90.8 % of the area within Tulsa City Limit is categorized under the low or intermediate overlay categories (categories OV1, OV2 and OV3 combined), and OV3 really stands out with the highest percentage among all OV categories (40.9%).

Regarding High Categories (OV4 and OV5):
The categories OV4 and OV5 represent only 8.4 % of the area within City Limits, and OV5 really stands out as the category with the lowest percentage (only 0.5%).

Highest Percentage: OV3, 40.9 %

Lowest Percentage: OV5, 0.5%

Conclusion:
In the analysis presented in the section *Results / Core* of this report we concluded that in general, the "High Categories" are the ones that have the lowest percentages, while the "Low Categories" are the ones that have the highest percentages in Tulsa (see *Results/ Core* for details).

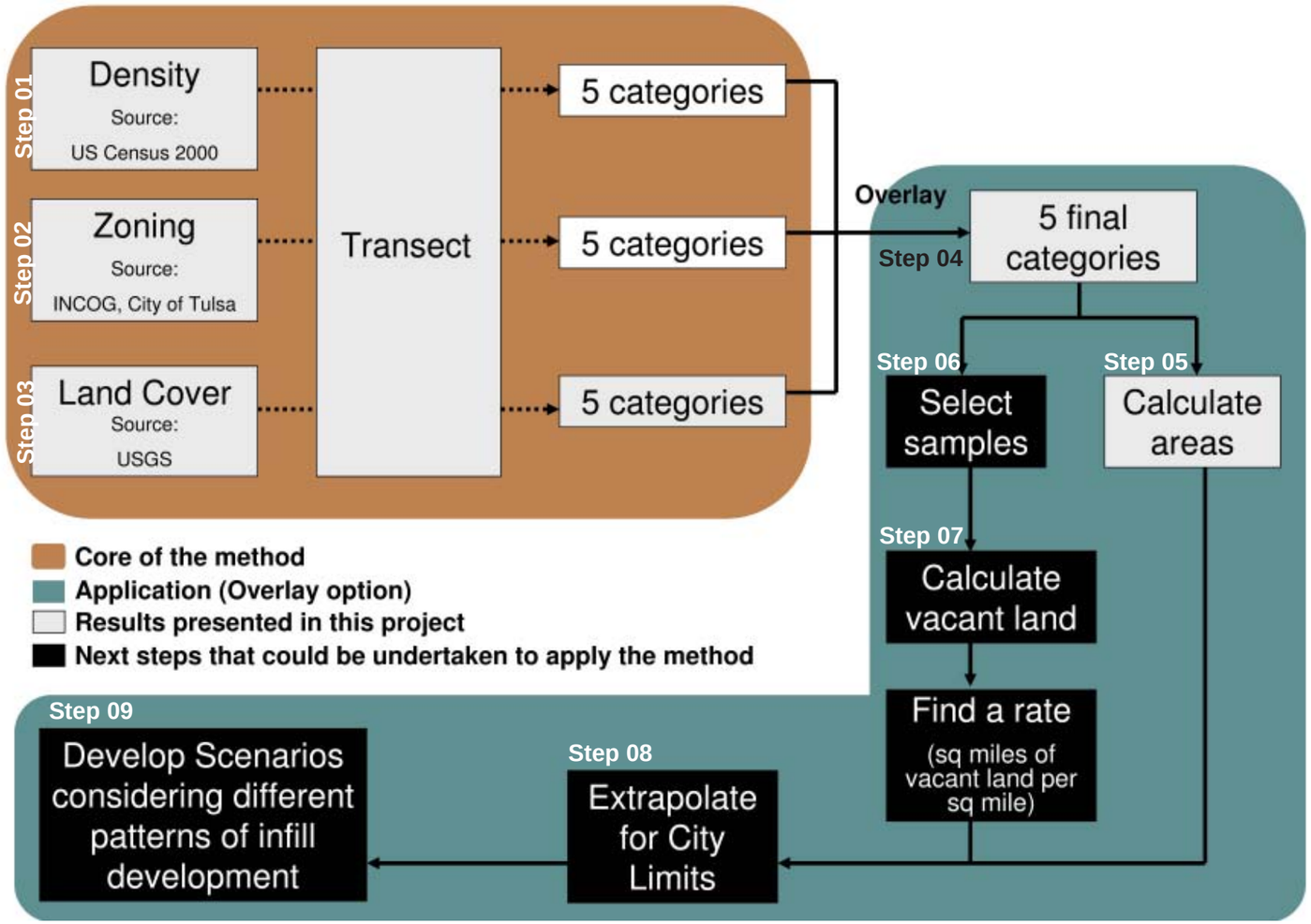
The Overlay pie chart shows that even more clearly: it shows that remarkable 90.8% (OV1, OV 2 and OV3 combined) of the area within Tulsa City Limits can be described as:

- low density areas
- areas that are zoned to allow and encourage low intensity of development
- areas that are not highly hardscaped (See Note 1)

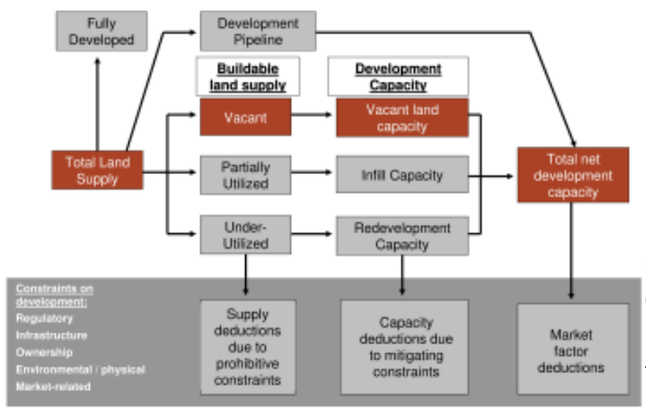
while only 9.2% of the area within City Limits can be described as:

- high density areas
- areas that are zoned to encourage high intensity of development
- areas that are highly hardscaped (See Note 1)

Graphic showing the process used fot the overlay option and the results obtained: maps and graphs showing percentages of areas occupied by each category within Tulsa City Limits.



Flowchart showing possible application of the method (using Overlay option): Quantify availability of vacant land.



Flowchart showing how the application of the method to quantify availability of vacant land could feed into the Land Capacity Monitoring flowchart.
Adapted from Moudon, A. V. , Hubner, M. (2000).
(See Reserach section for Details)

Results

b) Overlay Option

Possible Application:
Quantify Availability of Vacant Land

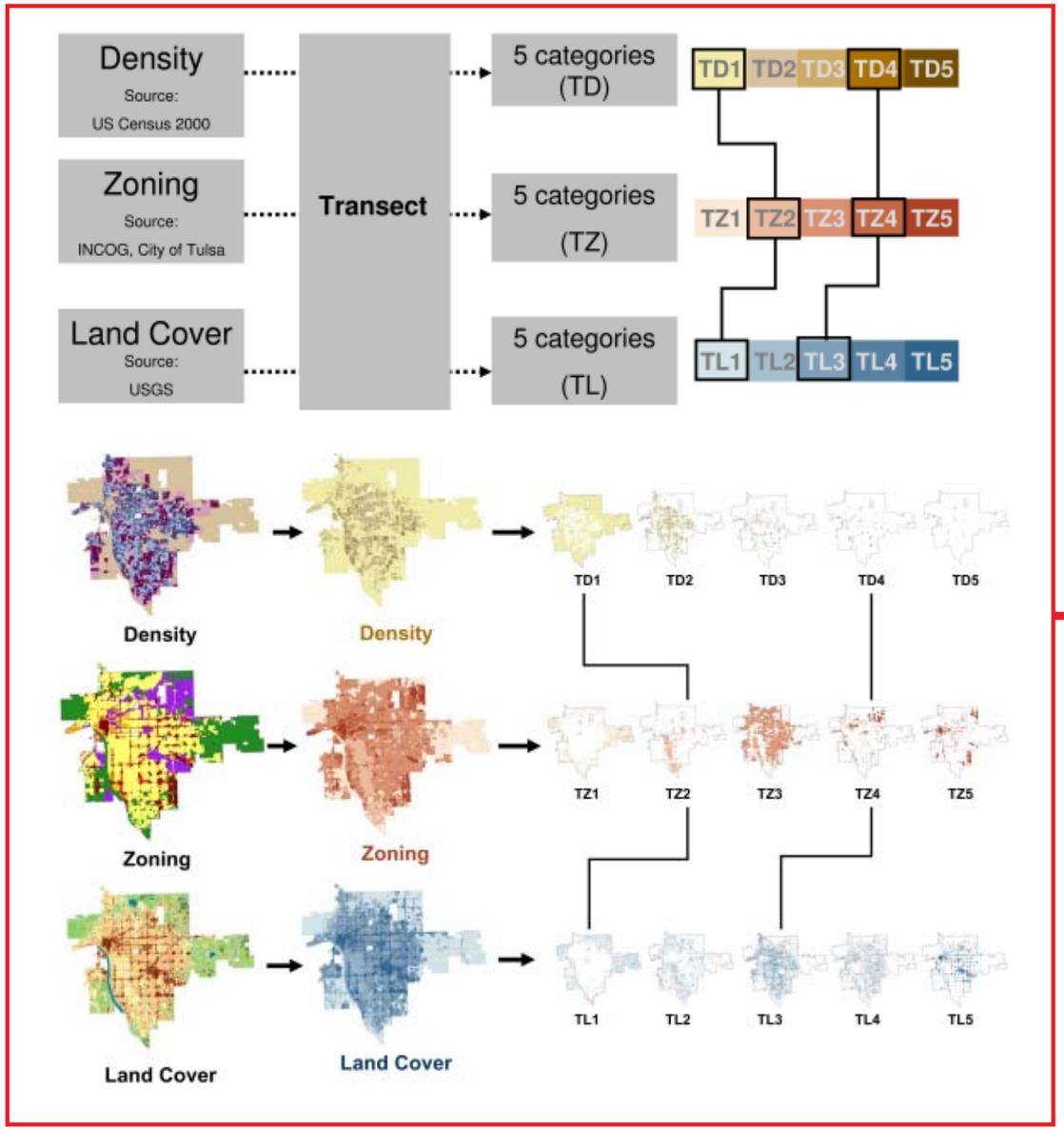
This flowchart located at the top of this page shows one possible application of the method presented in this project. This is an outline of the process that could be used to:

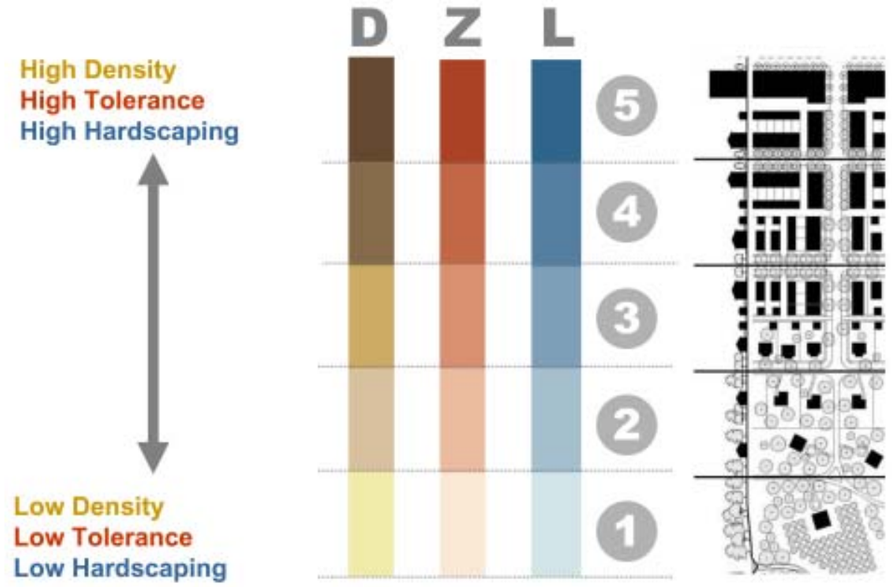
- Estimate the quantity of existing vacant land available for development within City limits by using sampling
- Create future growth scenarios to assess the potential of development of existing vacant land as an alternative to sprawl

The steps presented in this project are represented with the light grey boxes (Steps 01 to 05). The black boxes (Steps 06 to 09) represent next steps that could be undertaken, which are better explained following:

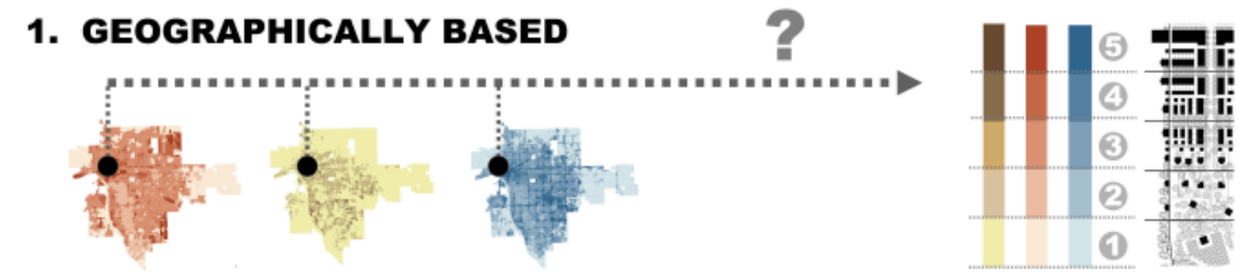
Step 05 – Calculate total areas of 5 final Categories
• Calculate total areas of 5 final categories within City Limits using GIS
Step 06 - Selection of Sample Areas:
• Select sample areas that are representative of the 5 final categories.
Step 07 - Mapping vacant land on Sample Areas:
▪ Map and calculate the current vacant land in each of the sample areas using aerial photography;
▪ Find a Rate (Sq Miles of vacant land / Sq Mile);
Step 08 – Estimate vacant land within the city limits by extrapolating Sample Areas results:
▪ Estimate availability of vacant land within the city limits by extrapolating the obtained rate (Sq Miles of vacant land / Sq Mile) as an average for the entire city. The obtained results should be applied considering the 5 Final categories.
Step 09 – Development of future scenarios:
▪ Scenarios could be developed considering different patterns of development and ranges of density that could be implemented through infill development. These scenarios could help decision makers and citizens visualize the potential of infill development of existing vacant land within city limits. Ultimately, it would be able to evaluate how infill development could be an alternative to sprawl when it comes to accommodating future urban growth.

The flowchart located at the bottom of this page was adapted from the "Land Cacacity Monitoring - Information for Plan Making and Implementation" flowchart that was presented earlier in this project, at the Research section. The flowchart presented on this page shows how the application of the method to quantify the availability of vacant land could feed into the Plan Making and Implementation flowchart (boxes highlighted in red).





Graphic that was developed to illustrate the combination of categories that is being presented. It will be used along all this section.



Graphic developed to illustrate the two different approaches used for the Combination Option: Geographically Based and Topic Based

Results

c) Combination Option

With the Combination option, the T categories are independent elements that can be combined however the user desires. The graphic located to the right of this page will be use along this section to illustrate what the combination that is being presented with the maps. It represents the scales used for Density (D), Zoning (Z) and Land Cover (L) and the notes located on the extremes of the scales show a general description of what is being represented.

The Results for the Combination option are presented based on two different approaches: Geographically Based and Topic Based. The graphic located at the bottom of the page illustrates the two different approaches.

Geographically Based:

Step 1:
- Select some areas of the city that stand out somehow when analyzing the maps or are of interest for other reasons

Step 2:
- Investigate how these areas are represented according to the T Categories

Topic Based:

Step 1:
- Select some combinations of T categories

Step 2:
- Verify where they are located in the city

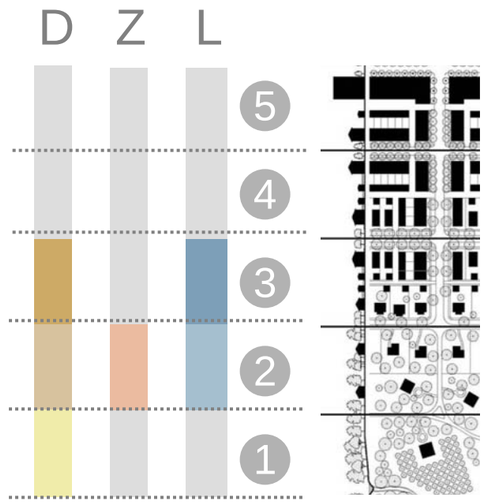
With the Geographically Based approach, the maps are the starting point and then the focus switches to the T categories, to investigate how some areas of the city can be described considering to the T Categories. With the Topic Based approach the opposite process is used: focusing first on the T Categories and then focusing on the map, to investigate where certain combinations are located in the city.

Some combinations are presented following in this order:
1) Geographically Based:
    1a) Midtown Characteristics
    1b) Downtown Characteristic
2) Topic Based
    2a) With one category for each aspect
    2b) With two categories for each aspect

The analysis of the results obtained with the Combination Option is presented in a graphic format. The text (bullet points) and diagrams located to the left of the page outlines the aspects that should be observed. In the results related to the Topic Based approach, small texts located at the bottom of the page show a current description of the areas showed on the maps (under item “Now”) and some examples of public policies that could be adopted regarding those areas (under item “Policies for the Future”).

Results

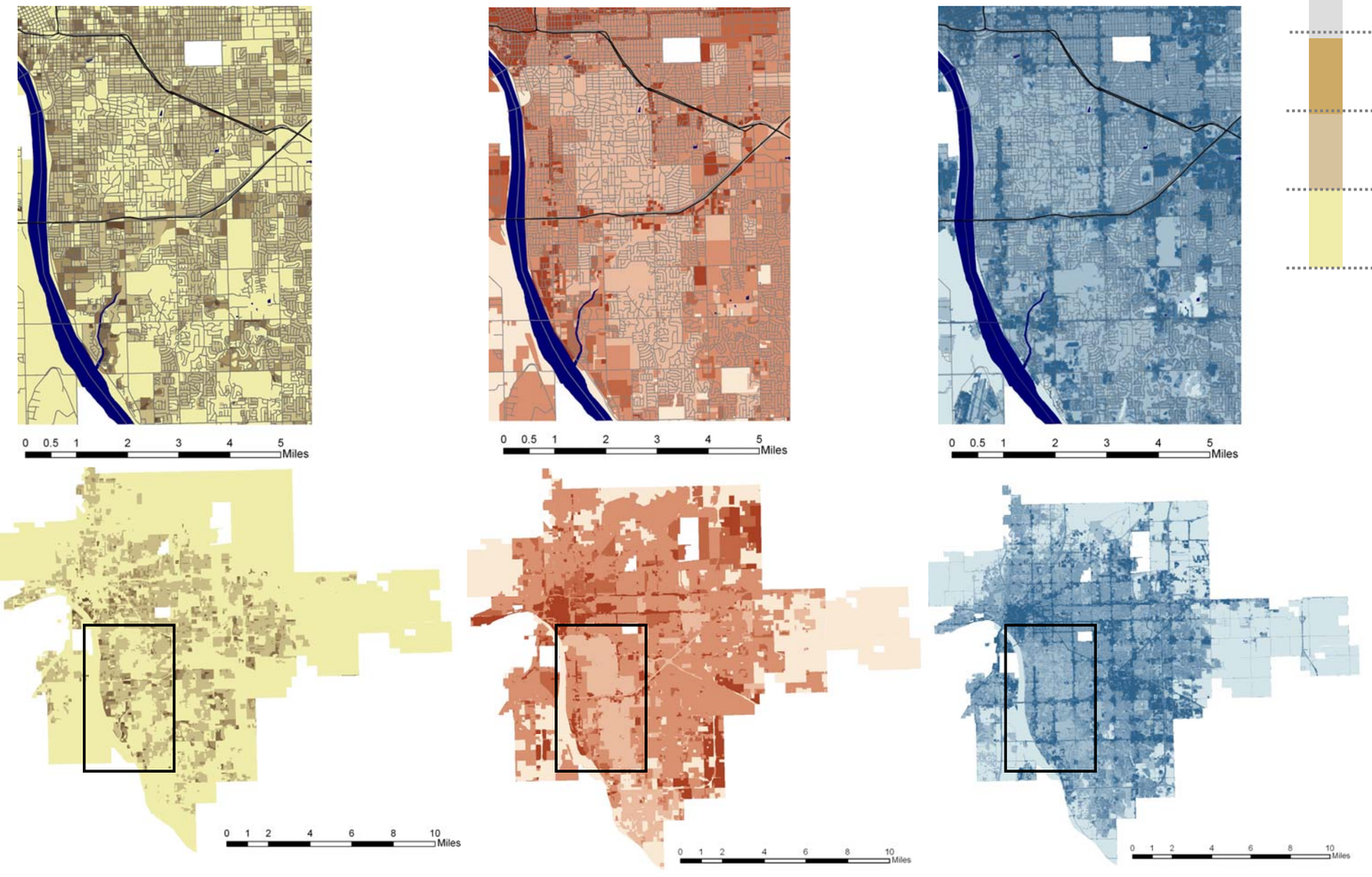
c) Combination Option



1. GEOGRAPHICALLY BASED:

1a) Midtown Characteristics

- **LOW** score for Density (mainly TD1, with scattered TD2 and TD3)
- **LOW** score for Zoning (TZ2)
- **MEDIUM** scores for Land Cover (TL2 and TL3)

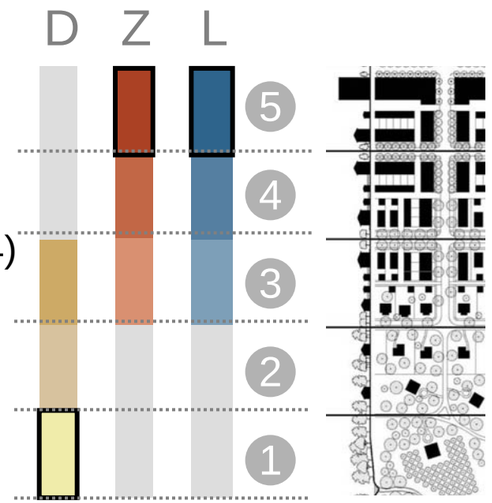


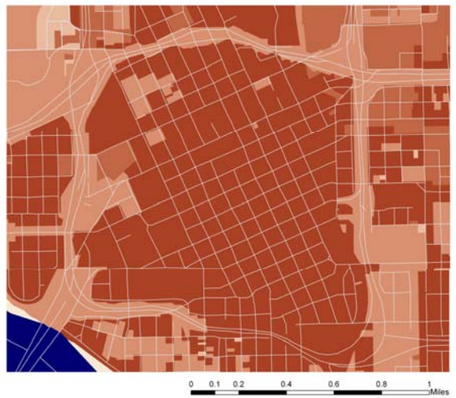
Results
c) Combination Option

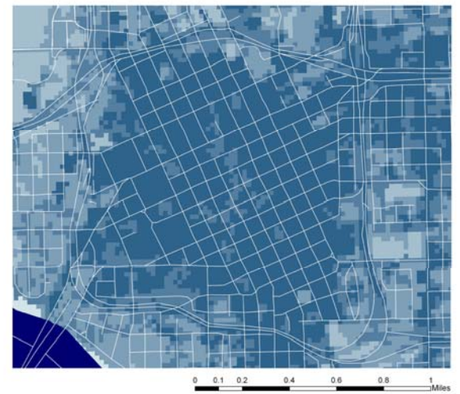
1. GEOGRAPHICALLY BASED:

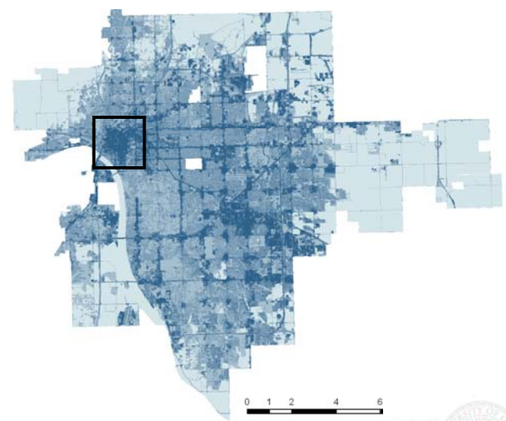
1b) Downtown Characteristics

- **LOW** score for Density
  (mainly TD1, with scattered TD2, TD3 and TD4)
- **HIGH** score for Zoning
  (mainly TZ5, with scattered TZ4 and TZ3)
- **HIGH** scores for Land Cover
  (TL5, with scattered TL4 and TL3)



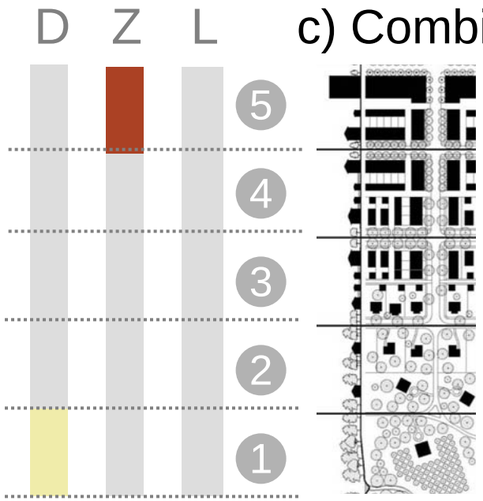






Results

c) Combination Option



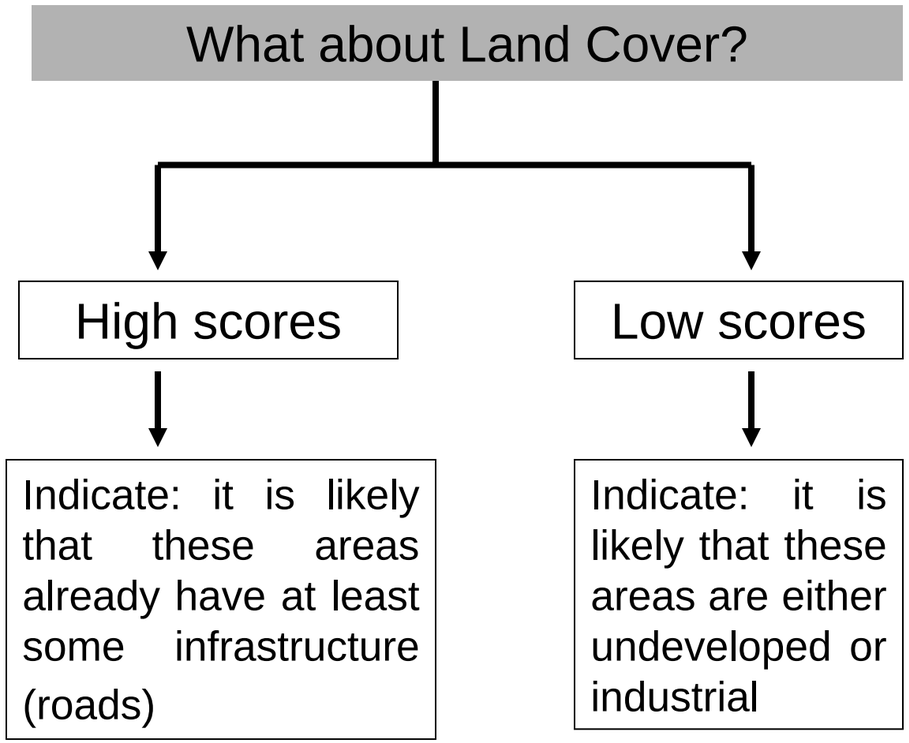
2. TOPIC BASED:

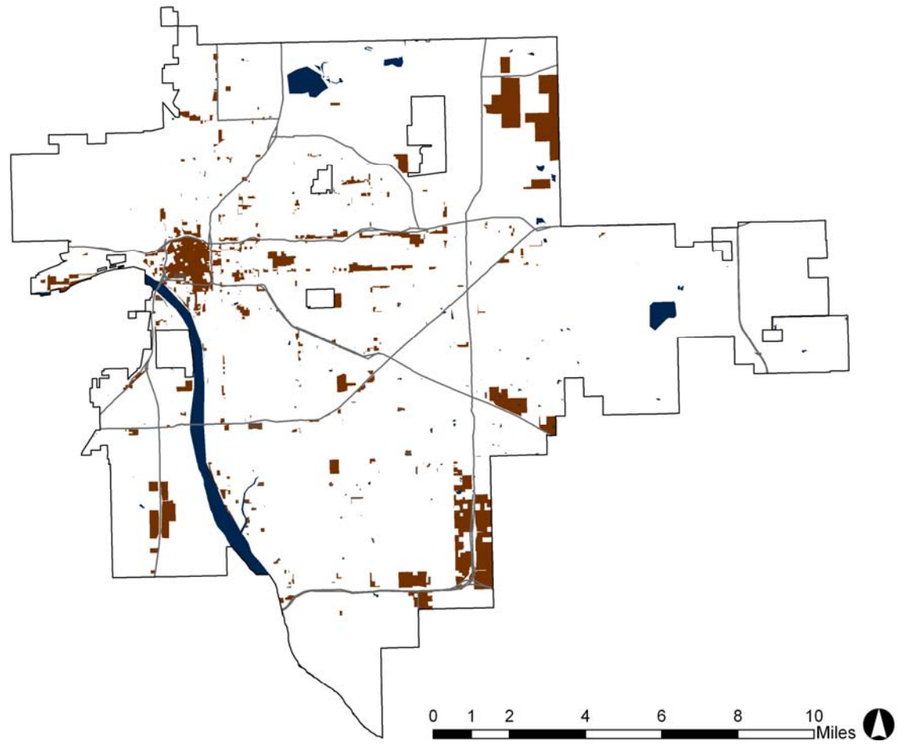
2a) With 1 category for each aspect:

LOW Scores for Density (TD1)

AND

HIGH scores for Zoning (TZ5)

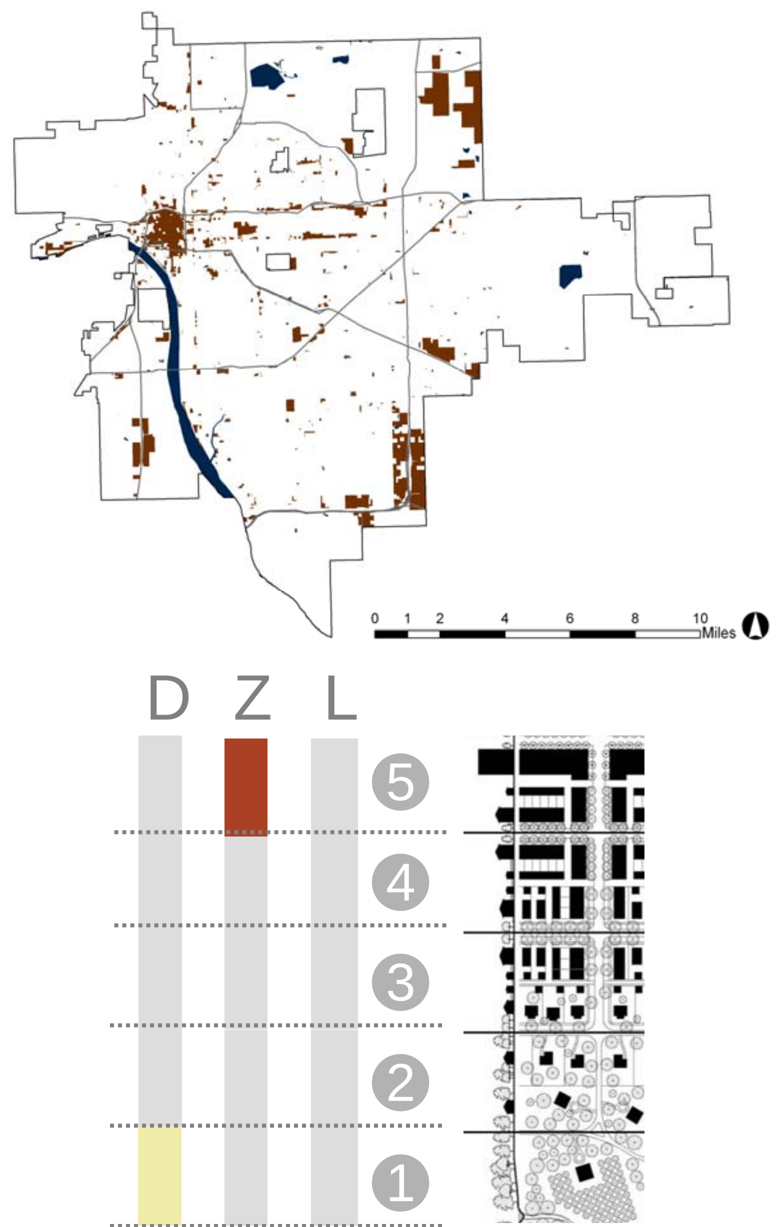


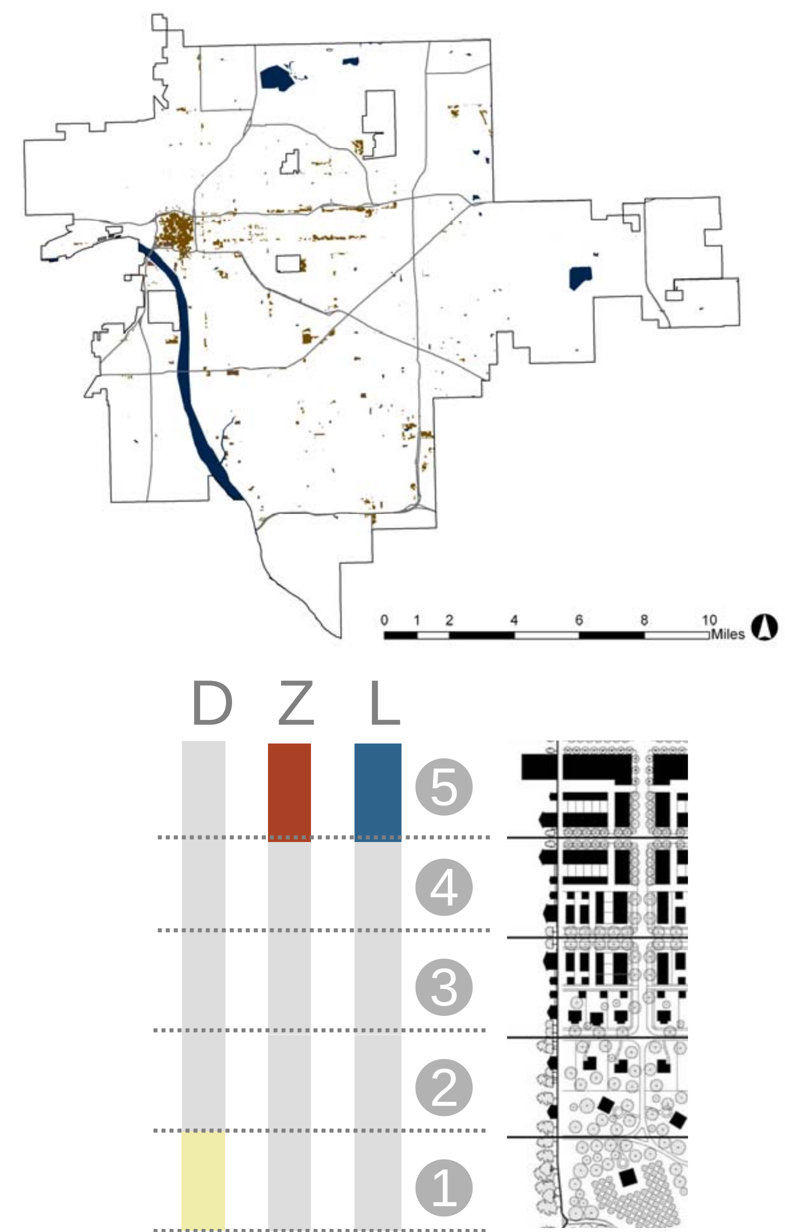


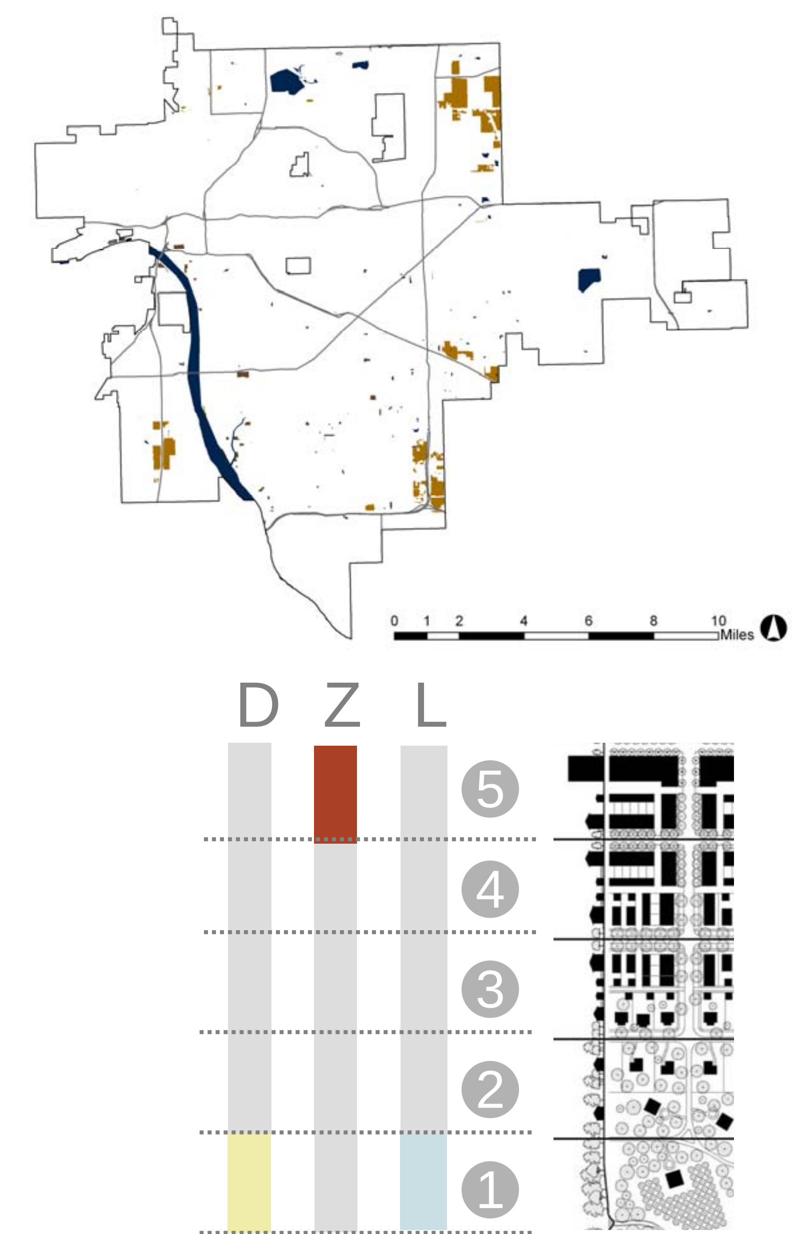
Results

c) Combination Option

2a) With 1 category for each aspect:







NOW	**Underutilized areas**	**Underutilized areas that have at least some infrastructure (roads)**	**Areas that are either undeveloped or Industrial areas**
POLICIES FOR THE FUTURE		**• Incentives for property owners who decide to develop these areas** **OR** **• Penalization for property owners who do not develop the area by a certain date**	**• For areas that are not industrial:** **Make Zoning less tolerant** **Direct development to underutilized areas that already have infrastructure (like the ones shown on the map in the middle of this graphic)**

Results

c) Combination Option

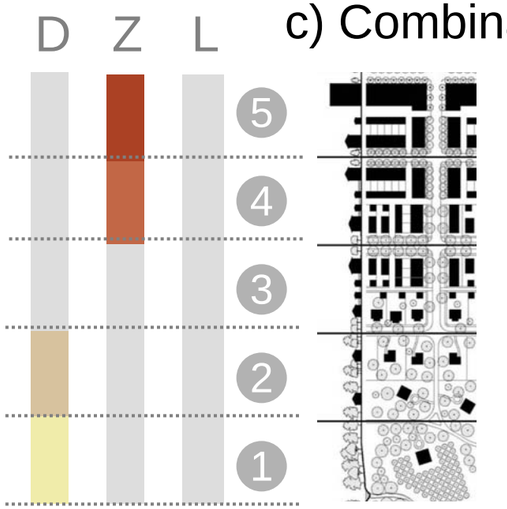
2. TOPIC BASED:

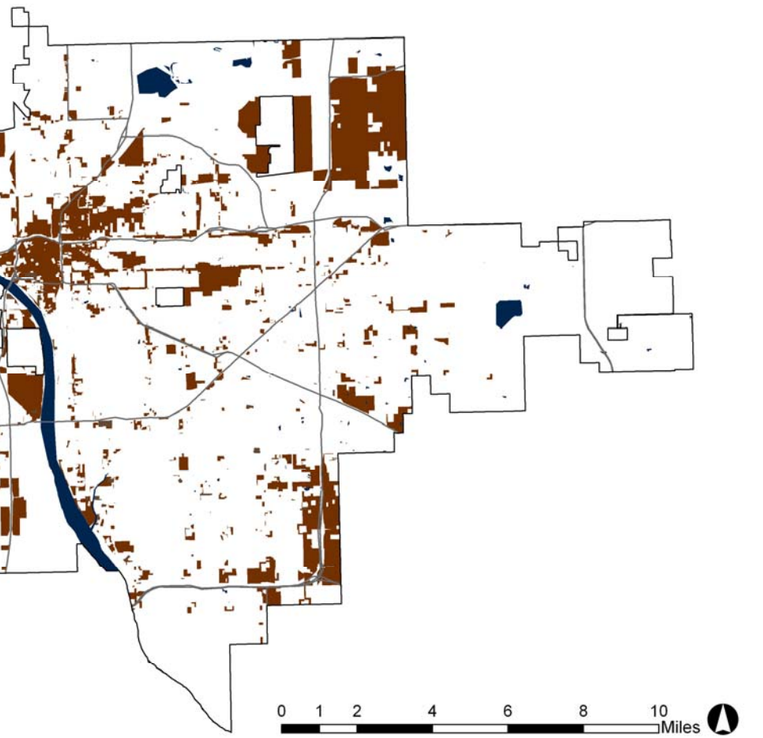
2b) With 2 categories for each aspect:

LOW Scores for Density (TD1 U TD2)

AND

HIGH scores for Zoning (TZ4 U TZ5)





What about Land Cover?

High scores

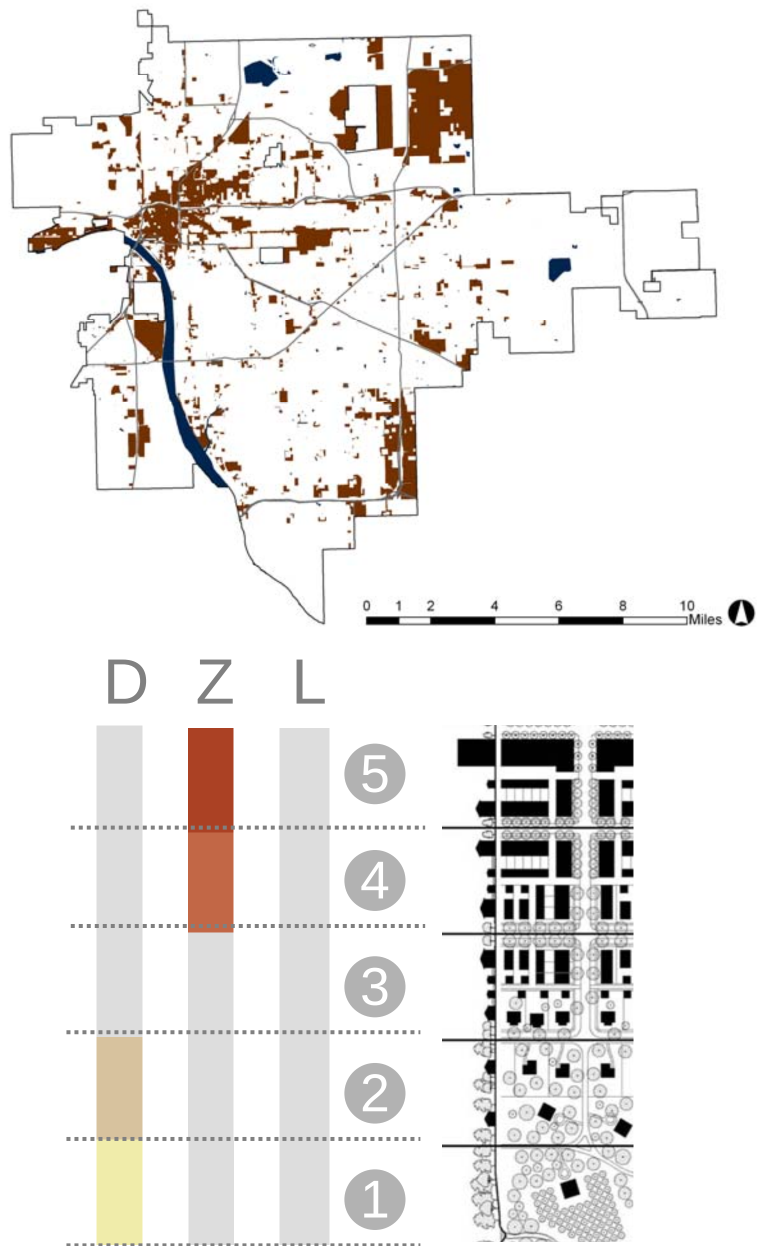
Indicate: it is likely that these areas already have at least some infrastructure (roads)

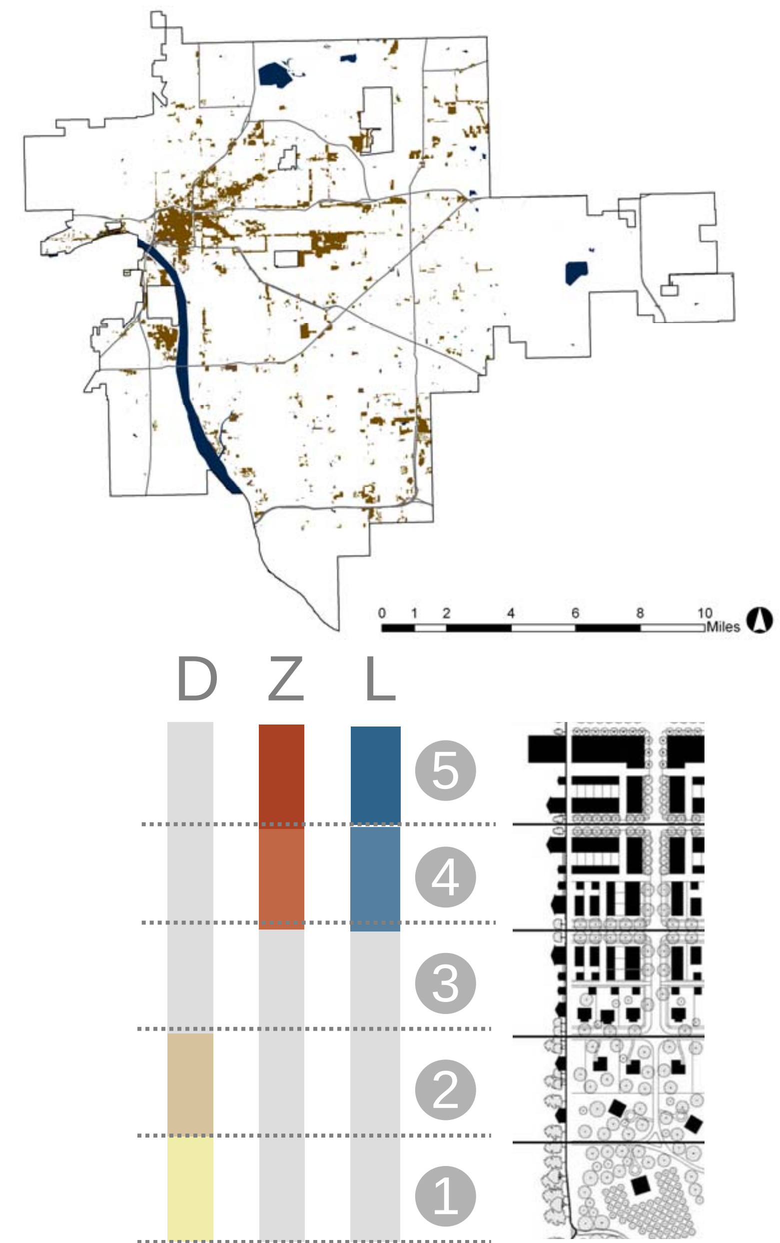
Low scores

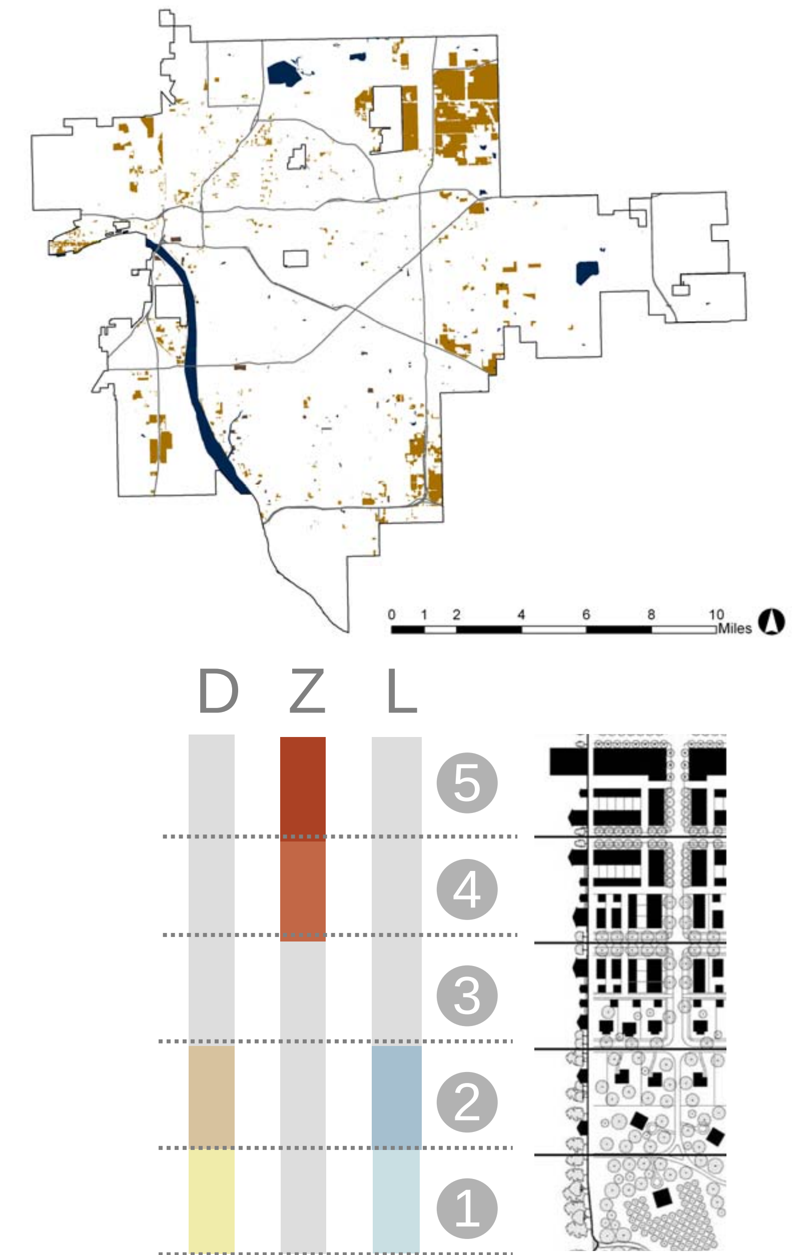
Indicate: it is likely that these areas are either undeveloped or industrial

2b) With 2 categories for each aspect:

c) Combination Option







NOW	**Underutilized areas** ***(BROADER SPECTRUM)***	**Underutilized areas that have at least some infrastructure (roads)**	**Areas that are either undeveloped or Industrial areas**
POLICIES FOR THE FUTURE		**• Incentives for property owners who decide to develop these areas** **OR** **• Penalization for property owners who do not develop the area by a certain date**	**• For areas that are not industrial:** **- Make Zoning less tolerant** **- Direct development to underutilized areas that already have infrastructure (like the ones shown on the map in the middle of this page)**

Results

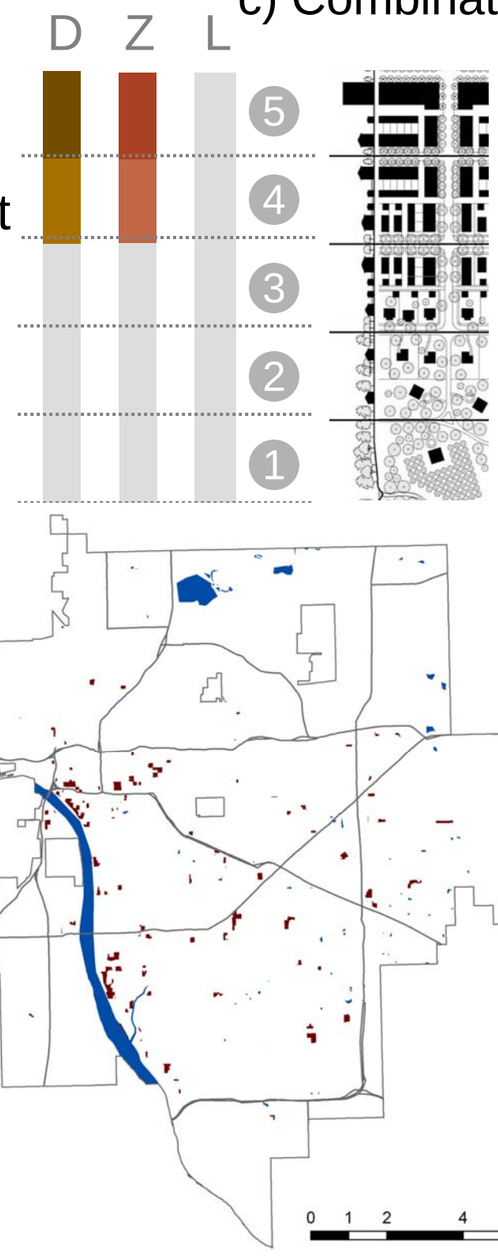
c) Combination Option

2. TOPIC BASED:

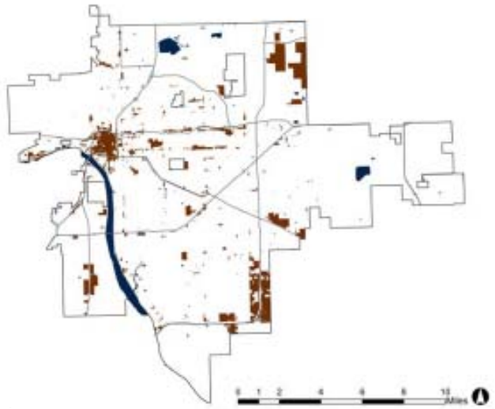
2c) Areas zoned for intense development and occupied by high density development

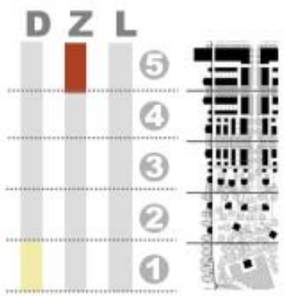
Areas that present:

- **HIGH** scores for Density (TD4 U TD5)
  AND
- **HIGH** scores for Zoning (TZ4 U TZ5)



1

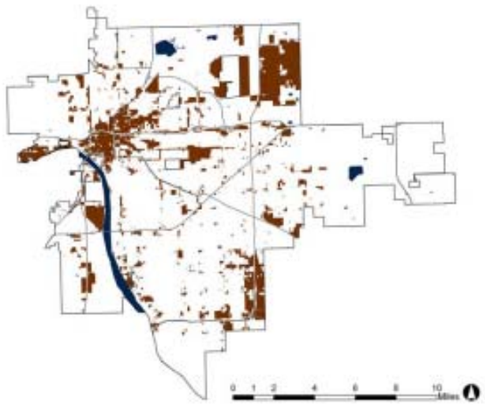


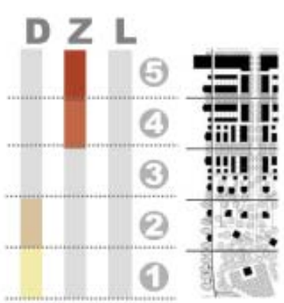


Examples of areas that are underutilized in Tulsa, considering:

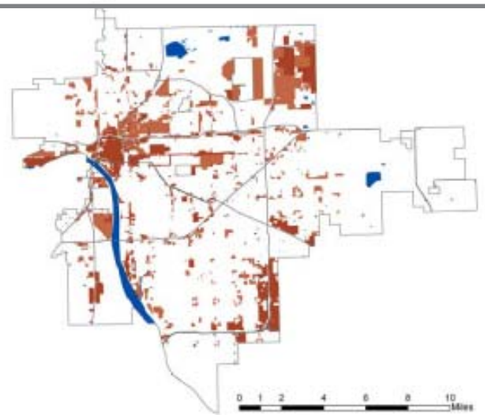
• One category for each aspect (to the left):
TD1 and TZ1

• Two categories for each aspect (to the right):
(TD1 U TD2) and (TZ4 U TZ5)

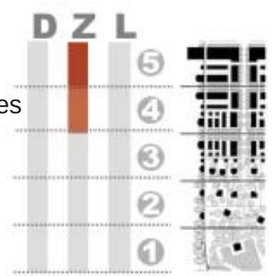


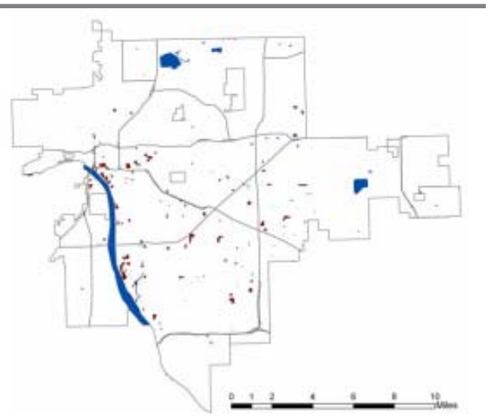


2

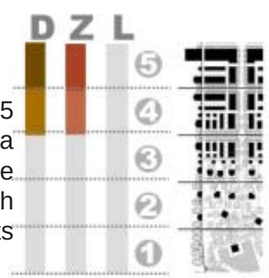


TZ4 and TZ5 categories within Tulsa City Limits





TZ4 and TZ5 categories within Tulsa City Limits that are occupied by high density developments (TD4 and TD5).



Conclusions

The Conclusions of this project are presented as following:

• About Tulsa City Limits being built out, as many people believe
• About areas that are zoned for high intensity development in Tulsa
• About Tulsa's density
• About the numbers presented by the Smart Code

1. About Tulsa City Limits being built out, as many people believe:

The area within Tulsa City Limits is not built out. There are many areas that are either:

- Vacant
- Under-utilized (developed in a very low density pattern, many times below zoning allowances)

The maps located at the top of this page show results presented previously in this report. They show areas that are developed below what is allowed by zoning. They are zoned for high intensity development (TZ4, TZ5) but are actually occupied by low density developments (TD1, TD2).

The difference between the two maps is that one of them considers just one category for each aspect and the other one considers two categories for each aspect (see graphics below maps and section Results / Combination Option for details).

2. About areas that are zoned for high intensity development in Tulsa:

Even though there are areas that are zoned for high intensity developments (TZ4 and TZ5), very few are actually occupied by high density developments. Many areas in Tulsa are developed below the maximum capacity allowed by zoning . See maps located at the bottom of this page.

3. About Tulsa's density:

One of the graphs located at the research section of this report shows that American citieshave low density in comparison to other cities in the world (See section Research / Sprawl in America, p. 2). The Density scales presented in n the section Methodology (p. 17) show that Tulsa has low density not only if compared to other cities in the world, but also in comparison with other American cities. Thus, we can conclude that Tulsa's density is very low.

VARIABLES	Zone	Smart Code	Used in this project (for Tulsa)	Name of Category in this project	Difference (%) *(See Note 1)*	Score used in this project
DENSITY						
Base Residential Density (By Right)	T1	0.01	2	TD1	20000.0%	1
Unit: units per acre - max.	T2	0.05	2	TD1	4000.0%	1
	T3	2	5	TD2	250.0%	2
	T4	4	10	TD3	250.0%	3
	T5	6	20	TD4	333.3%	4
	T6	12	higher than 20	TD5	175.0%	5
ZONING						
Lot Occupation	T1	Not availabe	NA	NA	NA	1
(Lot Coverage, max.)	T2	Not availabe	NA	NA	NA	1
	T3	0.6	NA	NA	NA	2
	T4	0.7	NA	NA	NA	3
	T5	0.8	NA	NA	NA	4
	T6	0.9	NA	NA	NA	5
Building Height (Principal Building)	T1	Not availabe	NA	NA	NA	1
Unit: stories, max.	T2	3	NA	NA	NA	1
	T3	Not availabe	NA	NA	NA	2
	T4	4	NA	NA	NA	3
	T5	6	NA	NA	NA	4
	T6	12	NA	NA	NA	5
FAR (max.) *(See Note 2)*	T1	NA	0.3	TZ1	NA	1
	T2	NA	0.3	TZ1	NA	1
	T3	NA	0.5	TZ2	NA	2
	T4	2.8	2	TZ3	71.4%	3
	T5	4.8	8	TZ4	166.7%	4
	T6	10.8	higher than 8	TZ5	287.0%	5
LA/DU (min. SF)	T1	Not availabe	26,250 *(see note 3)*	TZ1	NA	1
	T2	Not availabe	26,250 *(see note 3)*	TZ1	NA	1
	T3	Not availabe	26,250	TZ2	NA	2
	T4	Not availabe	10,875	TZ3	NA	3
	T5	Not availabe	4,200	TZ4	NA	4
	T6	Not availabe	lower than 2,200	TZ5	NA	5
LAND COVER DATA						
% of Land Coverage	T1	Not availabe	less than 20%	TL1	NA	1
(impervious surfaces)	T2	Not availabe	less than 20%	TL1	NA	1
	T3	Not availabe	20%	TL2	NA	2
	T4	Not availabe	49%	TL3	NA	3
	T5	Not availabe	80%	TL4	NA	4
	T6	Not availabe	100%	TL5	NA	5

Table comparing the numbers presented by the Smart Code and the numbersused in this project to establish scales (See Methodology / Scales for details).

LEGEND:
Text **Variables used in this project**

Notes:
1) Difference = (Used in this project - for Tulsa) DIVIDED BY (Smart Code), represented in percentage;
2) Floor Area Ratio = (Lot Occupation) MULTIPLIED BY (Building Height, Max.)
3) and also areas zoned as Agricultural (see Methodology / Scales for Details)

Conclusions

4. About the numbers presented by the Smart Code:

The Table to the left shows a comparison between the numbers used to establish the scales used in this project and the ones presented by the Smart Code table (See Note A). Unless noted, the following comments are based on the analysis of this table.

Density:

Based on the aspects discussed in the previous item we concluded that Tulsa has very low density and because of that the TUL density scale was developed specifically for Tulsa in this project. Based on that it is possible to conclude that the numbers used in this report regarding density are low (see comparison between Scales 1, 2 and TUL presented previously for details).

By comparing the Smart Code numbers and the numbers used in this project regarding density (see Table), it is possible to notice that the Smart Code numbers are much lower than the ones used in this report. In other words: the numbers used in this report are low, but the ones presented by the Smart Code table are even lower. Even though it is important to consider that it is noted that all the numbers presented by the Smart Code Table should be calibrated for local context, it is important to highlight that they are very low when observed in the context of American cities in general.

Zoning:

The criteria used in this project to categorize Zoning in the T Categories was: Floor Area Ratio, Land Area per Dwelling Unit and Description of Industrial Categories (see Methodology / Scales for details). Among these criteria, the only one that can be compared to the ones presented by the Smart Code is Floor Area Ratio. However, the Smart Code Table does not present Floor Area Ratio, but it presents two other aspects (Lot Occupation and Building Height) that, if multiplied, result in Floor Area Ratio (See Note B).

By comparing the numbers regarding Floor Area Ratio, it is noted that the numbers presented by the Smart Code are lower than the ones used in this project for categories T5 and T6 and are higher for category T3. However, the difference between the Smart Code numbers and the numbers used in this project is not as significant as the difference noticed regarding Density.

Land Cover:

The Smart Code table does not present any data regarding Land Cover Data, thus it is not possible to establish a comparison with the numbers used in this project regarding this aspect.

Notes: A) Even though it is noted on the Smart Code table that the numbers should be calibrated for local context, they will be used just as a reference in this part of this report). B) It was not possible to compare categories T1, T2 and T3 because there was no number for Building Height for those categories, which makes the multiplication process to get to Floor Area Ratio not possible.

Recommendations

1. General Recommendations:

1.1. Overlay Option:

The Overlay option provides a description of the city that is not limited to one aspect, but that incorporates several variables that help to describe the urban environment.

In this project we used three variables (Density, Zoning and Land Cover Data), but other variables could also be incorporated into the method. It is important to highlight that the variables to be added are closely related to what kind of analysis the user desires to make, and this should be considered when thinking about adding more variables to the method. This topic is discussed with more details in another section of the Recommendations. It is also important to mention that in this project the Overlay Option was applied using equal weights for the three components of the core. Depending on what kind of analysis the user wants to do, different weights could be assigned to the variables when doing the overlay.

This report shows one possible application of the Overlay option of the method, which is estimate vacant land within city limits that is available for development. However, since the overlay option of the method has the capability to provide a fairly good description of the urban environment, other applications of that could be explored in future studies.

1.2. Combination Option:

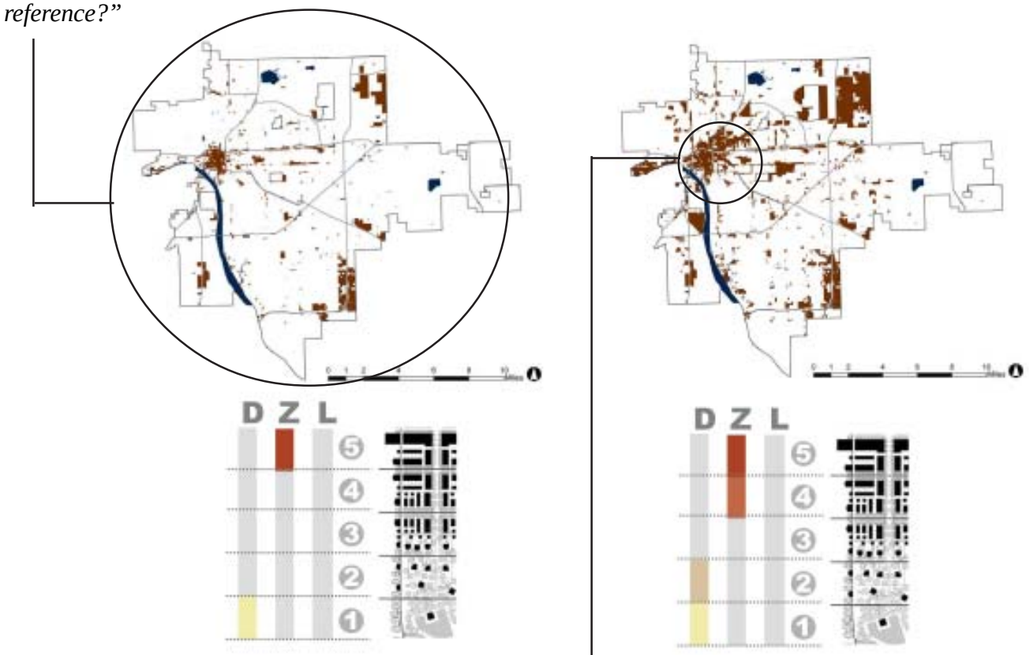
Since the method is flexible enough to allow for many possibilities, it is recommended that the user should think about what kind of result is wanted before starting to apply the procedures. In other words, the user should take a moment to think about what it is wanted from that analysis for before starting making combinations. This will help the user to define which options provided by the method best suits his goals and may also avoid getting lost with the several possibilities allowed by the method.

It is also recommended that the user thinks about how broad the spectrum should be, which relates to how many categories you should use in the combination. Another important thing that should be considered is the number of categories the user wants to include in the analysis. This is closely related to how broad you want your spectrum to be: the more categories you incorporate in your analysis, the broader the considered spectrum is. It is important to highlight that the combinations to be made should always be guided by what you want to get from that analysis. There is no right or wrong answer for this. The adequate answer to that question has to be determined by the purpose of your analysis. (See *Results / Combination Option / Topic Based* section for examples of analysis done considering different spectrums).

2. The method could also be used to create scenarios of future development:

Everything that is being shown in this report relates to the use of the method to describe cities as they are currently. However, the method could also be used to assist on the development of scenarios of future development. The results presented could be considered as the first step that could guide the second, which would be the development of scenarios that would reflect what is envisioned for the city being studied. This resport presents one example of a quantitative scenario that could be done using the method presented here, which relates to availability of vacant land (see Results/ Overlay for details). Besides that, the Combination Option could be also used to developd scenarios of future development that could help answer questions related to the whole city or to specific areas, such as:

• *"How many people could we acommodate within City Limits if we developed these areas as residential having this given specific pattern of development as a reference? And what if we had this other pattern of development as a reference?"*



• *"How many people could we acommodate in Downtown if 50% of these areas was developed as residential with this specific pattern of development? And what if we developed 70% `of these areas with this other pattern of development?"*

Recommendations

3. Applying the method to other American cities:

The method presented in this project could be also applied to other American cities. To do so, some procedures should be followed. This section of this report is dedicated to outline some recommendations to guide the application of this method to other cities.

The approach used in this project could be reproduced in other contexts to apply the method to other cities, it is important to highlight that the scales used in this project were developed to be applied specifically to Tulsa-OK. The Density and Zoning scales are not universal and should be calibrated for local context. The method is flexible and should be used in accordance to what kind of analysis the user wants to obtain.

Precision of the data:

The precision of the data should always be considered when analyzing the results of the application of the mehtod. Precision is closely related to the pixel size of the maps that are being generated. As previously mentioned in this report, the precision of the data presented here is 150 feet by 150 feet (se Methodology for details). and that is becaus that is the precision of the Land Cover Data

Density – Scale:

Density is the most specific criteria among the three components of the core of the method. It varies to a great extent from one city to another and this should be carefully considered when applying the method to other American cities. The numbers of the density scales will have to be carefully calibrated for local context. It is recommended that the same procedure used in this project should be adopted when defining the density scale. This procedure consist basically of: A) apply Scales 1 and 2 to the case study, B) evaluate how well these scales fit the local context, C) if necessary, develop a scale that best fits the local context, based in the results obtained from item B and use it to apply the method (like it was done in this project for Tulsa, OK).

Zoning – Scale:

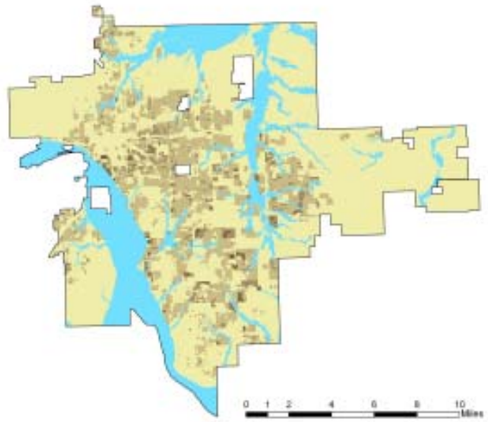
Zoning Ordinances vary from one city to another, but there are some aspects that make them similar in some ways. For example, it is not uncommon to find Zoning Ordinances that use Floor Area Ratio and Land Area per Dwelling Units and description of industrial categories as parameters. Since these are the parameters adopted in this project, the same approach could be used to apply the method to other cities. However, the numbers of the scales will have to be calibrated for local context.

Land Cover – Scale:

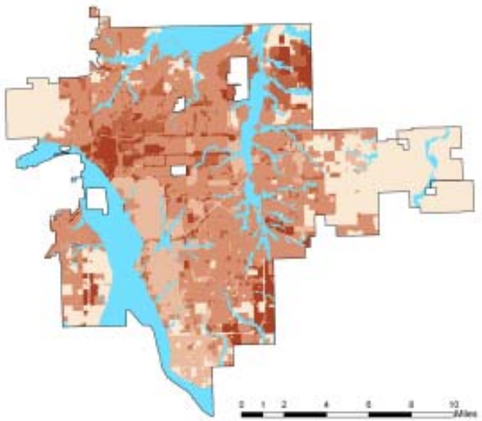
The Land Cover scale is the most universal scale of the ones presented in this project. The scale was based on USGS data and categories and since this does not vary within the US, the same scale could be used to apply the method to other American cities. However, this does not mean this scale could not be changed to best suit the goals of the user if that is necessary (see *General Recommendations* about thinking about the results the user wants to obtain before starting to apply the method). As mentioned previously in this report, the precision of the Land Cover data is given by the size of each pixel, which is 150 feet by 150 feet in this case. The precision of the Land Cover data should be considered should be considered when dealing with the data.

Comparing results obtained with the application of the method to different cities:

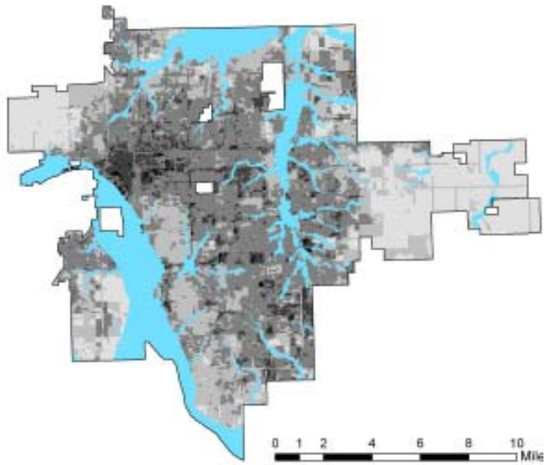
The method could also be applied to several cities and the results could be compared. This will probably lead to some interesting results and conclusions. It is important to highlight that to compare the results of different cities, the user should make sure the same scales are being used for all the cities being studied. Thus, the user should be specially careful when developing the scales that will be used to compare results of the application of the method to different cities. It is important to make sure that the scales for all aspects will work well in all cities being studied.



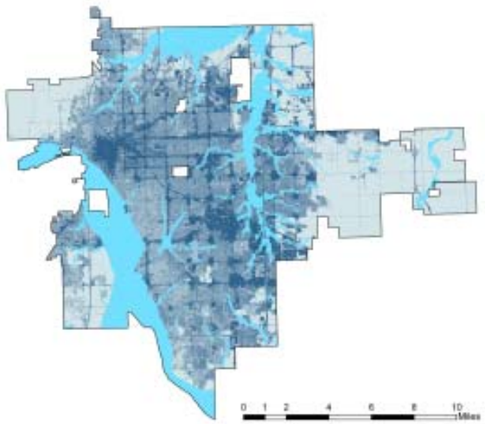
TD Categories with FEMA Floodplains



TZ Categories with FEMA Floodplains



OV Categories with FEMA Floodplains



TL Categories with FEMA Floodplains

Recommendations (cont.)

Other variables that could be incorporated into the method:

Data that could be overlaid on the results of the method:

The method could incorporate other variables besides the three ones presented in this project. Depending on what the user wants to obtain, other variables could be added to the method and a similar procedure to establish the T Categories could de adopted for those. Following some examples of variables that could be incorporated to the method are presented:

- Soil types
- Assessed Values of land (Value of Land and Value of Improvements)
- Occupancy Rates
- Availability of infrastructure (water lines, sewage, etc.)
- Availability of public transportation

Not a priority for Development (subtract):

There are some data that should be subtracted from the results of the method when moving to a more advanced phase of the application of the method. For example, if the results of the method were to be used to define underutilized areas that should be considered as priorities for development, some data should be subtracted from the results. The following list shows some examples of those:

- Floodplains *(Obs: just for ilustration purposes, the maps to the left show the FEMA Floodplains overlaid on the maps containing TD, TZ, TL and OV categories in Tulsa)*
- High sloped areas
- Areas that present valuable soil for agriculture
- Areas located close to airports, in areas whose development has to meet some requirements so it does not interfere with the flight path.
- Areas that present collapsible soils or other kinds of soils that are not adequate for urban development

Priority for Development:

On the other hand, other kinds of data could be overlaid to the results of the method to highlight areas that should be considered as priorities for development. Examples of those are:

- Brown fields
- Areas with infrastructure (water lines, sewer, etc.)
- Areas with public transportation

These are just some examples of data that could be added to the method when using its results for more detailed analysis. The lists presented here are not extensive. The intent of this section is just to outline some possibilities that could be undertaken from this point on. It is not the intent of this section to cover all possible approaches that could be developed from this point on. In fact, there would be no point on doing that since, as pointed out before, the aspects that could be incorporated to the method are closely related to what the user wants to obtain. Thus, we encourage the users to think about things that could be incorporated to best suits their goals.

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1. Introduction and Goals

2. Research

3. Methodology

4. Results
    - Core
    - Overlay Option
    - Combination Option

5. Conclusions

6. Recommendations

7. Bibliography

8. Appendices

Appendix 01
Description of Land Cover Categories

NLCD 2001 Land Cover Class Definitions

Source: http://www.mrlc.gov/nlcd_definitions.asp

11. Open Water - All areas of open water, generally with less than 25% cover of vegetation or soil.

12. Perennial Ice/Snow - All areas characterized by a perennial cover of ice and/or snow, generally greater than 25% of total cover.

21. Developed, Open Space - Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes

22. Developed, Low Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.

23. Developed, Medium Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units.

24. Developed, High Intensity - Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to100 percent of the total cover.

31. Barren Land (Rock/Sand/Clay) - Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.

32. Unconsolidated Shore* - Unconsolidated material such as silt, sand, or gravel that is subject to inundation and redistribution due to the action of water. Characterized by substrates lacking vegetation except for pioneering plants that become established during brief periods when growing conditions are favorable. Erosion and deposition by waves and currents produce a number of landforms representing this class.

41. Deciduous Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.

42. Evergreen Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.

43. Mixed Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.

51. Dwarf Scrub - Alaska only areas dominated by shrubs less than 20 centimeters tall with shrub canopy typically greater than 20% of total vegetation. This type is often co-associated with grasses, sedges, herbs, and non-vascular vegetation.

52. Shrub/Scrub - Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.and form a continuous cover principally on or at the surface of the water. These include algal mats, detached floating mats, and rooted vascular plant assemblages.

71. Grassland/Herbaceous - Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

72. Sedge/Herbaceous - Alaska only areas dominated by sedges and forbs, generally greater than 80% of total vegetation. This type can occur with significant other grasses or other grass like plants, and includes sedge tundra, and sedge tussock tundra.

73. Lichens - Alaska only areas dominated by fruticose or foliose lichens generally greater than 80% of total vegetation.

74. Moss - Alaska only areas dominated by mosses, generally greater than 80% of total vegetation.

81. Pasture/Hay - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.

82. Cultivated Crops - Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.

90. Woody Wetlands - Areas where forest or shrubland vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

91. Palustrine Forested Wetland* -Includes all tidal and non-tidal wetlands dominated by woody vegetation greater than or equal to 5 meters in height and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Total vegetation coverage is greater than 20 percent.

92. Palustrine Scrub/Shrub Wetland* - Includes all tidal and non-tidal wetlands dominated by woody vegetation less than 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Total vegetation coverage is greater than 20 percent. The species present could be true shrubs, young trees and shrubs or trees that are small or stunted due to environmental conditions.

93. Estuarine Forested Wetland* - Includes all tidal wetlands dominated by woody vegetation greater than or equal to 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent. Total vegetation coverage is greater than 20 percent.

94. Estuarine Scrub/Shrub Wetland* - Includes all tidal wetlands dominated by woody vegetation less than 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent. Total vegetation coverage is greater than 20 percent.

95. Emergent Herbaceous Wetlands - Areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

96. Palustrine Emergent Wetland (Persistent)* - Includes all tidal and non-tidal wetlands dominated by persistent emergent vascular plants, emergent mosses or lichens, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Plants generally remain standing until the next growing season.

97. Estuarine Emergent Wetland* - Includes all tidal wetlands dominated by erect, rooted, herbaceous hydrophytes (excluding mosses and lichens) and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent and that are present for most of the growing season in most years. Perennial plants usually dominate these wetlands.

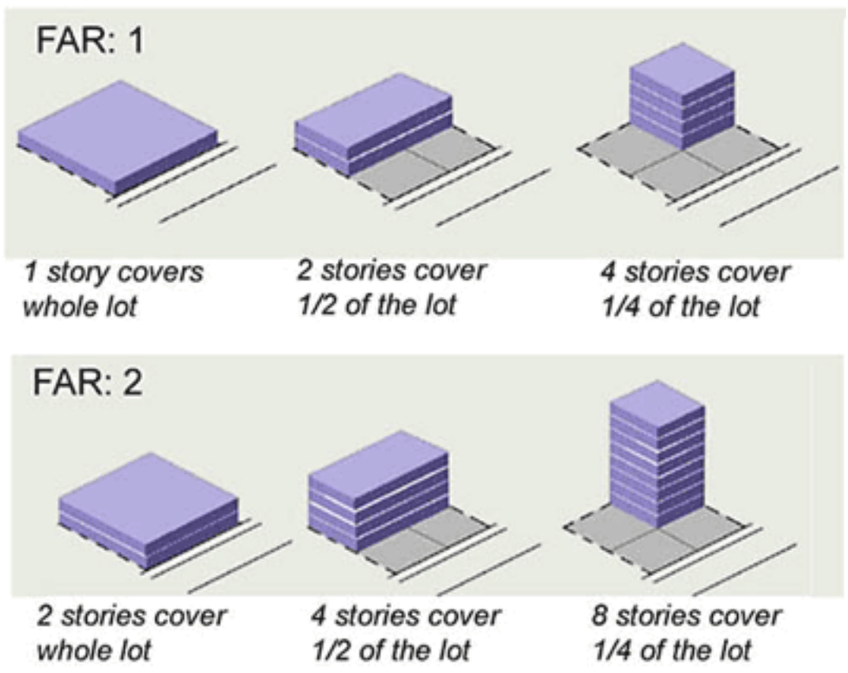
98. Palustrine Aquatic Bed* - The Palustrine Aquatic Bed class includes tidal and nontidal wetlands and deepwater habitats in which salinity due to ocean-derived salts is below 0.5 percent and which are dominated by plants that grow and form a continuous cover principally on or at the surface of the water. These include algal mats, detached floating mats, and rooted vascular plant assemblages.

99. Estuarine Aquatic Bed* - Includes tidal wetlands and deepwater habitats in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent and which are dominated by plants that grow and form a continuous cover principally on or at the surface of the water. These include algal mats, kelp beds, and rooted vascular plant assemblages.

Appendix 02
Floor Area Ratio and Land Area per Dwelling Units Schemes

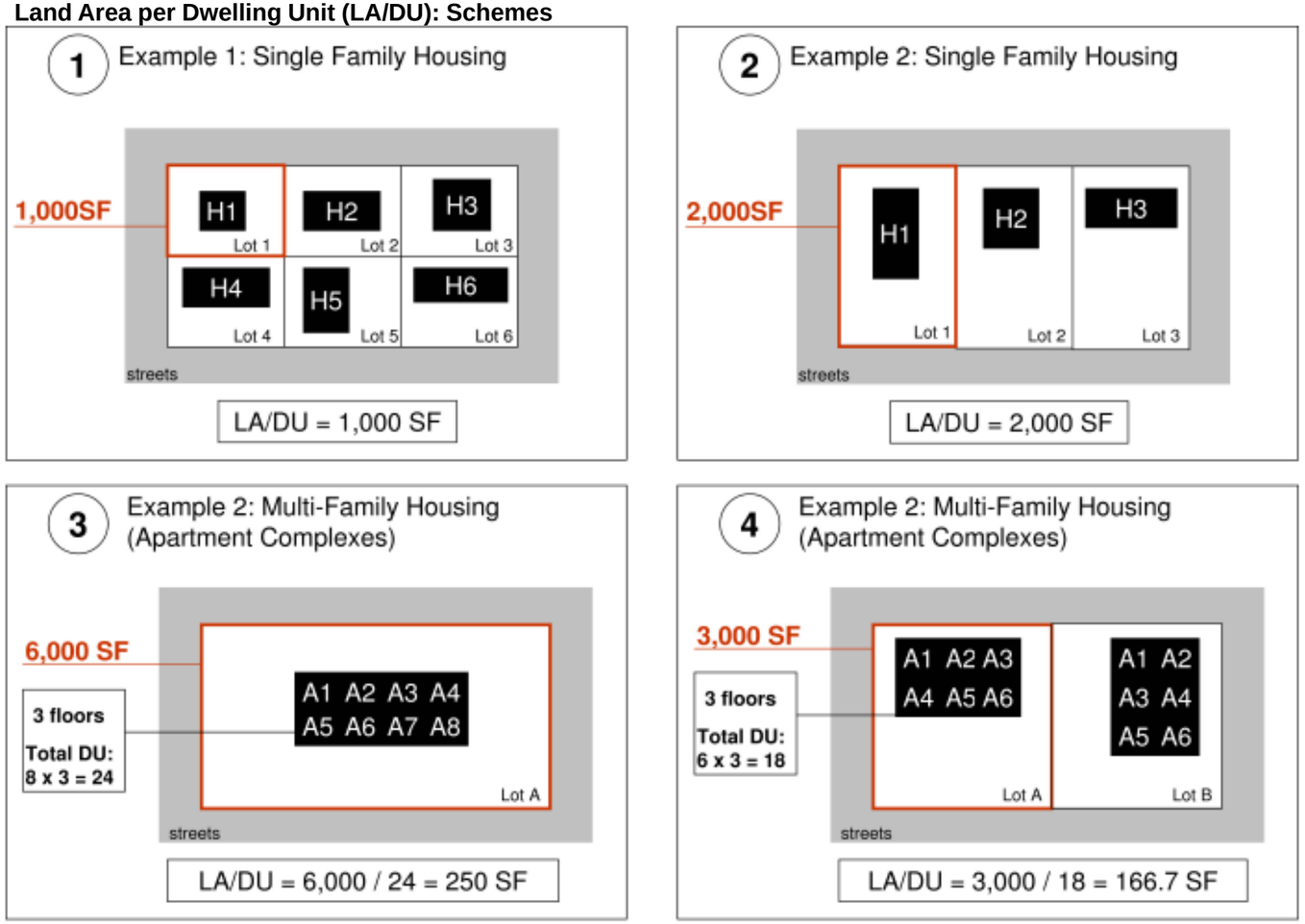
Floor Area Ratio (F.A.R.): Definition and Schemes

A density measure expressing the ratio between a building's total floor area and its site coverage. To calculate F.A.R., the gross square footage of a building is divided by the total area of its lot. F.A.R. conveys a sense of the bulk or mass of a structure, and is useful in measuring non-residential and mixed-use density.



Floor Area Ratio - Scheme and Text:
Source: http://www.lincolninst.edu/subcenters/VD/glossary.aspx#amenity

Land Area per Dwelling Unit (LA/DU): Schemes



Scheme created to explain and ilustrate Land Area per Dwelling Unit.

Appendix 03
Selected Definitions of US Census Terms

Source: Decenial Census Terms.

Available at: http://www.census.gov/dmd/www/glossary.html

Date of Research: 04/01/2008

Housing Unit (HU):

A single-family house, townhouse, mobile home or trailer, apartment, group of rooms, or single room that is occupied as a separate living quarters or, if vacant, is intended for occupancy as a separate living quarters. See separate living quarters.

Separate Living Quarters:
Living quarters in which one or more occupants live separately from any other individual(s) in the building and have direct access to the living quarters without going through another living quarters, such as from outside the building or through a common hall. For vacant units, the criteria of separateness and direct access are applied to the intended occupants.

Shelter for children who are runaways, neglected, or without housing:
Includes shelters and group homes that provide temporary sleeping facilities for juveniles. See emergency shelter; hotels, motels, and other facilities; regularly scheduled mobile food van; soup kitchen; and transitional shelter.

Shelter/Street Night (S-Night):
This operation was not used for Census 2000. It was a national operation during the 1990 census to count the homeless and others not covered by usual census procedures. The operation had a shelter phase and a street phase. See service-based enumeration and Transient Night Enumeration.

Transient location:
Living quarters for people who have no usual home elsewhere. They were enumerated during Transient Night Enumeration. Examples include YMCAs, YWCAs, campgrounds at racetracks, recreational vehicle campgrounds and parks, commercial and public campgrounds, fairs and carnivals, and marinas.

Transient Night (T-Night):
A type of group quarters enumeration in which special procedures are used to count people at transient locations, such as campgrounds at racetracks, recreational vehicle campgrounds and parks, commercial and public campgrounds, fairs and carnivals, and marinas. Enumerators conduct a personal interview using a (Simplified) Enumerator Questionnaire.

Transitional Shelter:
A shelter providing a maximum stay for clients of up to two years and offering support services to promote self-sufficiency and to help clients obtain permanent housing. See emergency shelter; hotels, motels, and other facilities; regularly scheduled mobile food van; shelter for children who are runaways, neglected, or without housing; and soup kitchen.

Appendix 04

Schedule

General | Core of the method | Overlay option | Combination option | Reviews

	Ago 07		Sep-07				Oct-07				Nov-07				Dez-07		Feb-08				Mar-08				Apr-08			
WEEKS	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	1	2	3	4	1	2	3	4	1	2	3	4
Research / Literature Review																												
Develop Criteria to establish categories T1, T2, T3, T4 and T5 for Density, Zoning and Land Cover (15 total)																												
Map Categories T1, T2, T3, T4 and T5 for Density, Zoning and Land Cover (15 total)																												
Calculate Areas of Categories T1, T2, T3, T4 and T5 for Density, Zoning and Land Cover (15 total)																												
Overlay “T Categories”, establish “OV Categories” and calculate areas																												
Outline possible applications of the method (Overlaying option)																												
Combine “T Categories”																												
Outline possible applications of the method (Combination option)																												
Conclusions / Recommendations																												
Book Making																												