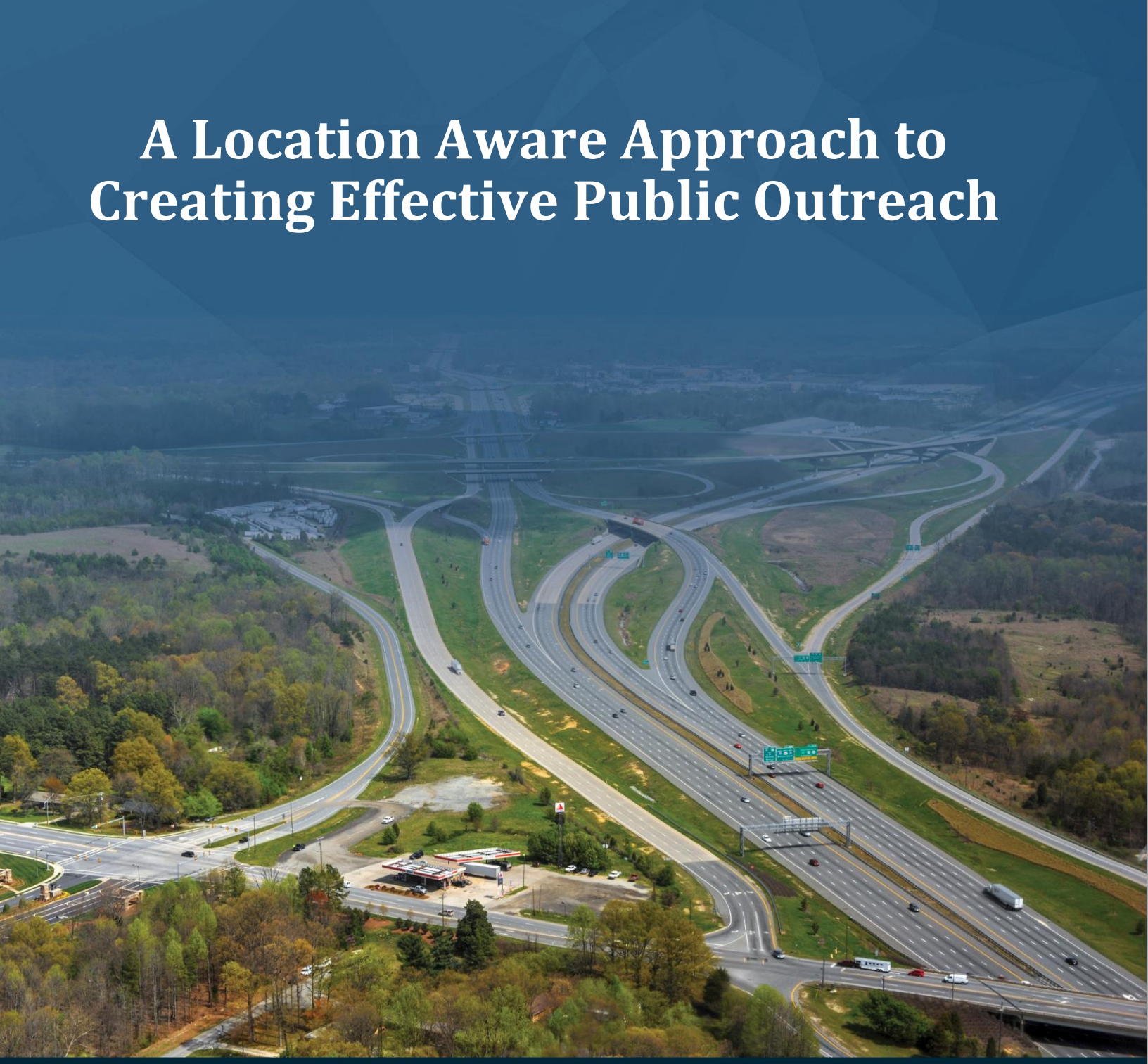
A Location Aware Approach to Creating Effective Public Outreach



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16. Abstract

NCDOT enhances its ability to establish relationships, credibility and consensus throughout the course of the transportation decision-making process by using a variety of methods to engage the public. Organizing and implementing public hearings, while effective, falls short on involving all stakeholder groups who would be affected by the implemented project. Public hearings inform and invite members of the public who live nearby and would incur the most perceived short- and medium-term adverse effects from the project. However, public hearings do not effectively engage members of the public who use the project corridor to transit and would have the most perceived medium- and long-term benefit. In this project we value-added existing public outreach strategies by augmenting them with powerful spatial analysis tools creating analytics and easy-to-understand visualizations, state of the art targeted information dissemination techniques, and a user friendly spatial public engagement portal. We worked with NCDOT staff members including Communications Office staff as well as construction project staff to evaluate the analysis and communication tools. The feedback we received was positive, concluding that the analysis tools were very useful, especially for large projects. Demo videos of the interactive mapping platform (WebApp) and all the analysis tools are accessible following this link: https://go.ncsu.edu/OutreachAnalysisToolsDemoVideos

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Executive Summary

NCDOT enhances its ability to establish relationships, credibility and consensus throughout the course of the transportation decision-making process by using a variety of methods to engage the public. Organizing and implementing public hearings, while effective, falls short on involving all stakeholder groups who would be affected by the implemented project. Public hearings inform and invite members of the public who live nearby and would incur the most perceived short- and medium-term adverse effects from the project. However, public hearings do not effectively engage members of the public who use the project corridor to transit and would have the most perceived medium- and long-term benefit. In this project we strived to value-add existing public outreach strategies by augmenting them with powerful spatial analysis tools creating analytics and easy-to-understand visualizations, state of the art targeted information dissemination techniques, and a user friendly spatial public engagement portal.

We achieved this in four project phases: “Discovery”, “Creation”, “Implementation” and “Transfer”. In each phase we completed a specific set of tasks which in turn contributed to the achievement of an overarching goal. In the Discovery Phase the project team identified all the internal and external resources such as data sources, geospatial analytics tools that can be used, various internet mapping implementations, literature, engagement strategies, etc.

The Creation Phase was the most productive phase with the project team creating many important components of the project successfully going above and beyond what was expected initially. These include but are not limited to: two complex geospatial analysis tools, geoprocessing tools based on the analysis tools, web maps, a robust WebApp to be used for analysis without having GIS tools on analysts’ computers, a template for the Spatial Public Information Portal (SPIP), detailed workflows to be used for implementation, and multiple versions of SPIP story maps in addition to public engagement processes to be followed, as well as a few scripts for data processing, tool enablement, etc.

During the Implementation phase the project team put its best effort to identify a project for implementation; however, due to various reasons that are out of our control, the evaluation of the methodology was only tested with the Communications Office analysts on the NCDOT side but not with the general public. The team built specific Public Information Portals for initial construction project alternatives, created and administered information and opinion surveys with NCDOT staff and also conducted interviews with NCDOT analysts and other staff who would be using the analysis platform. We also held group and individual meetings with various staff and project teams to demonstrate the application and collected feedback to complete the implementation and transfer phases. Demo videos of the interactive mapping platform (WebApp) and all the analysis tools are accessible following this link: https://go.ncsu.edu/OutreachAnalysisToolsDemoVideos

We worked with NCDOT staff members including Communications Office staff as well as construction project staff to evaluate the analysis and communication tools. The feedback we received was positive, concluding that the analysis tools were very useful, especially for large projects. Our recommendation to the NCDOT as the funding agency is for them to find a way to get the NCDOT personnel to use these tools and strategies to value-add their workflow. The NCSU

project team is always happy to provide more training, help with analysis and help with the technology transfer.

In the future, a full implementation on an actual construction project would be very useful. It would allow the practitioners to experience the benefits of such analysis, and be able to pinpoint the deficiencies in the analysis tools as well as information and visualizations provided through digital and in-person communication. This in turn could be used to implement future improvements through more useful analysis tools and better strategies for public outreach.

Table of Contents

Executive Summary 4

Table of Contents 6

1. Introduction 8

1. Background 9

1.1 Problem 9

1.2 Geospatial Analysis Using Road Network 9

1.3 Public Engagement 11

2. Methodology 11

3. Discovery Phase 12

4. Creation Phase 13

4.1 Application and Interface Design 13

4.2 Network Analysis Tool on Interactive Mapping & Analysis Platform 16

4.3 Demographic Analysis Tool on Interactive Mapping & Analysis Platform 20

5. Implementation & Transfer of Knowledge 26

5.1 Process Design 26

5.2 Location Tool: Location Targeting with Google Ads 27

5.3 Use of Demographic Hotspot Analysis 29

5.4 Creation of Campaigns 30

5.5 Spatial Engagement Portal (SPEP) 34

6. Evaluation 34

7. Conclusion and Recommendations 38

References 40

Appendices 42

Appendix 1: GIS Data Including NC State University Sources 42

Appendix 2: NC Department of Transportation GIS Data 45

Appendix 3: ESRI Story Maps & ArcGIS Web Mapping Application Examples 47

Appendix 4: Spatial Analysis Tools 49

Appendix 5: NCDOT Construction Projects in Development as of October 6th 2019 51

Appendix 6: Drive-Time Service Area Comparison - NCDOT vs ESRI Roadway Network 58

Appendix 7: Network Analysis Tool User Selection Options 59
Appendix 8: Network Analysis Tool Outputs 65
Appendix 9: Detailed Process Flowchart (Enlarged) 74
Appendix 10: Python Scripts Used for Network Analysis Data and Tool Set Up 75
Appendix 11: ArcGIS Pro Script to identify Zip Codes for exclusion 97
Appendix 12: Surveys Administered to Project Staff 98

List of Figures

Figure 1 - Location allocation through source-sink optimization on the road network (a) City-wide application, (b) neighborhood wide application. (Source: ArcGIS.com) 10
Figure 2 – Project Phases and Tasks 12
Figure 3- A general Application Architecture diagram depicting the application, its dependencies and its architecture as it currently is deployed in our environment 14
Figure 4: Interactive Web App Interface Housing Custom Developed Tools 15
Figure 5: Simplified Diagram of the Network Analysis Workflow - Generates Drive-Time Polygons and Demographic Report 16
Figure 6: Detailed Workflow of the Network Analysis Tool 17
Figure 7: Network Analysis Tool WebApp Interface (a)- All Default Values, (b)-Asian Females of 21-39 Travelling 8-8:30am 18
Figure 8: Drive-Time Analysis Tool Results Example 19
Figure 9: Demographic/Hotspot Analysis Tool Interface for User Selection Options 21
Figure 10: Demographic/Hotspot Analysis Tool on WebApp (before tool execution) 22
Figure 11: Demographic Hotspot Analysis Tool Flowchart 22
Figure 12- Demographic Distribution of (A) Race category of "African American" and (B) Gender and Age catergory of "Females under 20" 24
Figure 13 - Hotspot Analysis Results View (A) Race category of "African American" and (B) Gender and Age Category of "Females under 20" 25
Figure 14: Generalized Analyses & Implementation Flowchart 26
Figure 15: Detailed Process Flowchart 27
Figure 16: Demographic Identification Flowchart (Identification of areas with a significant density of specific demographics) 27
Figure 17: Identification of locations that need to be excluded 29
Figure 18: Identification of areas that need to exclude based on the shortest drive-time polygon 31
Figure 19: Only regular commuters to the YELLOW area that are within the GREEN area are targeted with advertisements 32
Figure 20: Hotspots of stakeholders with specific demographic profiles 33

List of Tables

Table 1: Demographic/Hotspot Analysis Tool: User Selections 21
Table 2: Demographics of people using public transit (Information acquired from [1] [4] [6] [8]) 30
Table 3: Demographic category: Commuting by Car (Information acquired from [4]) 30
Table 4: Indicators to Achieve Goal 1 and Methods of Analysis Information Acquired from [3] and [5]x 35
Table 5: Indicators to achieve Goal 2 and Methods of Analysis Acquired from [3] and [5] 36

1. Introduction

How does one effectively identify transportation stakeholders using spatial and demographic analysis in order to reach them using popular advertising platforms? As a part of the project development phase, the public outreach and engagement stage is one of the most crucial parts of transportation project planning. In this stage, the public is informed of the future plans and of the benefits for the broader community. Direct and indirect feedback is gathered. Organizing and implementing public hearings, while effective, falls short on involving all stakeholder groups who would be affected by the implemented project. One of the reasons for that is the difficulty in identifying and engaging certain transportation project stakeholders. It has been observed that local stakeholders, people who are in close proximity to the project, are more likely to get involved in the planning process compared to commuting stakeholders, people who live farther away but regularly travel through or to the project area. This may cause a one-sided representation in public hearings that may not reveal the actual value (or lack thereof) of the proposed transportation project. Therefore, in order to have equality in the representation of opposing points of view, it is important to identify and engage all stakeholders that have an interest in the outcome of the project. With the new techniques of identifying and engaging groups of stakeholders, we aim to alleviate some of these concerns of misrepresentation. The objective is to engage all stakeholders (both local and commuting) that will have a meaningful and constructive contribution to ensure that the transportation project team is able to gather feedback from both points of view. For this, we introduce targeting/ advertising using geospatial and demographic data along with geospatial analytics and online advertising. In terms of spatial/location targeting, we have developed a tool by combining existing options from popular advertising platforms in a novel way. This helps with the precise identification of local and commuting stakeholders. To digitally reach stakeholders with a high possibility of active participation, we also employed demographic analysis. For this, we performed a literature review to create demographic profiles of possible stakeholders who are more relevant or might have a greater interest in specific transportation projects. We developed a tool that pinpoints areas that have a significant population density of demographic categories of interest which are used as specific targeting locations for online outreach campaigns. Finally, the outputs of these two tools are used to create the targeted advertising campaigns. The overall purpose and effort of identifying stakeholders and appropriately targeting them is to have an equal, fair, and full representation of stakeholders as a part of the decision making and improvement process for a given transportation project.

1. Background

1.1 Problem

The planning process of a transportation project, composed of multiple stages, is multidimensional and complex. Each time the North Carolina Department of Transportation (NCDOT) plans a project, a preset procedure is followed including the acquisition of public input on the proposed project. Organizing and implementing public hearings, while effective, falls short on involving all stakeholder groups who would be affected by the implemented project. Specifically, the vast majority of the stakeholders have been those who are local to the proposed project and do not want construction near their home or work location. Outreach methods such as publicly announcing the proposed projects via social media or sending informational notices through the mail (North Carolina Department of Transportation, 2019) have not produced the desired increase in the participation rate of stakeholders.

The data from previous outreach and engagement campaigns have revealed public representation flaws. Local stakeholders, people who are in close proximity to the project's location, are more likely to attend public hearings compared to those who are commuting stakeholders, people who live farther away but regularly travel through or to the project area. This creates a one-sided perspective that may not reveal both the perceived positive and negative effects of the project. Additionally, participation data has shown that many people become involved in the planning process simply because they are skeptical about long term construction nearby. Finally, some stakeholders do not live in the vicinity of the project location and therefore they are unaware of the existence of the project at all. To mitigate the cascading effects of these flaws, we needed to implement an innovative public outreach and engagement strategy. It is evident that populations that may have a greater interest in the outcome of the project should be identified in addition to general local and commuting stakeholders in order to have an equal representation of both sides, so that NCDOT is able to implement the project in a way where everybody contributes to the decision making process. This project's aim is to increase public awareness of proposed transportation projects by identifying and targeting affected stakeholders using spatial analysis (to target the local and commuting stakeholders) and demographic analysis (to target areas with a high concentration of people particularly interested in the given project).

1.2 Geospatial Analysis Using Road Network

Defining accurate service areas has long been a problem [21]. Estimating these boundaries accurately would allow us to exclusively identify commuting and local stakeholders. This can be done in two ways. One is through travel time optimization where areas that can be reached by a vehicle originating from the project location are identified as a function of travel distance and posted speed limits [11], [24]. The other is through adding the use of supply-demand

data to the former optimization technique. This is often used to solve supply-demand type problems for site selection, such as retail location identification [23] or supply chain optimization [13]. There are also instances of its application on infrastructure distribution demand allocation [17], [18]. It is possible to adapt this approach for this project's purposes to create an accessibility model. We can use the pre-implementation road capacity at the project location along with destination locations and the number of vehicles each would contain. Then we can use that to optimize the road network while matching the road capacity (source) to destination locations such as census block groups (sinks) or business centric locations. A city-wide application of this as well as a neighborhood scale application is shown in Figure 1a and Figure 1b. We can also calculate the impact of the project by taking the following into account: the flow reduction during the project implementation, and flow increase that will occur after project implementation.

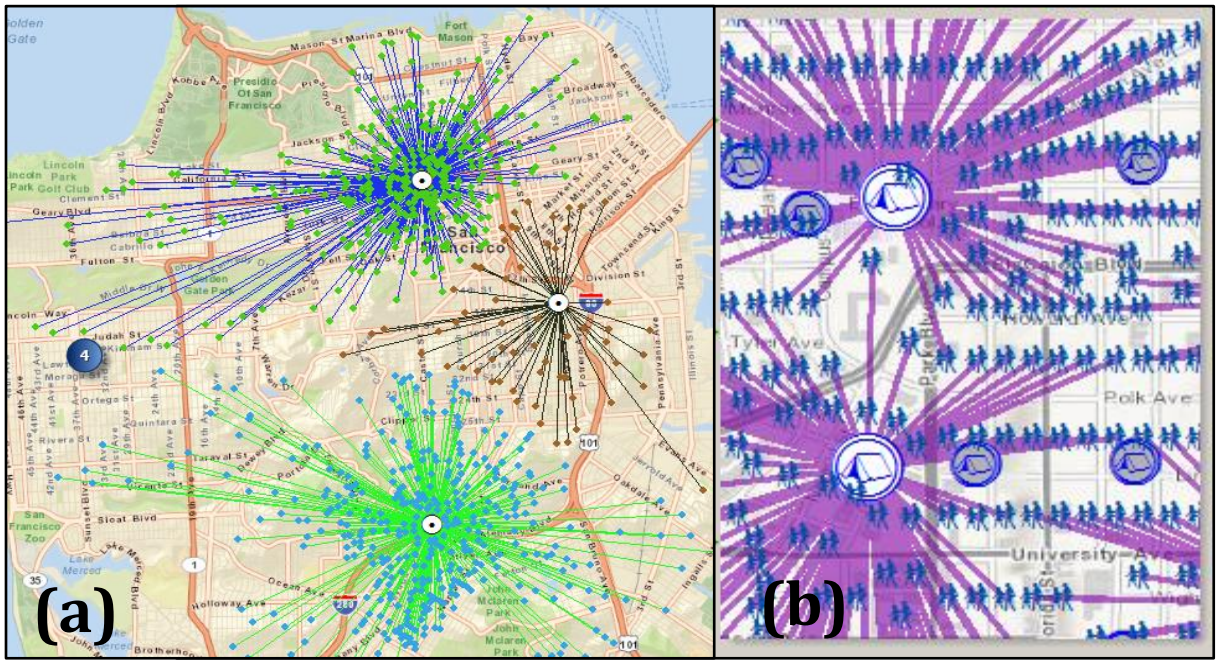

Figure 1 - Location allocation through source-sink optimization on the road network (a) City-wide application, (b) neighborhood wide application. (Source: ArcGIS.com)

Literature on collecting travel data from cellular networks or directly from personal cellular devices exists. However, these are limited in scope and depth due to data availability issues from private firms. In addition, private companies' development efforts are not usually published in academic publications. Among the few examples that exist, Nabolusi et al. (2016) [14] reviewed the multidisciplinary activities that rely on mobile traffic datasets and identified major categories and sub-categories in the literature. Another example is by [9] where they explain how to obtain parameters related to traffic from cellular-network-based data, describing methods used in existing simulation works as well as field tests in the academic and industrial environments.

1.3 Public Engagement

NCDOT maintains a website that provides detailed practical information for effective public engagement [20]. On this site a toolkit is provided that includes detailed practical information for project managers looking for ways to better engage the public. A long list of public engagement techniques is detailed, public engagement resources are identified, and a detailed glossary of terms is provided.

Earlier attempts of online engagement in NC were initiated by the City of Charlotte using ESRI's "Story Maps" concept [10]. Their story map was used to communicate the locations and details of all the transportation projects in and around the city. Later, a pilot project funded by NCDOT and implemented by Metro Quest showed the value of an interactive engagement system by recruiting 1262 participants providing feedback that generated 14366 data points using the NC Public Transportation Strategic Plan website "NC Public Transportation Strategic Plan" (2018) [15]. A similar system for "NC State Transportation Improvement Program 2018-2027" [16] was used to recruit 1452 participants who provided input generating 30704 data points. This shows the value of online engagement systems using interactive mapping interface to engage stakeholders. Even though this was a successful implementation, no formal evaluation was performed.

More on this can be found in Section 5.3 Use of Demographic Hotspot Analysis and Section 5.4 Creation of Campaigns.

2. Methodology

The overarching goal of this project is to provide added value to existing public outreach strategies by augmenting them with spatial analysis tools, state of the art targeted information dissemination techniques, and a user friendly spatial public engagement portal. We achieved this in four project phases: "Discovery Phase", "Creation Phase", "Implementation Phase" and "Transfer Phase". In this section we detail work completed in addition to the procedure that was followed to complete each phase. In each phase we completed a specific set of tasks which in turn contributed to the achievement of the overarching goal. In the Discovery Phase the project team identified all the internal and external resources such as data sources, geospatial analytics tools that can be used, various internet mapping implementations, literature, engagement strategies, etc. In the Creation Phase the team created two complex geospatial analysis tools and created geoprocessing tools based on the tools, created web maps, a WebApp to be used for analysis without having GIS tools on analysts' computers, a template for the Spatial Public Information Portal (SPIP) and multiple versions of SPIP story maps in addition to public engagement processes to be followed as well as a few scripts for data processing, tool enablement, etc. During the Implementation phase the project team put its best effort to identify a project for implementation; however, due to various reasons that are out of our control, the

evaluation of the methodology was only tested with the analysts on NCDOT side but not with general public. We also held group and individual meetings with various staff and project teams to demonstrate the application and collected feedback to complete the implementation and transfer phases. A graphical representation of the general project tasks in each phase is shown in Figure 2.

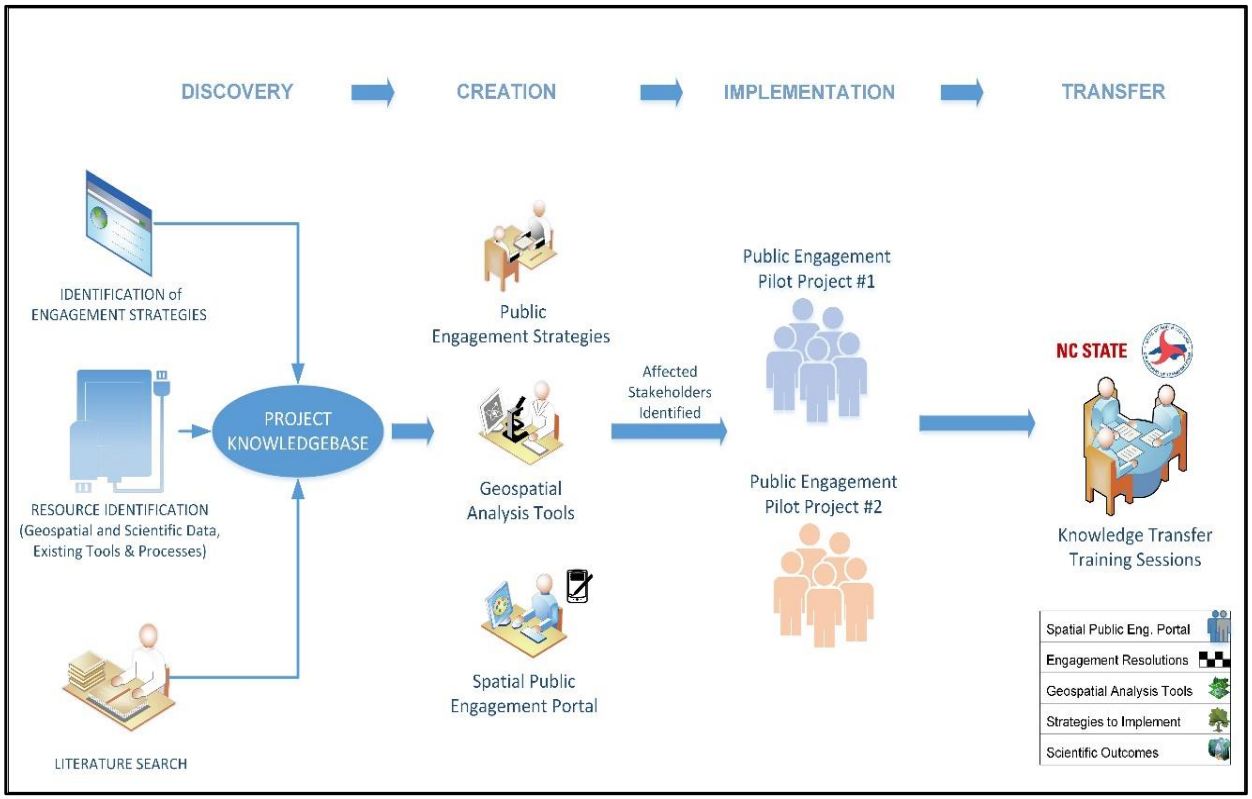

Figure 2 – Project Phases and Tasks

3. Discovery Phase

The discovery phase started even before the official project start date. Once we kicked off the project, we held regular meetings with NCDOT staff to learn more about the existing procedures and practices. We performed a review of existing literature including NCDOT documents. We also reviewed geospatial analysis techniques and tools that might be used to identify local stakeholders as well as stakeholders who are using the project location to travel through. We identified internal and external data sources that might pertain to this study and explored data from NCDOT, NC State University, and other sources. In addition, we reviewed and documented existing public involvement activities, plans, and stakeholder identification practices at NCDOT for project planning purposes. Some of these are in an effort to create a research baseline [19].

A detailed list of GIS data sources including NC State resources can be found in **Appendix 1**: GIS Data Including NC State University Sources. Similarly, **Appendix 2** details the data sources

at the NC Department of Transportation. **Appendix 3**: ESRI Story Maps & ArcGIS Web Mapping Application Examples. In **Appendix 4**: Spatial Analysis Tools we examined and researched.

In addition, the project team wanted to be prepared for implementation as soon as the creation phase concluded. Hence, in summer and fall of 2019 we reached out to our NCDOT contacts and asked them to help identify a few construction projects that we could start planning for. There were some initial candidates but these never solidified and proper connections were not made. Hence the project team decided to help with this process by researching upcoming construction projects using any publicly available resource published by NCDOT. The project team then created a list of upcoming projects along with detailed information about each of them and presented this to the NCDOT project team in late October in 2019. (We include this document in its entirety in **Appendix 5**). This helped reduce the number of candidate projects but the final decision on the implementation projects had to wait two more years due to COVID and other reasons.

4. Creation Phase

In this phase we created all the planned geospatial analysis tools (also known as Geoprocessing tools, henceforth referred to as GP tools), an interactive online web mapping and analysis platform that makes GP tools and other tools easily accessible to users without having to have any desktop GIS tools, and an interactive online public engagement platform template to be applied to any construction projects. We also developed a detailed process flow to be used for implementation in addition to various other scripts and tools. In the next few sections, we will discuss each of these items in detail.

4.1 Application and Interface Design

The project team has set up two servers to house this application. The database server (NCDOT Databox) is running an MS SQL database implementation and the ArcGIS Server (NCDOT Sandbox) is running Enterprise ArcGIS Server implementation. NCDOT Databox hosts two geodatabases, namely “NCDOT_Plan” and “NCDOT_Demographics”. NCDOT Sandbox hosts two Geoprocessing (GP) tools, namely “Network Analysis” and “Hotspot/Demographic Analysis”. It also hosts a Maps service called “CountyRoadsandBGs” serving the roadway dataset for visual display on the WebMap. The WebMap is called “NCDOT_web_app_layer” which was created using ArcGIS Pro and pushed to ArcGIS Online. The WebApp that the user interacts with uses this WebMap as well as the GP tools to provide needed functionality. Figure 3 shows the general application architecture including all above mentioned components and their connections to other components.

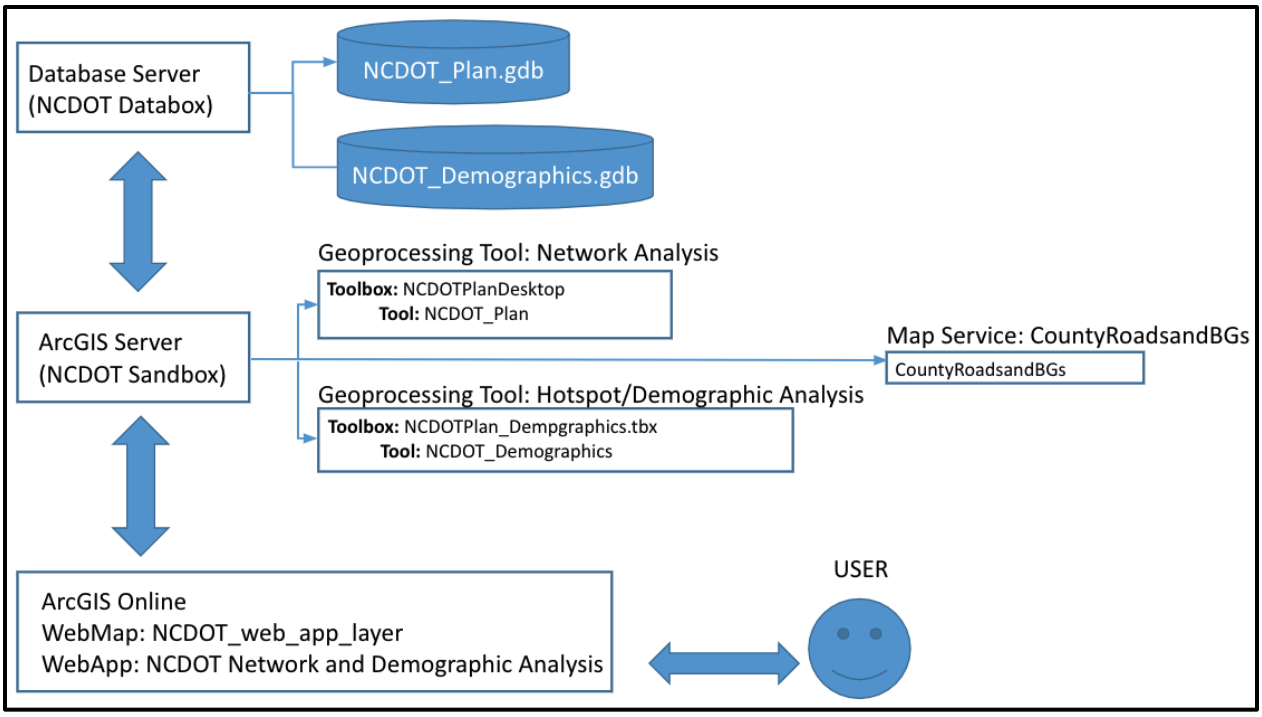

Figure 3- A general Application Architecture diagram depicting the application, its dependencies and its architecture as it currently is deployed in our environment

A geospatial analysis toolset was developed by the Center for Geospatial Analytics at North Carolina State University. Its functionality is set to assist in the improvement of the public outreach and engagement stage of the transportation planning process. The project utilizes network analysis and drive-time polygons with demographic data. The goal of the drive-time polygons is to create a clear and comprehensive mapping of the areas around the transportation project based on drive-time. This was used further in conjunction with spatial and demographic analysis for precise targeting.

The WebApp is the front end of this application where all the user interaction takes place. The user, presumably the analyst, has access to the custom developed Network Analysis and the Demographic (Hotspot) Analysis tools. In addition, the user can add their own data layers to the WebMap, search for points of interest, visualize the data layers' attribute tables, adjust symbology, export tool outputs as geospatial layers, download the tool outputs, and more. Figure 4 below shows the WebApp and the location of various tools and user affordances. Demo videos can be viewed at this link: https://go.ncsu.edu/OutreachAnalysisToolsDemoVideos

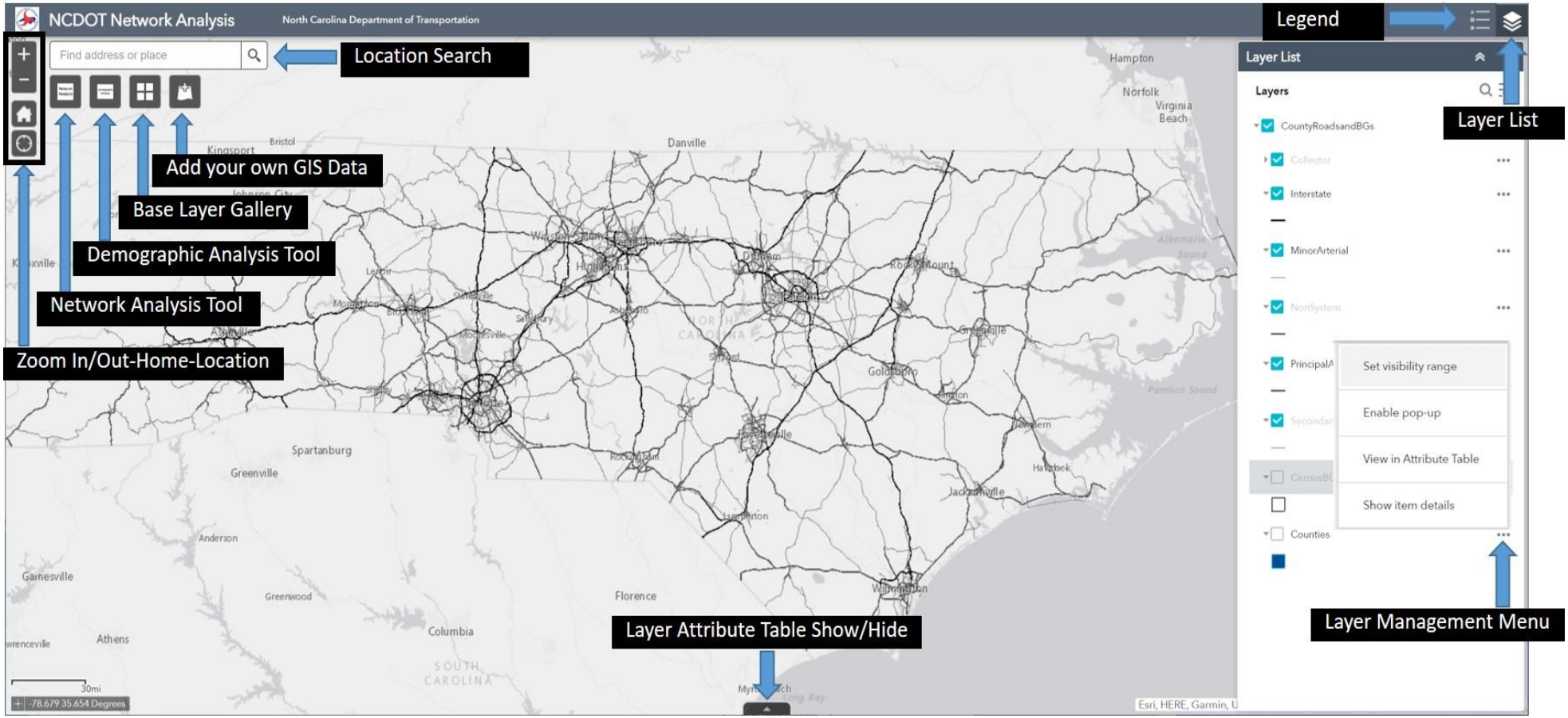

Figure 4: Interactive Web App Interface Housing Custom Developed Tools

4.2 Network Analysis Tool on Interactive Mapping & Analysis Platform

One of the project's aims is to reach out to local and commuting stakeholders. One way of achieving that is to first identify the areas where various stakeholder groups might live and work. The project utilizes network analysis and drive-time polygons with demographic data. The purpose of the drive-time polygons is to create a clear and comprehensive mapping of the areas around the transportation project based on drive-time.

The first step for creating drive-time polygons was to collect relevant data to conduct network analysis. A variety of road data was collected from different sources to construct a full transportation network; however, the bulk of the roadway data was comprised of NCDOT's roadways data layer. We obtained the roadways dataset and made some changes to update the connectivity before creating the NC road network data in ESRI Network Data format. This was needed to perform the drive-time distance (service area) analysis. We performed the update in many iterations as the connectivity needed for the ESRI network data model was not present in the input roadways dataset obtained from NCDOT. We implemented some service area analysis of this data using ESRI desktop tools as well as ESRI's online roadway data layer service to compare the outputs and tool functionality (**Appendix 6**).

Furthermore, demographic data from the American Community Survey (ACS) was incorporated to estimate populations of specific demographic categories within the borders of the driving polygons. The ACS data was obtained and implemented at the Census Block Group level. A simplified workflow of the Network Analysis Tool is presented in Figure 5. A more detailed workflow of the tool is presented in Figure 6.

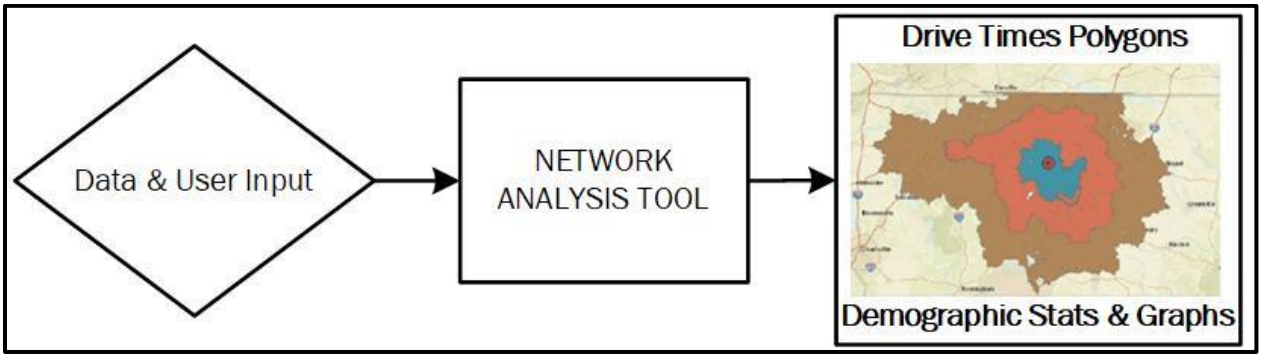

Figure 5: Simplified Diagram of the Network Analysis Workflow - Generates Drive-Time Polygons and Demographic Report

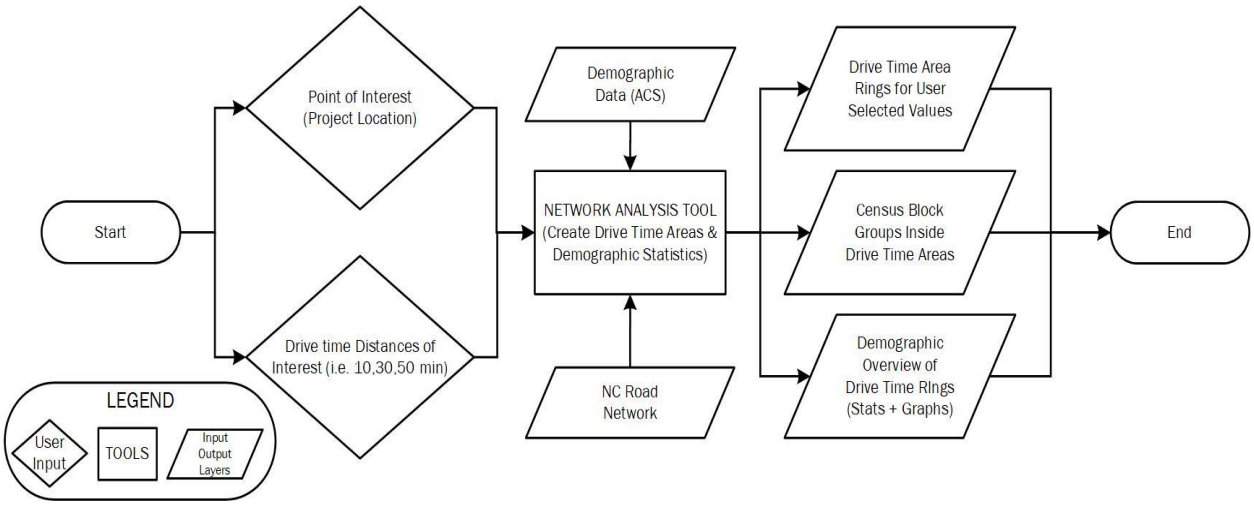

Figure 6: Detailed Workflow of the Network Analysis Tool

Each drive-time polygon shows how far someone can travel in a specified amount of time from the center of the transportation project. The specified drive times in the above picture are 10 minutes, 30 minutes, and 50 minutes indicated by the colored concentric polygons from smallest to largest respectively. Each polygon relates to an approximate population of specific demographic categories. We leverage this spatial analysis tool to better identify and target transportation project stakeholders. Outputs of the tool include downloadable service area layers separately for each user defined drive-time in addition to a combined service area layer that also includes the data from census data it overlays (DriveOut.zip). It also provides census stats in MS Excel format (CensusStats.xls), Demographic analysis output data as text file (PopAnalysisAll.txt), Graphs (PopAnalysisGraphs.pdf and CensusGraphs.pdf).

Tool Usage:

The location placement tool is placed at the top left of the Network Analysis Tool interface (Figure 7) which also comes with a delete button to replace misplaced location pointers. The user selects the location placement tool and points on the map to pick the location of a construction project. It is also possible to use the search bar on the WebApp to first find a Point of Interest (address, intersection, town, etc.) before placing the pointer on the map. When a search term is entered, the WebApp zooms the view into a specific address, town or intersection. The starting point on the map is going to be any point of interest on or near the construction project's location. We recommend using the middle of the road segment for roadway construction and improvement projects.

The next step is to choose the break values, which is a set of three numbers separated by commas. These numbers can indicate value in "Travel Time" in minutes or "Travel Distance" in miles based on the user's preference. The next few selections are made to indicate population groups of interest. The Network Analysis tool has five different ACS (American Community

Survey) data query categories available for selection. These are namely: “Time of Travel” (ToT), “Mode of Transportation” (MoT), “Language Spoken” broken down by age categories, “Race” as well as “Gender” broken down by age categories. A detailed list of the options for each category is available in **Appendix 7A**. The Network Analysis tool on the WebApp is a pop-up window accessed by a tool button on the interface (Figure 4). The user interface for the tool is presented in Figure 7. The left side of the figure shows default selections, and the right side of the figure shows the same interface with analysis focusing on Asian Females aged 21-39, who drive alone between 8:00 am and 8:30 am.

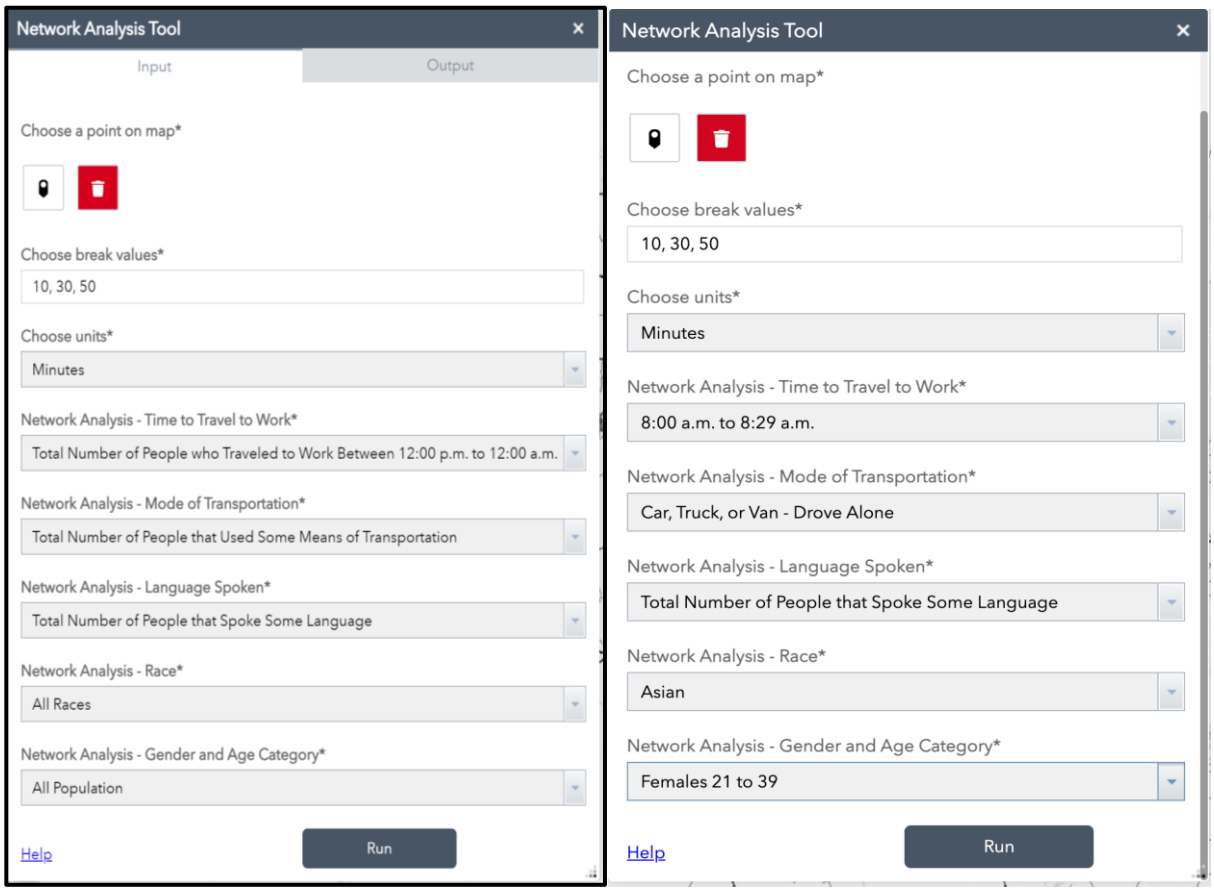

Figure 7: Network Analysis Tool WebApp Interface (a)- All Default Values, (b)-Asian Females of 21-39 Travelling 8-8:30am

The user selects a location on the map, provides necessary input values and makes selections on the Input tab of the Network Analysis Tool window and presses the Run button to execute the tool. The request initiated on the ArcGIS Online hosted WebApp front end under the tool interface is linked to the corresponding GeoProcessing (GP) tool which executes on the ArcGIS Server on NCSU computing environment (NCDOT Sandbox). It connects to the database server (NCDOT Databox) to retrieve appropriate geospatial layers and other tables to execute the code in the GP tool. Once the GP tool completes the analysis, it returns the results to be added as geospatial layers to the interactive WebApp. A compressed (.zip) version of the output drive-time analysis layers as well as the data tables, statistical analysis tables and graphics are linked

on the Network Analysis Tool's "Output" tab for user to download. The layers along with associated demographic data tables are also added to the WebMap that WebApp uses for visualization and further analysis purposes.

For illustration purposes we executed a sample analysis on a location close to one of the construction projects in Southeast Wake County with drive times of 10, 30 and 50 minutes and all the ACS query options left at default selections. Figure 8 displays the results of the Network Analysis tool query on the WebApp. The red dot on the map is the project location selected by the user. The layer listed as "Service Area3" on the Layer List is the innermost drive-time polygon (10 minutes), "Service Area2" is the middle ring (30 minutes), "Service Area1" is the outermost ring (50 minutes) whereas "LinkedSA" is the combination of the three.

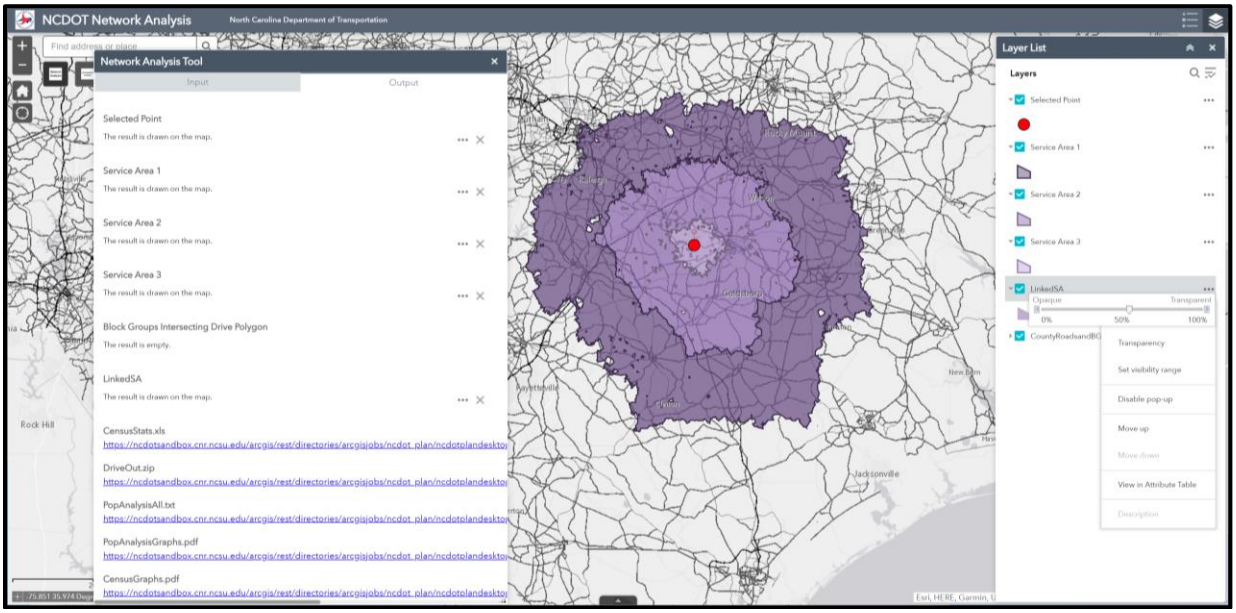

Figure 8: Drive-Time Analysis Tool Results Example

The Output tab on the network Analysis Tool window shows the downloadable service area layers (DriveOut.zip), census statistics (CensusStats.xls), demographic analysis output data (PopAnalysisAll.txt) as well as graphs (PopAnalysisGraphs.pdf and CensusGraphs.pdf). The drive-time service area layers are also added to the map for easy visualization. The analyst is supposed to use this tool to generate output multiple times with different choices for age, race, language, travel time, etc. Then he/she examines the results of the initial demographic analysis this tool provides along with the drive-time service areas to determine age, race and language groups of interest in each drive-time ring (**Appendix 8: Network Analysis Tool Outputs**). The combined version of the service area layer (LinkedSA) is used as an input for the Demographic/Hotspot Analysis tool.

Below is a list of custom code files we wrote and their purpose.

- ACS_Modify.py: Used during pre-processing to clean up select ACS 5-Year Estimates tables derived from American Fact Finder;
- CensusTotal.py: Allows the user to choose a demographic from census categories and output the statistical totals for each in a table;
- DriveTotal.py: Allows the user to pick a point along any street on the map, input three drive-time /distance thresholds and their units, and output the drive polygon on the map;
- Demographics.py: Allows the user to choose a demographic from census categories and output the statistical totals for each in a table;
- Fill_Speeds.py: Used for replacing null speed limit values based on NCDOT route characteristics metadata; and
- LRPredict.py: Used to predict population values using time as a function.

4.3 Demographic/Hotspot Analysis Tool on Interactive Mapping & Analysis Platform

In the previous section we explained the Network Analysis tool which we use to identify local and commuting stakeholder groups by age, gender, language breakdown, and more. Once initial analyses are completed with the Network Analysis tool and stakeholder groups of interest are identified, the output service area layer is used as an input to the Demographic/Hotspot Analysis tool. This tool generates 10 different map layers as output layers chosen across various demographic categories and the values the user chooses for each of these, as described below:

The Demographic/Hotspot tool provides two analysis types as the name indicates: Detailed Demographic Analysis and Hotspot Analyses. The tool lets the user select one (or all) of the service area polygons created by the network analysis tool and uses that as an input. The user first has to execute the Network Analysis Tool to complete the initial analysis. Hence, three drive-time (or distance) service area layers as well as the combined version of those would be available in the table of contents. While executing this tool, the user has access to all the drive-time service area layers that the Network Analysis Tool created in the previous step. The user has the option to focus on a specific drive-time ring or use the combined drive-time service area polygon to run the analysis on the whole study area. Figure 9 shows the tool interface with user selection options as a part of the WebApp. WebApp is presented in Figure 10. The following required input can be selected from the drop-down box; each of the variables' description is in the table below (Table 1). Details of the Demographic/Hotspot Analysis Tool's input is available in **Appendix 7: Analysis Tools User Selection Options**.

Table 1: Demographic/Hotspot Analysis Tool: User Selections

Input Name	Input Type	Value Range	Description
Travel Work Time	Interval	12:00am-11:59pm	Time the travelers use transportation means
Race	Category	N/A	Race
Language Spoken	Category	N/A	What language(s) does the traveler speak
Gender & Age	Category	N/A	Gender and a range of ages of the travelers
Means of Transport	Category	(means) & (number of passengers traveling together)	The # of passengers that travel by selected means
Drive-Time Polygon	Shapefile/ Area	N/A	A boundary determined by start point and required driving time start point. Generated by the Network Analysis Tool. User selects SA1, SA2, SA3 for three rings or the combined version (LinkedSA)

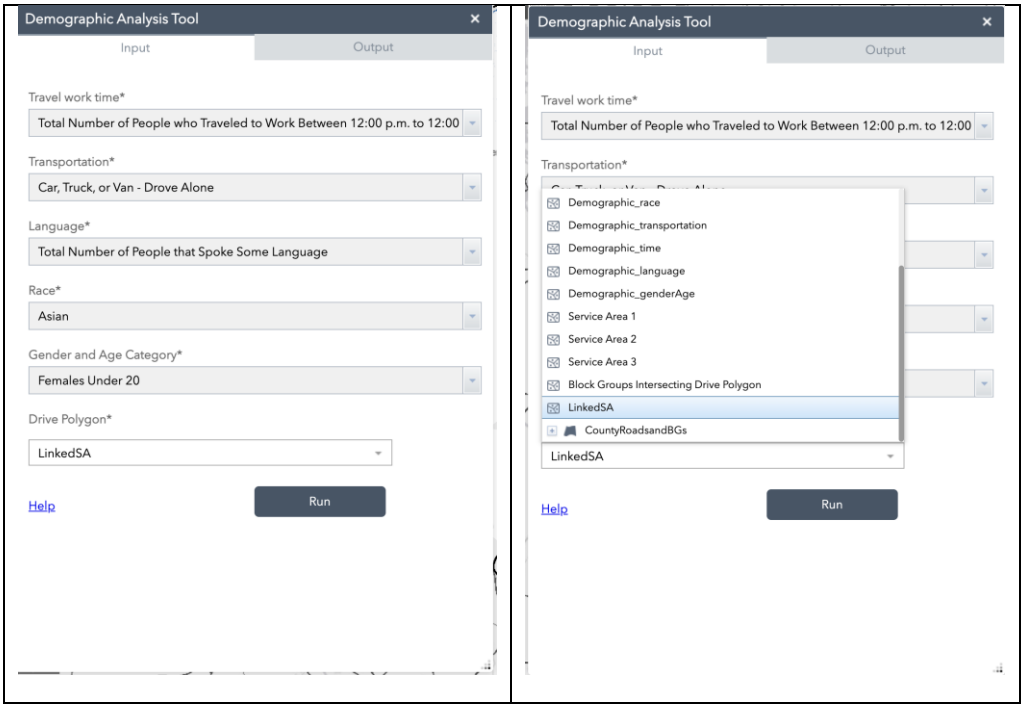

Figure 9: Demographic/Hotspot Analysis Tool Interface for User Selection Options

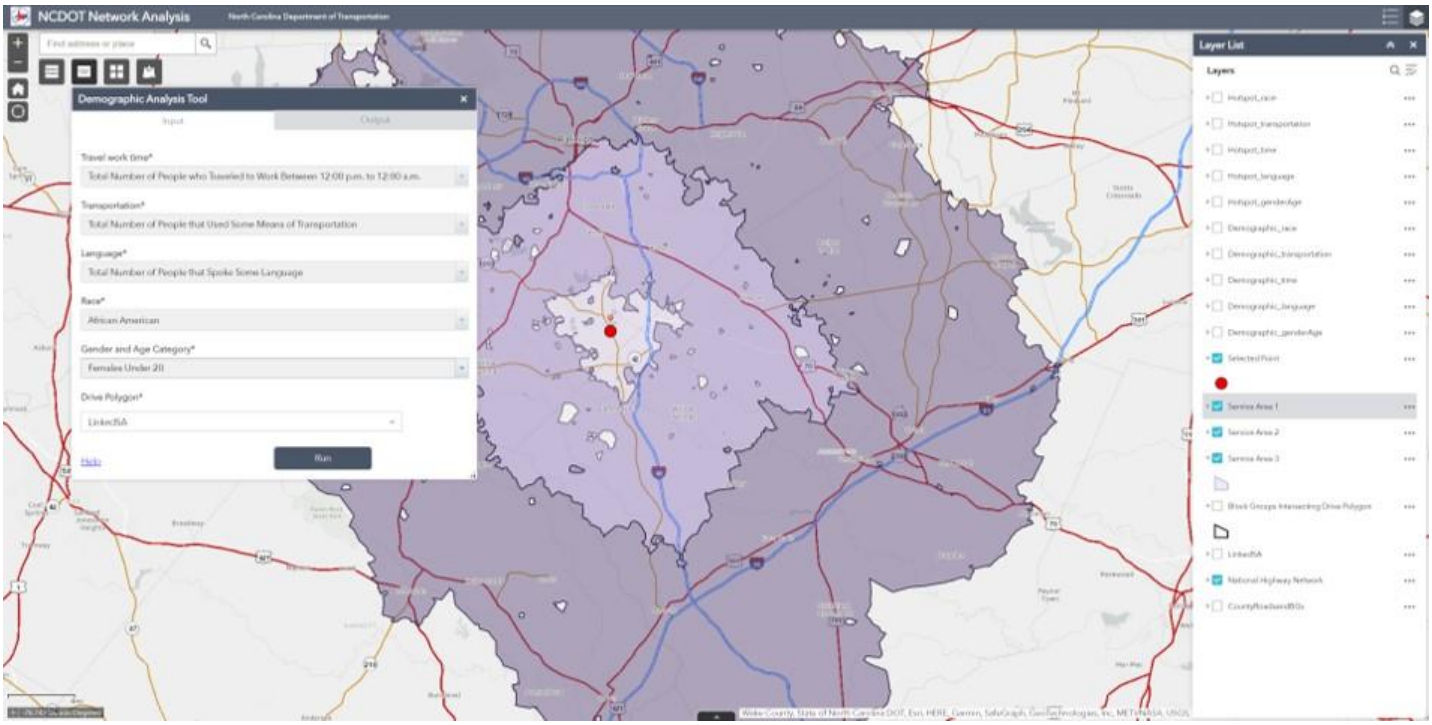

Figure 10: Demographic/Hotspot Analysis Tool on WebApp (before tool execution)

The flowchart below (Figure 11) depicts the inner workings of the tool detailing the input and output layers, user inputs, as well as the tools used.

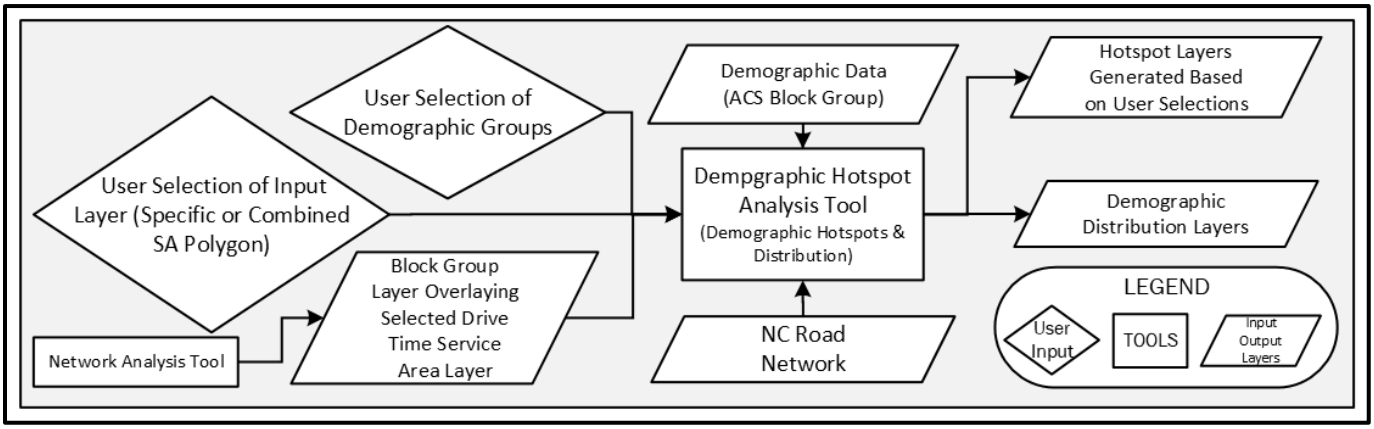

Figure 11: Demographic Hotspot Analysis Tool Flowchart

Once the user selections are made and the tool executes, the "Demographic_DescriptiveName" and "Hotspot_DescriptiveName" layers are respectively added to the Table of Contents (ToC), displayed on the WebApp, and listed on the tool's "Output" tab. The demographic data underlying this tool is ACS 2019 Block Group level data. The layers generated by the Demographic/Hotspot Analysis Tool are added to the WebApp's Table of Contents and can be displayed with a preset symbology. The user can also click on the map

features to get information, double click it to zoom into that one or just click on it to have a specific feature highlighted on the map. The user can also export these layers by clicking on the layers and choose to export to save as a local geospatial (or table) file. They also have an option to save to the “My Content” area of the ArcGIS online platform.

The geospatial data layers and corresponding tables that are generated by this tool are available to be downloaded or saved and shared through ArcGIS Online using the WebApp interface. Below is a list of output data layers generated by the Demographic/Hotspot tool.

- Hotspot_Race
- Hotspot_Transportation
- Hotspot_Time
- Hotspot_Language
- Hotspot_GenderAge
- Demographic_Race
- Demographic_Transportation
- Demographic_Time
- Demographic_Language
- Demographic_GenderAge

The “Demographic_xxxx” layers show maps of intervals of the number of people that fit into the calculated ranges of selected inputs. For example, “Demographic_Transportation” maps the spatial distribution of the number of people who have selected transportation means (car, truck, van; public transportation) within the area. Darker color means more population fits into the selected transportation means. “Demographic_Race” maps the spatial distribution of the number of the selected race (African American) within the area. Darker color means more African American population in that area. “Demographic_GenderAge” plots the spatial distribution of the number of the selected gender and age combination group (Females Under 20yo) within the area. Darker color means more female persons under the age of 20 exists in that area (Figure 12).

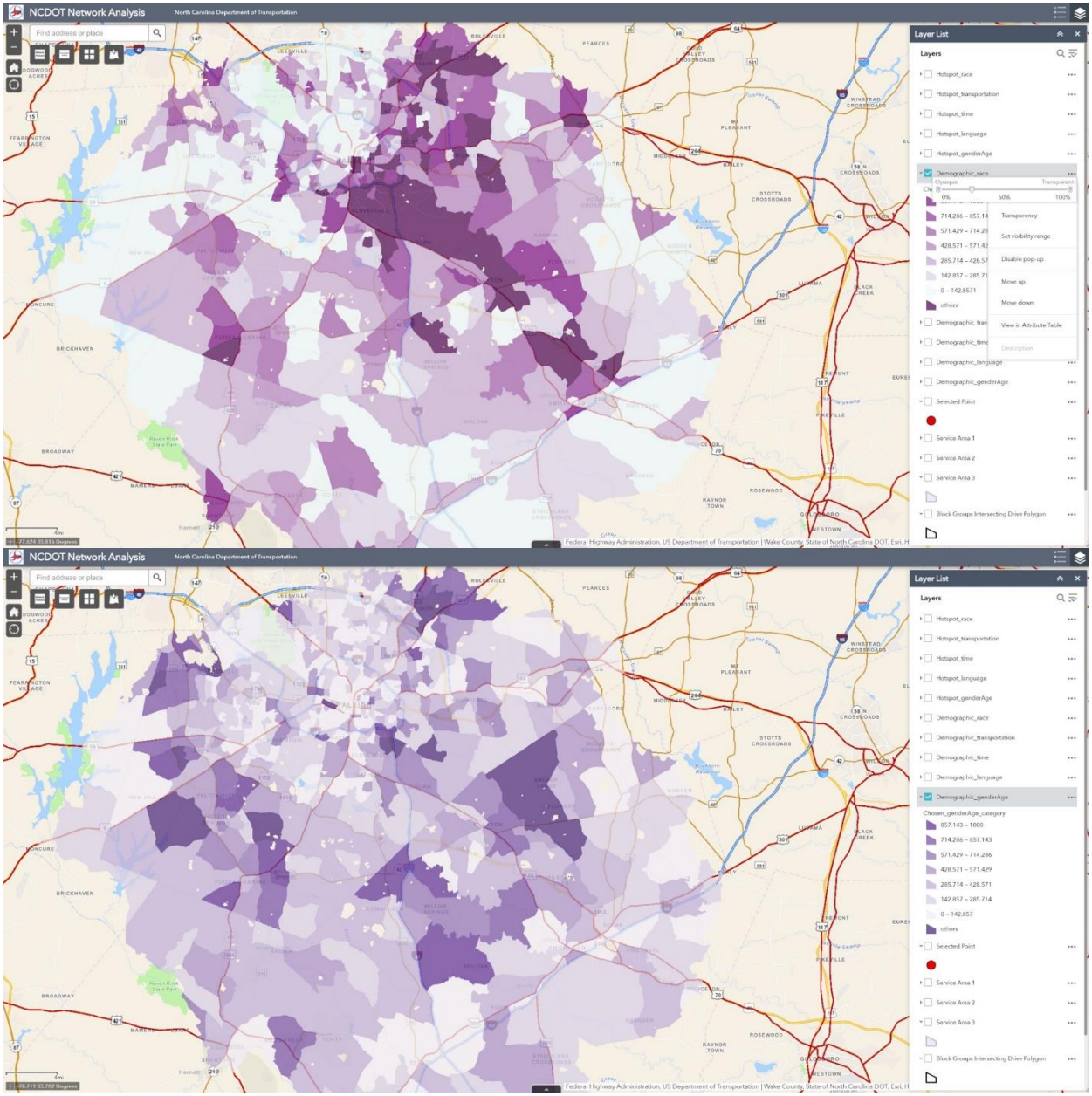

Figure 12- Demographic Distribution of (A) Race category of "African American" and (B) Gender and Age catergory of "Females under 20"

The “Hotspot_xxxx” layers show the distribution of people within selected category according to a geospatial statistical clustering called “Hot Spot Analysis”. The symbology is set so that the number of people who fit into the category is set to a red to blue color scale representing high to low numbers. For example, we've chosen “African American” people in this area. These red values show that there's a higher statistical confidence in the concentration (higher density) of people who fit the chosen category in this area compared to the rest of the drive-time area. The inverse of that is the blue areas which have higher statistical confidence in the lower

concentration of people who fit the chosen category compared to the rest of the area of interest. Hotspots in the map represented by colors of orange (significance value = 1) to red (significance value = 3). Cold spots in the map represented by colors of light blue (significance value = 1) to dark blue (significance value = 3). The white values represent the areas with no statistical significance, not significantly higher or lower number of people who fit the category here (Figure 13).

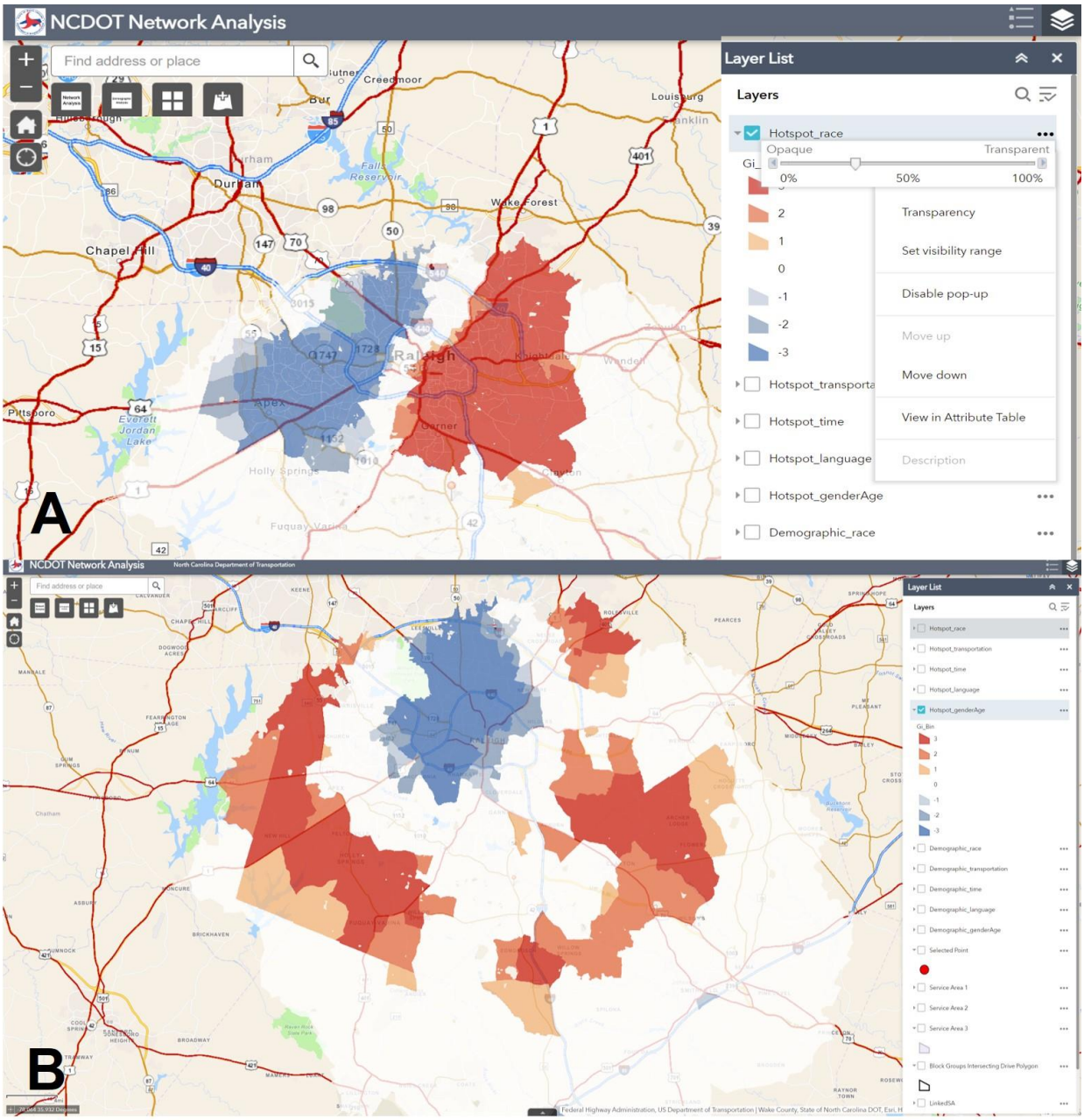

Figure 13 - Hotspot Analysis Results View (A) Race category of "African American" and (B) Gender and Age Category of "Females under 20"

5. Implementation & Transfer of Knowledge

5.1 Process Design

The project team designed an "end-to-end" process to execute the analysis, set up the Spatial Public Information Portal(s), set up the outreach campaigns and collect feedback. Figure 14 below shows the generalized analyses and implementation flowchart. Figure 15 shows a detailed version of the end-to-end project implementation workflow. Please see **Appendix 9** for the enlarged version of this graphic. In addition, Figure 16 shows an even more detailed version of the online stakeholder outreach workflow showing the process for identification of areas with a significant density of specific demographics.

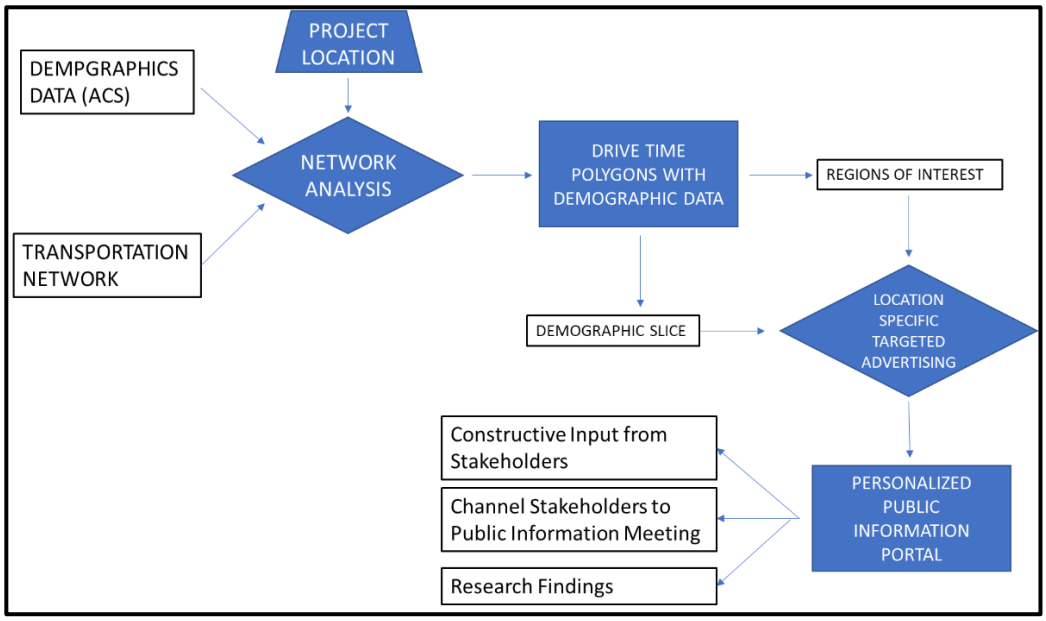

Figure 14: Generalized Analyses & Implementation Flowchart

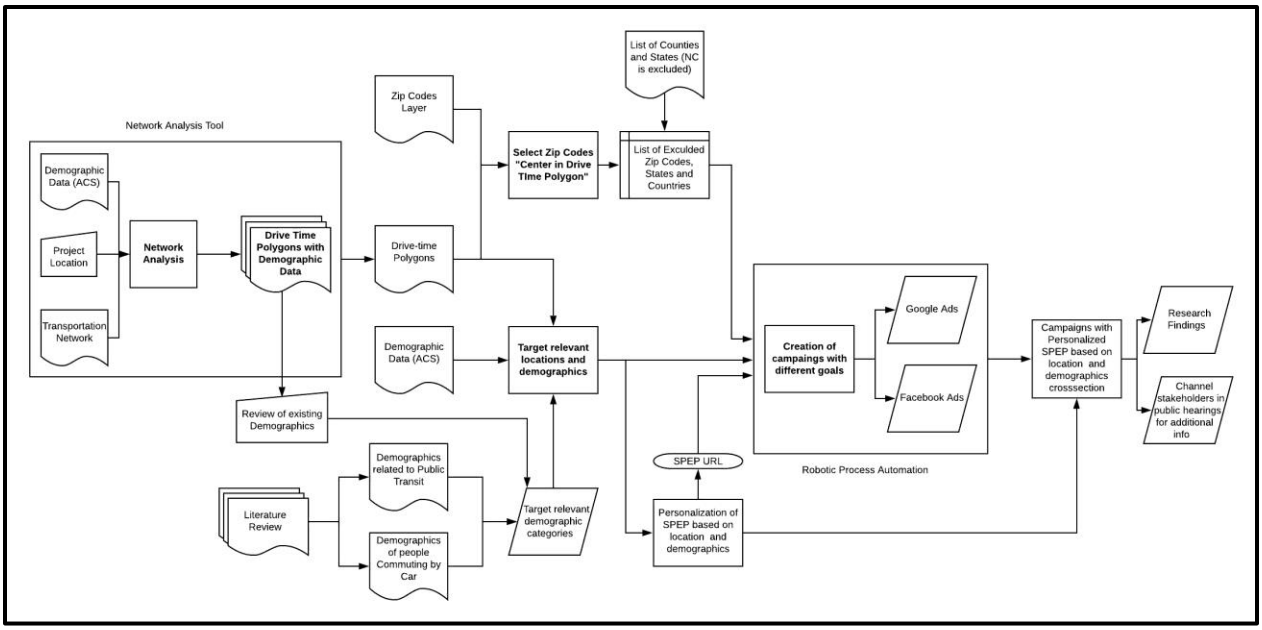

Figure 15: Detailed Process Flowchart

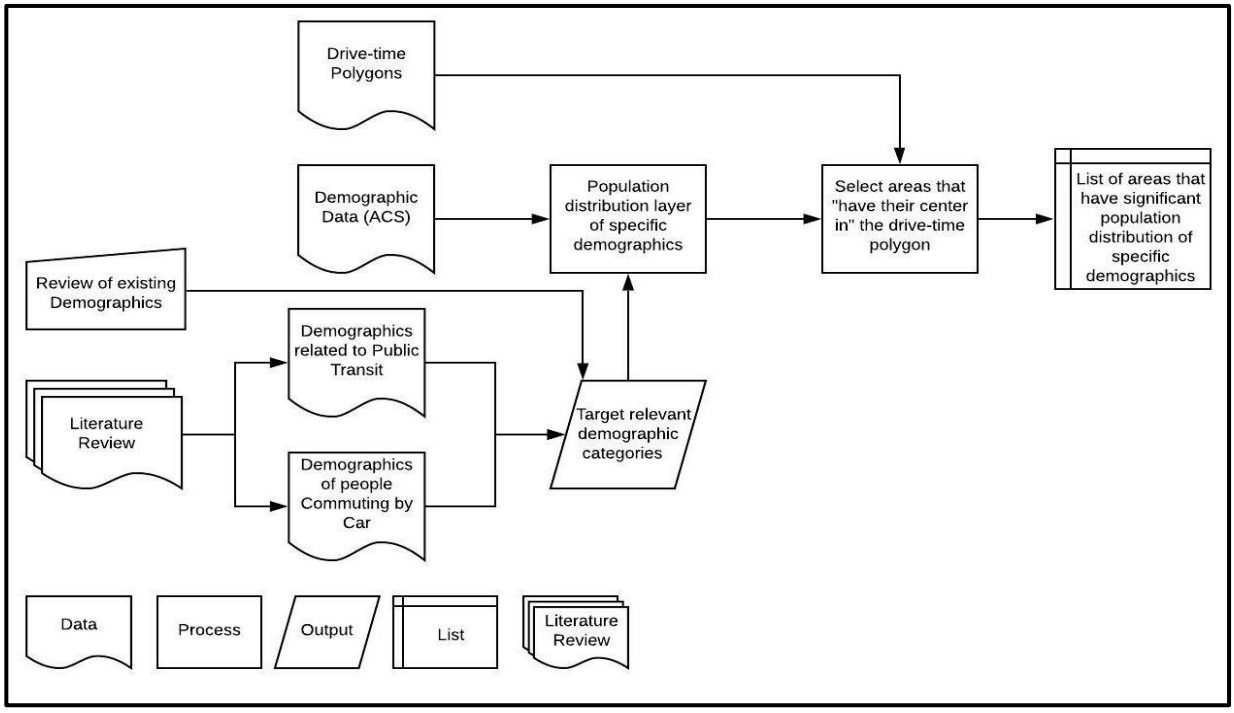

Figure 16: Demographic Identification Flowchart (Identification of areas with a significant density of specific demographics)

5.2 Location Tool: Location Targeting with Google Ads

The drive-time polygons are used to identify areas with the population affected by a specific transportation project. The outer drive-time polygon determines the last area for targeting. Everything outside of that border is considered irrelevant for targeting, hence excluded from analysis. People from the excluded areas may not receive any type of advertisement that is

related to the transportation project. We assume that people outside that region won't be affected since they are too far away from the project's site (i.e., more than an hour away). Consequently, we need to target the stakeholders up to the outer driving polygon border who may be affected by the implemented transportation project.

The most effective way to determine the areas that need to be included or excluded is through the zip codes and produced drive-time polygons. In Google Ads' platform, targeting by Zip Codes is the most precise and computationally feasible way to emulate the drive-time polygons. Based on which drive-time polygon needs to be mapped, a specific relationship between the Zip Code layer and drive-time polygon layer is selected. If the outer drive-time polygon needs to be mapped, the location script identifies Zip Codes that have their center in the outer drive-time polygon. If the inner drive-time polygon needs to be mapped, the location script selects Zip Codes that intersect with the inner drive-time polygon (Figure 17). To create the list of excluded Zip Codes the selection is inverted, meaning that Zip Codes that do not have their center in or do not intersect with the corresponding drive-time polygon are selected. We automated this process and recorded it as a python script to be used in ArcGIS Pro. You can find the commented ArcGIS Pro Script used to identify Zip Codes for exclusion in **Appendix 11**. Since all of North Carolina has been dealt with in terms of exclusion, the final step is to exclude all the other states and countries to leave us the final area of interest.

Google Ads' platform restricts the number of excluded locations to a thousand. This forces the smallest drive-time polygon to include at least three Zip codes. However, it is exceedingly rare that this restriction would have any effect on this type of targeting.

The total number of Zip Codes in North Carolina: 808

Total number of countries as of 2020 excluding the United States: 194

Total number of states (North Carolina is excluded): 49

Zip Codes included in the drive-time polygon >= 3

There are 808 Zip codes in North Carolina; however, 48 of them are not recognized by Google Ads' platform for privacy purposes. Consequently, the available number of Zip Codes for processing is 760. The locations that will always be in the excluded list are given by Countries + States (North Carolina is excluded) = 194 + 49 = 243. So, knowing that Google Ads allows for only 1000 location exclusions, we still have 757 to work with (in terms of Zip Codes), 1000 - 243 = 757 slots for Zip codes exclusions used later in the process. At least three Zip Codes should be included within the drive-time polygon, total number of Zip Codes in North Carolina - available slots for Zip Codes exclusions = 760 - 757 = 3.

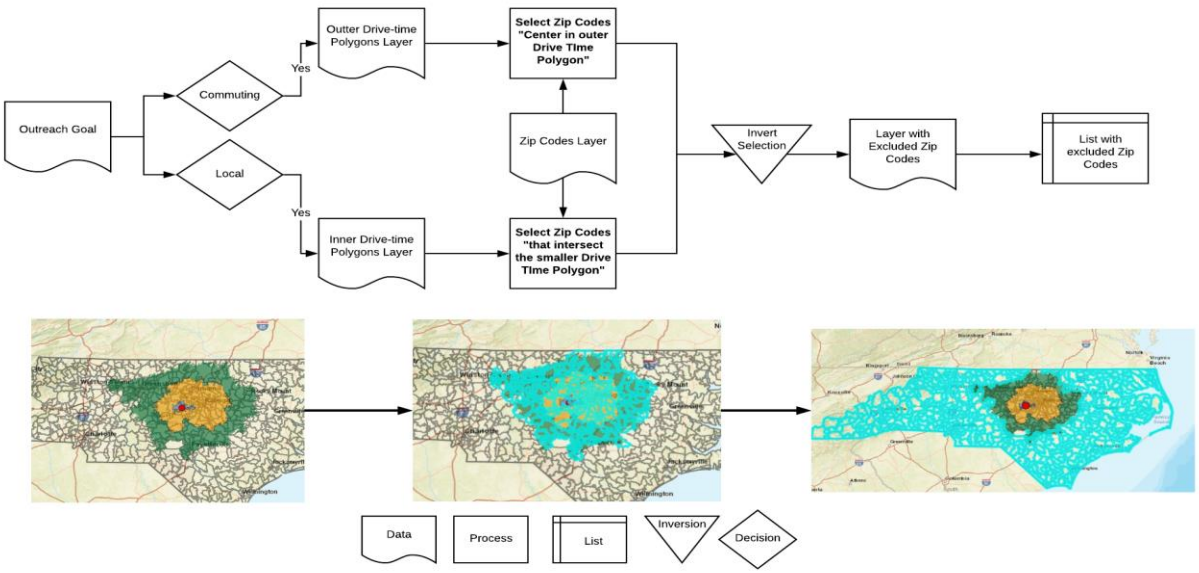

Figure 17: Identification of locations that need to be excluded

5.3 Use of Demographic Hotspot Analysis

We performed a literature review to identify the demographics of stakeholders who may have a greater interest or be more relevant to a specific transportation project. We concluded that specific stakeholder groups are often underrepresented throughout the public outreach process due to economic, cultural or accessibility issues. Feedback from these "underrepresented" stakeholder groups would provide valuable addition to the feedback from traditionally contributing stakeholders as they would help public officials understand non-traditional views and needs. This would be an improvement in the planning and development process. However, engaging traditionally underrepresented demographic groups requires a process that would help officials identify areas of concentrations of these stakeholders. For instance, consider people who regularly use public transportation to go to work - their feedback on a new public transportation project may be more applicable. Demographic profiles were created for stakeholders that use public transit (Table 2) and stakeholders who commute by car (Table 3). Stakeholders who may be affected by the implementation of a public transportation project can now be identified more accurately with the use of the corresponding demographic profile.

Table 2: Demographics of people using public transit ([1] [4] [6] [8])

Demographic category: **Public Transit**
1. **Age:** Younger people use public transit more often a. Majority of trips taken by people between 25 and 54 years in age **2. Ethnicity:** a. The single largest group of riders consists of White/Caucasian riders (40%). Combined communities of color make up a majority of riders (60%). **3. Gender:** a. Female account for 55.5% while males account for 44.5% **4. Household Income:** People below the poverty level are less likely to own, or have access to, a personal vehicle a. Households with annual incomes less than $25,000 were 10 times more likely, on average, to be zero-vehicle households than households with annual incomes of $75,000 and above **5. Household size:** a. Two people are the most common transit rider household size followed by one-person households. 6. **Higher education** implies more frequent use of public transit 7. Public transit is more frequent in **urban areas**

Table 3: Demographic category: Commuting by Car ([4])

Demographic category: Commuting by Car
1. Age: As age increases, car use increases as well. 2. Gender: Car use is predicted by being male 3. Income: As income increases, car use increases as well 4. Household size: The greater the household size, the smaller the percentage of households that use public transportation. So, we assume that these households may use an automobile to commute 5. Car use is more frequent in rural areas

5.4 Creation of Campaigns

Three outreach goals have been established aiming to capture local and commuting stakeholders and those as well as stakeholders that may have a greater interest in the proposed transportation project (based on their demographic profiles). To successfully target and engage the stakeholders that belong to the above categories, we use our developed spatial and demographic tools in conjunction with the targeting options available in popular advertising platforms. Google's targeting option "People in or regularly in targeted locations" is commonly used. As explained by Ginny Marvin in the article "Google is expanding when it shows ads to 'people in targeted locations'" [2], instead of showing ads to people only when they are physically

located in the targeted locations at the time of their search, it also includes people who regularly commute or travel to the targeted locations even when they aren't physically there when they perform a search [2]. We designed our campaigns to also send ads to people who are not in the targeted location but who make searches relevant to the transportation project and regularly commute to the area of interest. The idea is that the location-targeted campaigns can reach people with ads targeted to their work locations when they are home and vice versa [2].

Goal 1: Target local stakeholders.

This approach targets and engages stakeholders that are local to the project area. This is done using the shortest drive-time polygon and the Google Ads targeting option "People in or regularly in targeted locations". For targeting local stakeholders, the Google ads exclusion process mentioned above exclude all areas of the world except this smallest drive-time polygon (Figure 18). This way we only target stakeholders whose main residence is in close to the project's site, people who are mostly in the smallest drive-time polygon. Additionally, the "ad projection time" option is used to further restrict the pool of stakeholders that are eligible to receive the advertisement. For instance, let us consider a specified campaign aiming to target people that have their main residences inside the small polygon. The system would show ads between 7 pm and 12 am, a time period when most companies are closed and consequently employees have returned to their residences.

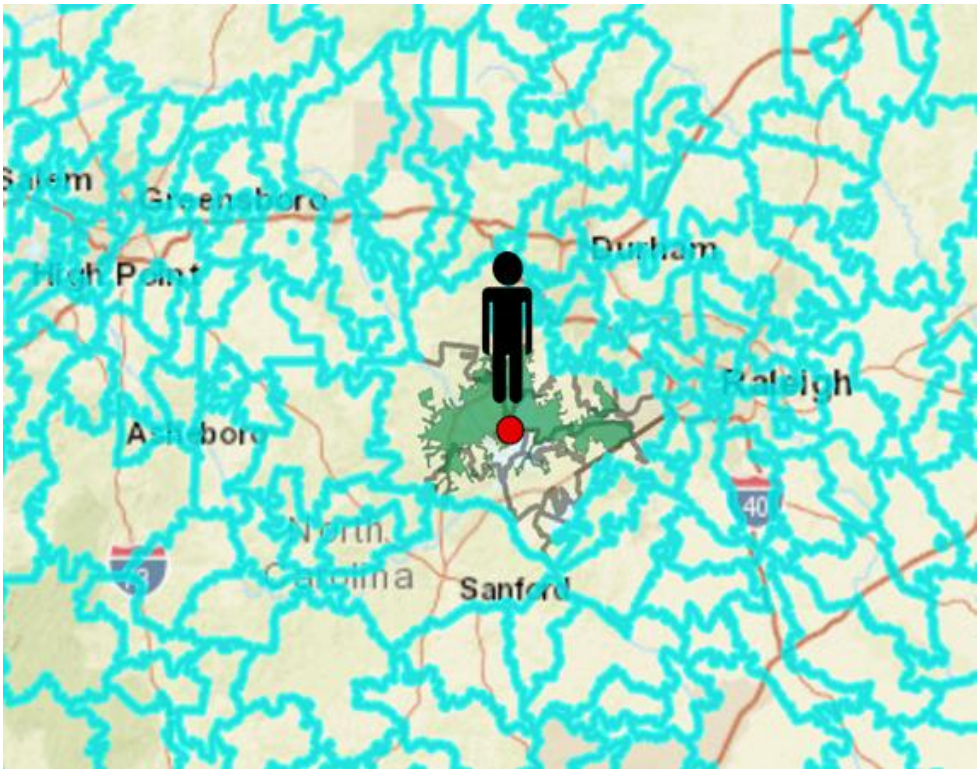

Figure 18: Identification of areas that need to exclude based on the shortest drive-time polygon

Goal 2: Target commuting stakeholders that regularly commute to or through the project's location.

This approach is targeting commuting stakeholders that regularly commute to or through the project's site. The Google Ads targeting option "People in or regularly in targeted locations", as its name indicates, sends advertisements to people that are often in the targeted location but also to people who regularly commute or travel to the targeted location even when they are not physically there [2]. Using our location tool, we further restrict the areas that regularly commuting stakeholders reside in. Only stakeholders who are within the bounds of the outer drive-time polygon (green region) are eligible to receive our advertisements. Stakeholders located outside the outer drive-time polygon (green region) would not be targeted no matter how often they travel to the targeted location (yellow region) since they are in regions that have been excluded regions. Again, the Google Ads exclusion process using the targeting option "People in or regularly in targeted locations" is used to eliminate all areas of the world except locations bounded by the outermost drive-time polygon (green region) (Figure 19).

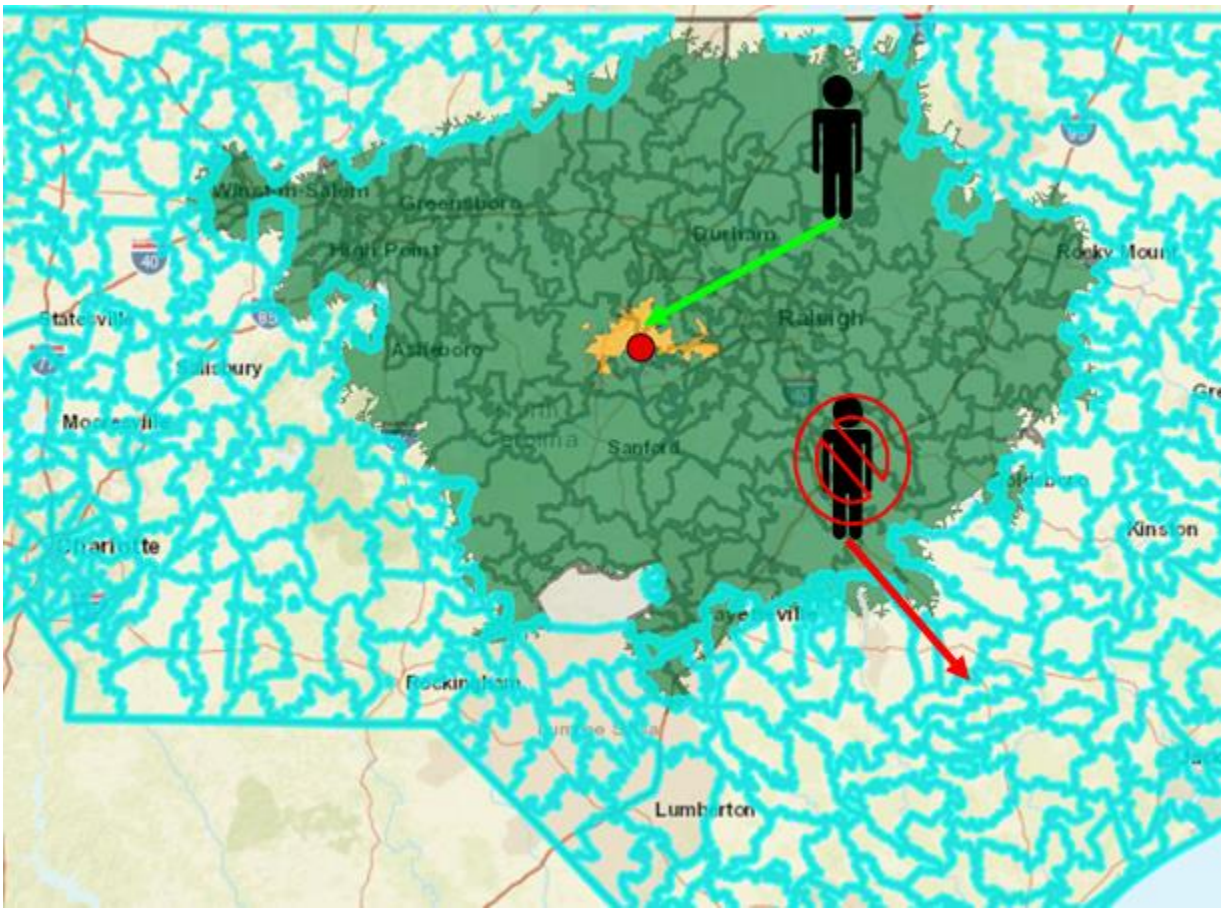

Figure 19: Only regular commuters to the YELLOW area that are within the GREEN area are targeted with advertisements

Goal 3: Target stakeholders with specific demographic profiles.

This approach targets stakeholders who are more relevant or might have a greater interest in specific transportation projects based on their demographic profiles. The location tool in conjunction with the demographic tool pinpoints areas that have a significant population of stakeholders with a specific demographic profile. Regions of demographic interest are identified across the state of North Carolina. Overlaying the demographic density layer with the drive-time polygons produces the final mapping (*Figure 20*) of areas with relevant stakeholders. Finally, these areas are used as specific targeting locations for online outreach campaigns. (Locations are specified either by Zip Codes or by manually drawn circles)

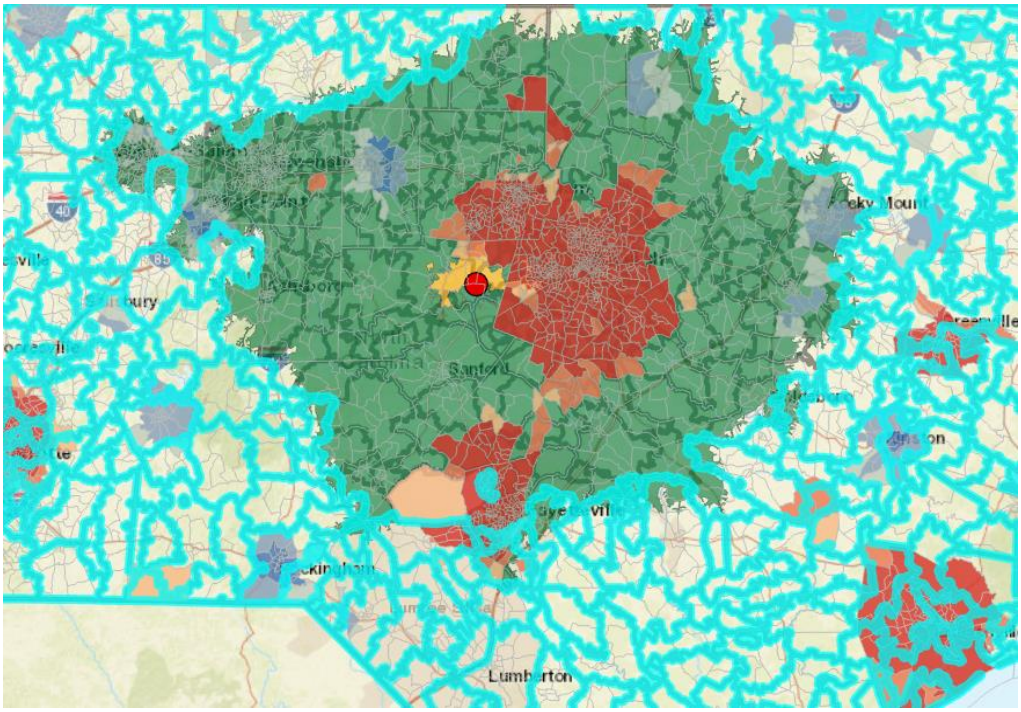

Figure 20: Hotspots of stakeholders with specific demographic profiles

Robotic Process Automation

It would be time consuming to individually run the spatial and geographical tools and use their results to structure advertising campaigns for several transportation projects. Thus, the project team explored the use of Robotic Process Automation to enable the creation of targeted advertising in the most efficient way. Robotic Process Automation, RPA, stands at the process-driven side of the continuum known as Artificial Intelligence. Along with Robotics and Artificial Intelligence technology, scientists and software developers have also constructed programs whose aim is to automate repetitive tasks. Gartner, the well-known news website, defines Robotic Process Automation as follows: “RPA tools perform [if, then, else] statements on

structured data, typically using a combination of user interface interactions, or by connecting to APIs to drive client servers, mainframes or HTML code." [8]

The process is planned so that the RPA calls the corresponding spatial and demographic analysis scripts that run on ArcGIS Pro. The results of the scripts are saved locally for future use by the RPA. Then, the automated script locates the CSV files with the outcome of the analysis and uses them as input to set up the location targeting in a platform such as Google Ads. However, we planned this to be semi-automated allowing the analysts to make changes based on their expert knowledge.

5.5 Spatial Engagement Portal (SPEP)

Once the affected and relevant stakeholders have been attracted, they are directed to the Spatial Engagement Portal (SPEP). The SPEP portal works with ArcGIS Story Maps and ESRI Survey123. For this we developed an interactive, user-friendly spatial public engagement portal that uses the "Story Maps" concept with an interactive "drill-down" online mapping environment [12]. Its aim is to provide detailed information and engage the stakeholders with the perceived project outcomes through a user friendly, highly engaging interface. Additionally, the attracted stakeholders can provide their feedback on the project and any suggestions that they may have. Finally, they are asked to complete a quick survey to help us evaluate our innovative public outreach and engagement approach. We have made a template for this and created four different versions of it for four candidate implementation construction projects.

6. Evaluation

It is vital to assess the success of our proposed public outreach and engagement approach. Some formal methods are followed which allow us to gauge the success of our approach compared to other already existing approaches. The guidelines that were developed by the NCDOT in conjunction with the guidelines from the Florida DOT and the Texas DOT are adjusted and used to measure the effectiveness of our approach. The study was designed to run on two different NCDOT transportation projects. For each construction project, one of two public outreach/engagement methods would be used, the one that NCDOT is currently using and our innovative approach. Finally, the results would be studied to reveal the areas that require improvement and also examine the scientific importance of our findings.

Through literature review, measures for evaluating the effectiveness of public involvement activities have been identified and adjusted to meet our needs. ESRI Survey123 was integrated into our SPEP portal that helps with the evaluation of our targeting and engagement approach. Additionally, Survey123 allows us to collect location information that is relevant to the affected population. "A logical first step in developing a performance methodology for public involvement is to identify appropriate goals (or what the agency wants to achieve) and objectives

(how the agency proposes to achieve the goal) that could provide an effective framework for performance measurement" [3].

Goal 1: Ensure that all interested parties have an opportunity to participate [3]

The aim of this goal is to evaluate our outreach approach. We need to quantitatively measure if we have successfully identified and targeted relevant stakeholders to the transportation project. Qualitative input also plays a large role in distinguishing people who are local or commuting and are perceived to be positively or negatively affected (Information Acquired from [3] and [5]).

Table 4: Indicators to Achieve Goal 1 and Methods of Analysis ([3], [5])

Analysis	**Survey**
1. Outreach a. Number of clicks b. Number of organizations attracted c. Different organizations represented d. Cost 2. Outreach Participation a. Number of forms submitted b. Number of people who clicked on our ad/number of people submitted the form (rate of engagement)	1. Demographics (demographics of people relevant to different transportation projects) a. Race/ethnicity b. Income c. Age d. Education e. Employment f. Parental Status g. Gender h. Household size i. Household vehicles j. Geographic identifier i. Address ii. Zip iii. Neighborhood k. Do you have a mobility impairment? l. Do you identify yourself as an underrepresented group? 2. Do you identify yourself as a local or commuting stakeholder in regard to the project's location? 3. Was the advertising method effective?

Goal 2: Ensure that our engagement method is efficient and effective

The aim of this goal is to evaluate the SPEP portal and its role in the engagement process. These measures require dialogue or interaction with members of the public and are both quantitative and qualitative. They measure whether and how members of the public were

engaged and what kind of experience those participants had as a result. Taken together, these objective and subjective measures can be combined to describe how meaningful the public engagement efforts were [5].

Table 5: Indicators to achieve Goal 2 and Methods of Analysis ([3], [5])

Survey
1. Convenience (Was this the most convenient way to provide initial feedback?) (This can measure the accessibility that our implementation provides) a. Were you provided with contact information for individuals that would address any questions you had prior to the meeting? If you had questions before the meeting, were they adequately addressed? b. Did you experience any issues accessing the SPEP portal? c. Availability of information in languages other than English [1] d. Was this information dissemination technique more effective than other techniques (flyers, post, etc.)? e. Rate how convenient was this method for providing your input regarding the proposed project 2. Clarity of information (Story maps evaluation) a. Was the information you heard beneficial in understanding the project? b. Was the information presented clearly? c. Do you believe the information could have been more easily understood if it was presented differently? d. Do you feel that you have been informed early enough about the project? e. Affected parties feel that ample notice was provided of construction projects f. Stakeholders feel that this engagement method adequately informed them g. Stakeholders feel that this engagement method gave the opportunity to actively participate and express their opinion h. Was the information presented in standard English? i. Was the SPEP portal personalized enough?

All the above indicators align with the Public Involvement Performance measurements that the NCDOT published in 2011. Additionally, to formulate the survey's questions, responses from NCDOT's surveys were considered. Qualitative responses that are related to our goals were used to create survey questions to further connect previous stakeholders' concerns with our current approach.

Initially our team had to wait for a long period of time for NCDOT to identify an implementation construction project. We had requested at least two projects. Due to COVID and other extraneous reasons, the NCDOT was not able to initially identify an implementation project. During this time, our project team had put together a detailed and extensive list of NCDOT candidate projects and shared the list with the NCDOT (**Appendix 5**). In 2021, our team was assigned four construction projects for implementation and was told to pick at least two. The projects are listed below. Our team put together SPIP's for each of these projects based on

the template we had created during the creation phase. These are hyperlinked to the list of projects below. We also performed some initial analysis using the tools for each of these projects. The initial analysis results were also recorded as a story map for project staff to use. SPIP's for the construction projects:

- I-40/I-440 Interchange, I-40 Widening
- U-5751 (US 401/NC 55)
- U.S. 70 Improvements (Durham County)
- Capital Boulevard North Upgrade (Raleigh to Wake Forest, Wake County)

We also held interviews and presented the tool usage to Communications Office analysts, other NCDOT staff, and the project committee. Besides the quarterly meetings we presented to the research committee, we set up a meeting with the staff that works on the construction projects. After the presentation, we performed a demonstration of the analysis platform. Next, we emailed the staff with a survey. One of the purposes of this survey was to understand the stage each project was currently in. We also wanted to collect baseline information about the demographic make-up of the area and expected demographic groups based on the staff's prior experience. We inquired if there were any public information meetings held for the specific project, and if yes, what was the approximate demographic breakdown. If no previous meetings were held then we asked about the expected demographic breakdown by the project staff. The surveys were prepared in Qualtrics and included the initial analysis we performed to get feedback for more improved analysis. You can find the links for each project survey below (Feel free to click on the links below and fill them out. Your responses will not affect the outcome). You can also find a printed version of one these surveys in **Appendix 12**: Surveys Administered to Project Staff.

- U-5307: https://ncsu.qualtrics.com/jfe/form/SV_2o65AiLC2cHqTOK
- I-5701/5703: https://ncsu.qualtrics.com/jfe/form/SV_9HqMRXfXbrt7UMe
- I-5720: https://ncsu.qualtrics.com/jfe/form/SV_4IcCTFaBZIHqHlA
- I-5751: https://ncsu.qualtrics.com/jfe/form/SV_9pGktrk5c69QVD0

We summarized the results of these surveys. When we looked at the responses, we realized that many of the staff provided generic answers to our questions or chose not to answer some/all of them. We later learned that the staff was confused about this survey's purpose, even though this had been communicated clearly before.

Next, we set up meetings with some of the NCDOT project staff along with the Communications Office staff. The feedback we received from the Communications Office staff was incredibly positive. It was noted that the analysis platform could be especially useful for running demographic analysis for large, long-term projects. The story maps concepts could be

useful for most projects; however, the information posted needs to be filtered carefully to avoid any confusion. We also had issues with the IT team regarding our project team setting these up for the NCDOT projects.

7. Conclusion and Recommendations

The overarching goal of this project is to provide added value to existing public outreach strategies by augmenting them with spatial analysis tools, state of the art targeted information dissemination techniques, and a user friendly spatial public engagement portal. We achieved this in four project phases: “Discovery”, “Creation”, “Implementation” and “Transfer”. In each phase we completed a specific set of tasks which in turn contributed to the achievement of an overarching goal. In the Discovery Phase the project team identified all the internal and external resources such as data sources, geospatial analytics tools that can be used, various internet mapping implementations, literature, engagement strategies, etc. The Creation Phase was the most productive phase with the project team creating many important components of the project successfully going beyond what was expected initially. These include but are not limited to: two complex geospatial analysis tools, geoprocessing tools based on the analysis tools, web maps, a robust WebApp to be used for analysis without having any desktop GIS tools on analysts’ computers, a template for the Spatial Public Information Portal (SPIP), detailed workflows to be used for implementation and multiple versions of SPIP story maps in addition to public engagement processes to be followed as well as a few scripts for data processing, tool enablement, etc. During the Implementation phase the project team put its best effort to identify a project for implementation; however, due to several reasons that are out of our control, the evaluation of the methodology was only tested with the analysts on the NCDOT side but not with the general public. The team built specific Public Information Portals for initial alternative construction projects, created/administered information and opinion surveys with NCDOT staff/contractors and conducted interviews with NCDOT analysts and other staff who would be using the analysis platform. We also held group and individual meetings with various staff and project teams to demonstrate the application and collected feedback to complete the implementation and transfer phases.

Our recommendation to the NCDOT is for them to find a way to get the NCDOT personnel to use these tools and strategies to value-add their workflow. The NCSU project team is always happy to provide more training, help with analysis and help with the technology transfer.

Future Work:

Possibilities for future work on this project are clear. First, even though our team was able to administer surveys and implement interviews with NCDOT personnel on the use of the tools and applications, a full implementation of an actual construction project would be especially

useful. It would allow the personnel and the contractors to experience the benefits of such an analysis, especially on large and long-term construction projects. It also would allow them to pinpoint the deficiencies in the analysis tools and information and visualizations provided through digital and in person communication. This could be used to implement future improvements through more useful analysis tools and help set up better strategies for public outreach.

Gathering and organizing historical data to employ data mining techniques to identify trends in public feedback and participation would be insightful. This would also provide us with an insight into the demographic cross-section profiles of participants. We could then relate these to the project type and other project attributes. We could define demographics of stakeholders who chose to provide feedback that may be directly or indirectly affected. We could relate these to the reasons for the public to provide feedback or be present at public information meetings. If we can learn the reasons motivating stakeholders to get involved, we could relate them to concrete and measurable criteria to be used for analysis for future projects. Some of these criteria could be, but are not limited to, the stakeholders' proximity to the project location, their demographic attributes (age, gender, income level, race, and more), as well as perceived direct, indirect, short-term/ long-term benefits and adverse effects.

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Appendices

Appendix 1: GIS Data Including NC State University Sources

Name of Service	Description
NCSU Libraries Geospatial Data Services https://www.lib.ncsu.edu/gis/datalist	Provide all active directories to available GIS data sources.
NCSU Libraries GIS Lookup: Keyword Search https://www.lib.ncsu.edu/gis/search/search.php?q=%22Transportation%22&rk=1&s=ds	Gives a list of all GIS data related to the keyword 'Transportation' (some outdated / old data sources listed)
***NC OneMap** https://www.nconemap.gov/	Collection of GIS data from various agencies of all levels (local, state, federal); various categories including boundaries, demographics, imagery and raster, location, transportation, and utilities
NC OneMap - Parcels for North Carolina https://www.nconemap.gov/pages/parcels	Parcels for each county; can use for population **File (Wake County):** wake_parcels.zip
Bike extracts OpenStreetMap https://extract.bbbike.org/	Allows the user to extract shapefiles and other vector data for any location in the world. Limit: 128 mb.
	File (custom): planet_-78.704,35.667_-78.573,35.901.osm.shp.zip
	File (search): planet_-78.819,35.75_-78.469,35.93.osm.shp.zip
***Open Data Raleigh** https://data-ral.opendata.arcgis.com/	GIS data for City of Raleigh; various categories including transportation, urban planning, and housing & neighborhoods.
***Wake County Open Data** http://data-wake.opendata.arcgis.com/	GIS data for Wake County; various categories including boundaries, demographics, property, transportation, and zoning.
TIGER/Line Geodatabases https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-geodatabase-file.html	National and state boundaries in geodatabases; contains addresses, census blocks, hydrography, rails, roads, school districts, etc. ("geographic entity").
	File: tlgdb_2018_a_37_nc.gdb.zip **Note(s):** State - NC, 2019
	File: tlgdb_2018_a_37_nc_edges.gdb.zip **Note(s):** State - NC, 2019
TIGER/Line with Selected Demographic and Economic Data https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-data.html	American Community Survey (ACS) 5-year estimates in geodatabase form. Linked to geographic entity code.

	File (Block Group): ACS_2017_5YR_BG_37.gdb.zip **Note(s):** State - NC, 2017
	File (Census Group): ACS_2017_5YR_TRACT_37.gdb.zip **Note(s):** State - NC, 2017
	File (County Subdivision): ACS_2017_5YR_COUSUB_37.gdb.zip **Note(s):** State - NC, 2017
TIGER/Line with Selected Demographic and Economic Data (Metadata) https://www.census.gov/programs-surveys/geography/technical-documentation/records-layout/tiger-line-demo-record-layouts.html	Metadata for each attribute of interest in ACS 5-year survey estimates.
American Community Survey (ACS) Guide https://www.census.gov/programs-surveys/acs/guidance/estimates.html	When to use a certain ACS year estimate based on population and data.
TIGER/Line(R) Shapefiles https://www.census.gov/cgi-bin/geo/shapefiles/index.php	Several more categories of data most are repeated from TIGER/Line data sources above.
****NC Capital Area Metropolitan Planning Organization (CAMPO)** https://www.campo-nc.us/mapsdata	**File(s):** CAMPO_DCHC_MTP_2040_Transit_Projects, TRM_V5_Linear_Transit_2015_Base_Network
****Transit Feeds** http://transitfeeds.com/l/140-north-carolina-usa	"Link to the GTFS data to be used to create CAMPO in-house dataset - NC".
*Data.gov - Datasets https://catalog.data.gov/dataset	Comprehensive geospatial datasets available for topics
RTI Synthetic Microdata – Data Download by State http://synthpopviewer.rti.org/obesity/download.html	Gives shapefile (EPSG: 4326) of populations greater than or equal to 20 and their BMIs.
*Decennial Census of Population and Housing https://www.census.gov/programs-surveys/decennial-census/data/datasets.2020.html	Decennial Census of Population and Housing Datasets. All years up to year 2020. Demographic Profile with Geos Summary File Dataset for North Carolina. **File(s):2020:** nc20201.dp.zip **2010**, nc20101.dp.zip
USGS National Transportation Dataset (NTD) Downloadable Data Collection https://catalog.data.gov/dataset/electric-vehicle-population-data	Features associated with transport; just TIGER/Line data formatted, available in the National Map Viewer **File:** TRAN_North_Carolina_State_Shape.zip
Web Services:	
NC OneMap https://services.nconemap.gov/secure/rest/services	Many North Carolina statewide feature and orthoimagery layers
Wake County https://maps.wakegov.com/arcgis/rest/services	Web services hosted by Wake County
City of Raleigh https://maps.raleighnc.gov/arcgis/rest/services	Web services hosted by City of Raleigh

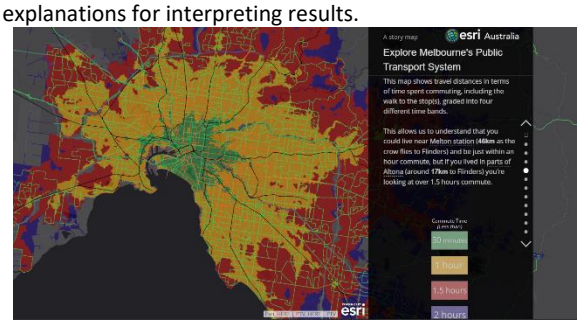
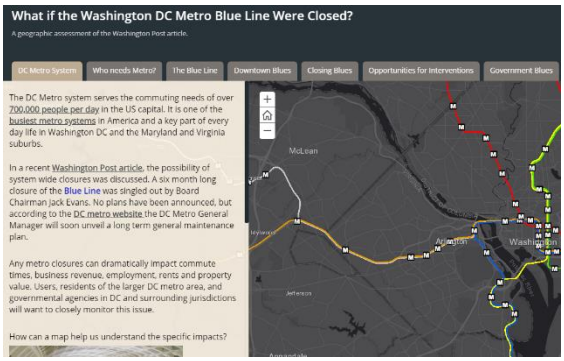
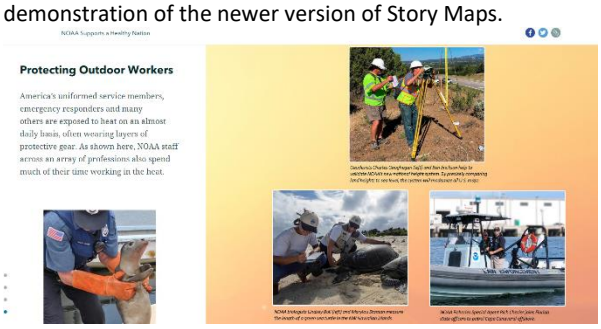
NC Emergency Management https://spartagis.ncem.org/arcgis/rest/services/Public	Web services hosted by NC Emergency Management
USA Public Buildings http://www.arcgis.com/home/item.html?id=d5d5b513a40145ffa60b67d9c7ab9680	Public Buildings File: 1974-Present layer package
US Catalog: https://catalog.data.gov/dataset/?metadata_type=geospatial	Data and Web Services by US Government

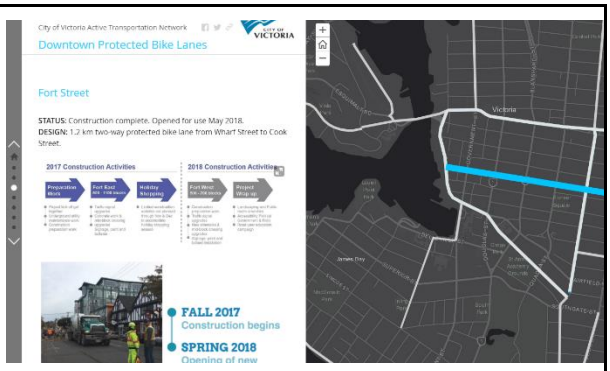
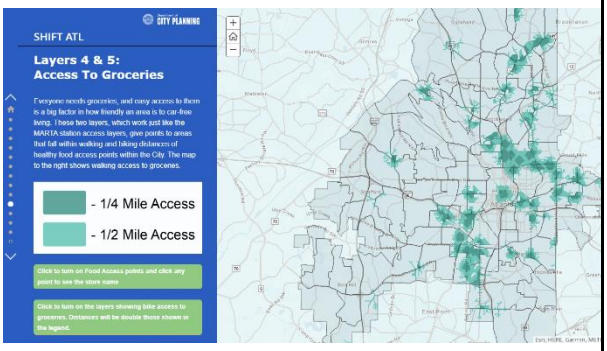
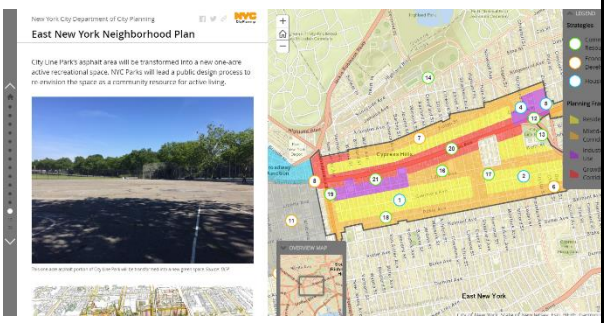
Appendix 2: NC Department of Transportation GIS Data

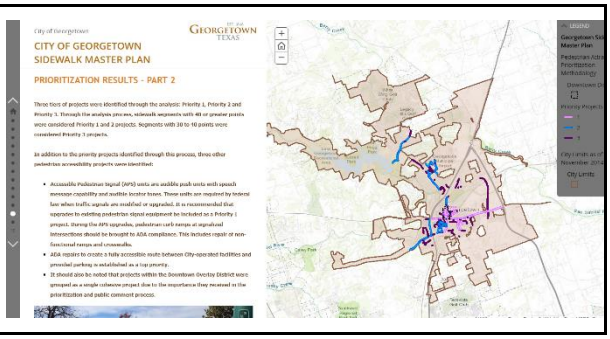
Name of Service	Description
Connect NCDOT - GIS Data Layers http://ncdot.maps.arcgis.com/home/index.html	NCDOT related GIS data, updated quarterly.
Road Data	**File (Road Characteristics Arcs File Geodatabase Format):** NCRouteCharacteristics_GDB.zip **Note(s):** Road attributes for state roads (i.e., "Interstate, US, NC, Secondary Routes, Ramps"); "all non-state maintained and projected roads." *-Road Characteristics Field Descriptions (pdf)* *-Guide to NCDOT Eleven Digit Route Number (pdf)*
	File (NCRoutes File Geodatabase Format): NCRoutes_GDB.zip **Note(s):** Linearly referenced attributes by "County/Route/Milepost"; "all non-state maintained and projected roads." *-NCDOT Routes Field Descriptions (pdf)*
	File (NCRouteArcs File Geodatabase Format): NCRouteArcs_GDB.zip **Note(s):** State Road system with linearly referenced attributes; "all non-state maintained and projected roads." *-NCDOT Route Arcs Field Descriptions (pdf)*
Boundary Data	**File (Municipal Boundaries):** MunicipalBoundaries.zip **Note(s):** Polygon shapefile of "Powell Bill" (state street-aid program) municipalities.
	File (State MPO/RPO Boundaries): MPO_RPO_BOUNDARY.zip **Note(s):** MPO (Metropolitan and Rural Planning Organizations) and RPO (Rural Planning Organizations) boundaries for whole state. "Include all territory in Census 2010 UZAs (urbanized areas))."
	File (Smoothed Urban Boundaries): Smooth_Boundary.zip **Note(s):** 2010 NC Census urban area boundaries; smoothed, original from US Census Bureau
	File (County Boundaries): CountyBoundary.zip **Note(s):** Source is from North Carolina Geodetic Survey
	File (DOT Division Boundaries): DOTDivisionBoundary.zip

	Note(s): NCDOT Division boundaries
	File (County Boundary Shoreline): CountyBoundaryShoreline.zip **Note(s):** County boundaries with shoreline
Other NCDOT Data and Web Services:	**File (State Bicycle Routes):** Bikeroutes_shp.zip **Note(s):** NC bike routes "as defined by the Division of Bicycle and Pedestrian Transportation"; North Carolina Stateplane NAD83 meters *-State Bicycle Routes (pdf)*
	File (NCDOT Bridges & Other Structures): NCDOTStructureLocations.zip **Note(s):** Bridges and signs
	File (NCDOT Rail Division Data): NC_RailLayers_GDB.zip **Note(s):** NCDOT rail track, crossings (grade/separate), facilities (Amtrack related)
Traffic Survey GIS Data Products & Documents https://connect.ncdot.gov/resources/State-Mapping/Pages/Traffic-Survey-GIS-Data.aspx	Traffic survey data from 2018 **File(s):** ncdot-2015-vc-stations, NCDOT 2018 AADT Stations Shapefile Description, NCDOT 2018 Traffic Segments Shapefile Description
Crash Data and Maps https://connect.ncdot.gov/resources/safety/Pages/Crash-Data.aspx	**File:** 2014 - 2018 Total Crash Frequency by Intersection
Road Inventory Data and Reports https://connect.ncdot.gov/resources/State-Mapping/Pages/Road-Inventory-Data-and-Reports.aspx	**File:** 2019 1st Quarter Mileage Report
Traffic Volume https://connect.ncdot.gov/resources/State-Mapping/Pages/Traffic-Monitoring-Reports-Statistics.aspx	**File:** 2018 Excel Spreadsheet
NCDOT Public Web Services https://gis11.services.ncdot.gov/arcgis/rest/services	**All public Web Services** **(Source: Eric Wilson)**
NCDOT ArcGISOnline Web Services https://services.arcgis.com/NuWFvHYDMVmmxMeM/arcgis/rest/services/	**All AGOL Web Services** **(Source: Eric Wilson)**
NCDOT ATLAS Services https://gis23.services.ncdot.gov/arcgis/rest/services https://gis24.services.ncdot.gov/arcgis/rest/services	**ATLAS REST Services** **Requires NCID Authentication.** **(Source: Eric Wilson)**

Appendix 3: ESRI Story Maps & ArcGIS Web Mapping Application Examples

Name of Application	Description
Explore Melbourne's Public Transport System http://esriau.maps.arcgis.com/apps/MapJournal/index.html?appid=780ce9229b1f497eb97222f410c9192c#	A good example of the 'Drive Time' tool in use with detailed explanations for interpreting results. 
What if the Washington DC Metro Blue Line Were Closed? https://arcgis-content.maps.arcgis.com/apps/MapSeries/index.html?appid=6e5dbdc88fc3488b95257baad8898309	Professional story map that details the impact of commute time from station to station. 
NOAA Supports a Healthy Nation https://storymaps.arcgis.com/stories/18f938b4fb444a139ff49d2f4358b22f	Does a nice job narrating what NOAA does; a demonstration of the newer version of Story Maps. 
Downtown Protected Bike Lanes https://vicmap.maps.arcgis.com/apps/webappviewer/index.html?id=92ffcfd4764e485e8e0b2c37cced4b78	Use of easy to read, clear, and themed contrasting images allows citizens to see which bike lanes are protected and what development efforts are being put in-- something to aim for in the SPEP.

	
***SHIFT ATL** https://gis.atlantaga.gov/shiftatlanta/	"Gives points to areas that fall within walking and biking distance of certain access points within the city." Also, details on methods to reach the "widest array of stakeholders" in the city (Areas of Analysis). 
East New York Neighborhood Plan http://dcp.maps.arcgis.com/apps/MapJournal/index.html?appid=f941ce15e1494c75a7eb1b2f9c2754f2	Another nice looking map; this one pinpoints proposed project locations for improving public life, with lots of pictures. 
CITY OF GEORGETOWN SIDEWALK MASTER PLAN http://georgetowntx.maps.arcgis.com/apps/MapJournal/index.html?appid=f8ab659f07944842b3919fde32023c7f	This one shows sidewalks that needed renovation based on public input along with a suitability analysis for prioritizing / ranking sidewalks.

Appendix 4: Spatial Analysis Tools

Name of Tool	Description
Closest Facilities https://pro.arcgis.com/en/pro-app/help/analysis/networks/closest-facility-analysis-layer.htm *-Specific questions, slower, output true route along road network, driving directions provided*	"The closest facility solver in ArcGIS Network Analyst is used to determine the cost of traveling between incidents and facilities to find which ones are nearest. You can perform closest facility analysis to quickly learn which hospitals are closest to a car crash, for example. Or, you can determine which fire stations are nearest to a fire. You can also add barriers to better model real-world travel impediments." (ESRI). **Example:** • Find facilities (businesses) closest to incidents (transportation projects).
***Origin-destination cost matrix analysis** https://pro.arcgis.com/en/pro-app/help/analysis/networks/od-cost-matrix-analysis-layer.htm *-Further analysis, faster, output straight lines only, no driving directions*	"An origin-destination (OD) cost matrix analysis can be used to create a matrix showing travel times or distances along a transportation network using a network dataset. You can use the OD cost matrix solver to assign customer locations to the nearest stores, for example, where you do not need the actual route and driving directions… . The results of OD cost matrix analyses often become input for other spatial analyses in which the network cost is more appropriate than straight-line cost" (ESRI). **Example:** • Which are the 'best' transportation infrastructures by driving time (longest/shortest) that reach the most stakeholders in a city? • Which stakeholders are located nearby to project sites? • How many people live within a certain distance of each project location (Use with Summary Statistics tool)? *-"Hot Spot Analysis tool uses the results of an OD cost matrix analysis to show statistically significant spatial clustering"* *-"Generate Network Spatial Weights calls the OD cost matrix solver to create an SWM (spatial weights matrix) file, which can be input to other tools like Spatial Autocorrelation"*
Generate Service Areas https://pro.arcgis.com/en/pro-app/help/analysis/networks/service-area-analysis-layer.htm	"A service area is a region that can be reached from a location within a given travel time or travel distance. Service areas help you evaluate coverage, accessibility, or efficiency. The concentric areas around the point or points demonstrate how these things are affected by costs in the network. Service areas can show you how long of a drive it would be to reach a certain percentage of a population. Or, areas between service areas can reveal where consumers live who are not close enough to a store." (ESRI).

	Example: • How far can a stakeholder drive from a project site in 5 minutes? • What areas are covered within a 5-mile drive distance of project sites? • What areas are within 10 minutes of our transportation infrastructures?
Suitability Analysis https://pro.arcgis.com/en/pro-app/help/analysis/business-analyst/understanding-suitability-analysis.htm	"Suitability Analysis allows you to qualify, compare, and rank candidate sites based on how closely they adhere to criteria that you select and define" (ESRI). **Example:** • Determine the best meeting places that don't interfere with construction paths (for project sites), but remain close to the site, large highways and easily accessible pedestrian sidewalks.

Appendix 5: NCDOT Construction Projects in Development as of October 6th 2019

Name of Project	County	Estimated Cost	Start Date	End Date	First Public Meeting Date	Second Public Meeting Date	STIP Number	Status	Link
U.S. 17 Hampstead Bypass & Military Cutoff Road Extension	Multiple	$51.6 million (U-4751), $133 million (R-3300B), unfunded (R-3300A)	2017	TBD	October 19, 2017	-	U-4751, R-3300, U-5732	-	https://www.ncdot.gov/projects/us-17-hampstead-bypass/Pages/default.aspx
U.S. 74 Express Lanes - I-277 to Wallace Lane	Mecklenburg	$13.7 million	2017	TBD	-	-	U-5526	-	https://www.ncdot.gov/projects/us-74-express-lanes-i-277/Pages/default.aspx
Harkers Island Bridge Replacement	Carteret	$36.18 million	2019	2022	March 2, 2017	-	B-4863	-	https://www.ncdot.gov/projects/harkers-island/Pages/default.aspx
N.C. 105 Widening	Watauga	49.3 million	2019	TBD	-	-	R-2566B	-	https://www.ncdot.gov/projects/nc-105-widening/Pages/default.aspx
Rea Road Extension	Union	$49 million	2019	TBD	June 20, 2017	-	U-3467	Temporarily suspended.	https://www.ncdot.gov/projects/rea-road-extension/Pages/default.aspx
U.S. 19/74/64/129 Improvements	Cherokee	$11.3 million	2019	TBD	Dec. 8, 2016	-	R-5735	-	https://www.ncdot.gov/projects/us-19-improvements/Pages/default.aspx
U.S. 321 Widening - Hickory to Lenoir	Multiple	$288.3 million	2019	TBD	July 11-12, 2016	July 27, 2017 October 12, 2017	U-4700	Temporarily suspended.	https://www.ncdot.gov/projects/us-321-hickory-lenoir/Pages/default.aspx
U.S. 1/15-501 Improvements	Moore	$27.8 million	2020	TBD	Sept. 18, 2017	-	U-5814, U-5815	Preliminary engineering activities for	https://www.ncdot.gov/projects/us-1-15-501-moore/Pages/default.aspx

(Moore County)								sections U-5814 and U-5815B of this project have been temporarily suspended	
Russ Avenue Improvements	Haywood	$17.75 million	2020	TBD	November 14, 2017	-	U-5839	-	https://www.ncdot.gov/projects/russ-avenue/Pages/default.aspx
U.S. 19/23 (Future I-26) Improvements Project	Buncombe	$200 million	2020	TBD	2019	-	A-0010A	Temporarily suspended.	https://www.ncdot.gov/projects/us-19-23-improvements/Pages/default.aspx
U.S. 220 Widening (Greensboro)	Guilford	$16.9 million	2020	2022	November 13, 2018	-	U-5892	-	https://www.ncdot.gov/projects/us-220-widening-greensboro/Pages/default.aspx
14th Street Widening	Pitt	12.03 million	2021	TBD	November 9, 2017	April 3, 2018	U-5917	-	https://www.ncdot.gov/projects/14th-street/Pages/default.aspx
Asheville I-26 Connector	Buncombe	$950 million	2021	TBD	December 4, 2018	-	I-2513	-	https://www.ncdot.gov/projects/asheville-i-26-connector/Pages/default.aspx
Catawba Avenue Improvements	Mecklenburg	TBD	2021	TBD	April 10, 2014	June 21, 2016	R-2555B	Temporarily suspended.	https://www.ncdot.gov/projects/catawba-avenue/Pages/default.aspx
East John Street/Old Monroe Road Widening	Multiple	$101 million	2021	TBD	July 31, 2017	October 11, 2016	U-4714	Temporarily suspended.	https://www.ncdot.gov/projects/east-john-old-monroe/Pages/default.aspx
Fire Tower/Portertown Roads Widening	Pitt	$30 million	2021	TBD	Sept. 22, 2016	July 31, 2017	U-5785, U-5870	-	https://www.ncdot.gov/projects/fire-tower-portertown-widening/Pages/default.aspx

Liberty Road I-40 Interchange	Buncombe	$41.1 million	2021	TBD	May 23, 2017	-	I-4759	Temporarily suspended.	https://www.ncdot.gov/projects/liberty-road-i-40-interchange/Pages/default.aspx
U.S. 21 Widening	Mecklenburg	$42.7 million	2021	TBD	April 12 2018	April 19, 2018	U-5767, U-5771	Temporarily suspended.	https://www.ncdot.gov/projects/us-21-widening/Pages/default.aspx
U.S. 70 Improvements in James City	Craven	$171.6 million	2021	TBD	Feb 26, 2019	February 27, 2019	U-5713, R-5777AB	-	https://www.ncdot.gov/projects/us-70-james-city/Pages/default.aspx
Capital Boulevard North Upgrade (Raleigh to Wake Forest)	Wake	$465 million	2022	TBD	October 9, 2018 October 29, 2018	May 6, 2019	U-5307	Temporarily suspended.	https://www.ncdot.gov/projects/capital-boulevard-upgrade/Pages/default.aspx
I-40/I-440 Interchange & I-40 Widening	Wake	$179 million	2022	2024	May 6, 2019 May 9,2019	Fall 2019	I-5701, I-5703	Temporarily suspended.	https://www.ncdot.gov/projects/40-440-us-1-interchange/Pages/default.aspx
N.C. 73 Improvements (Mecklenburg & Cabarrus)	Multiple	$160.8 million	2022	TBD	January 28, 2019	Jan 29, 2019	R-2632AB, R-5706	-	https://www.ncdot.gov/projects/nc-73-mecklenburg-cabarrus/Pages/default.aspx
Sweeten Creek Road Improvements	Buncombe	$49.52 million	2022	TBD	Nov 13, 2018	-	U-2801A	Temporarily suspended.	https://www.ncdot.gov/projects/sweeten-creek-road/Pages/default.aspx
U.S. 158 (Reidsville Road) Improvements	Multiple	$110 million	2022	TBD	October 2017 (Design)	October 10, 2019	R-2577	-	https://www.ncdot.gov/projects/us-158-reidsville-road/Pages/default.aspx
U.S. 74 Express Lanes - Conference Drive to I-485	Mecklenburg	$405 million	2022	TBD	-	-	U-2509	-	https://www.ncdot.gov/projects/us-74-express-lanes/Pages/default.aspx

Airport Parkway	Rowan	$33.4 million	2023	TBD	June 12, 2018	-	U-5901	Temporarily suspended.	https://www.ncdot.gov/projects/airport-parkway/Pages/default.aspx
N.C. 73 Improvements (Lincoln & Mecklenburg)	Multiple	$177 million	2023	2026	February 5, 2018	October 16, 2018 October 18, 2018	R-5721, U-5765	-	https://www.ncdot.gov/projects/nc-73-improvements-lincoln-mecklenburg/Pages/default.aspx
U.S. 25/U.S. 70 Improvements	Madison	$34.7 million	2023	TBD	Summer 2019	-	R-5837	-	https://www.ncdot.gov/projects/us-25-us-70-improvements/Pages/default.aspx
Allen Road Widening	Pitt	$30.4 million	2024	TBD	March 27, 2017	March 29, 2018	U-5875	Temporarily suspended.	https://www.ncdot.gov/projects/allen-road/Pages/default.aspx
Evans Street/Old Tar Road Widening	Pitt	$70.05 million	2024	TBD	-	-	U-2817	Temporarily suspended.	https://www.ncdot.gov/projects/evans-old-tar/Pages/default.aspx
N.C. 54 Corridor Improvements	Multiple	$297 million	2024	TBD	July 10-11, 2018	-	U-5774	Temporarily suspended.	https://www.ncdot.gov/projects/nc-54-corridor-improvements/Pages/default.aspx
Poplar Tent Road Widening	Cabarrus	$70 million	2024	TBD	October 14, 2019	-	U-3415	Temporarily suspended.	https://www.ncdot.gov/projects/poplar-tent-road/Pages/default.aspx
Independence Boulevard Extension	New Hanover	$159.8 million	2025	TBD	July 22, 2019	-	U-4434	Temporarily suspended.	https://www.ncdot.gov/projects/independence-boulevard/Pages/default.aspx
Kinston Bypass	Multiple	$379.1 million	2025	TBD	August 17-20, 2019	-	R-2553	-	https://www.ncdot.gov/projects/kinston-bypass/Pages/default.aspx
U.S. 64 Improvements in Apex & Cary	Wake	$113.8 million	2025	TBD	June 21, 2018	May 6, 2019 May 14, 2019	U-5301	Temporarily suspended.	https://www.ncdot.gov/projects/us-64-apex-cary/Pages/default.aspx
N.C. 147 Extension	Wake	$63.5 million	2027	TBD	Fall 2019	-	U-5966	Temporarily suspended.	https://www.ncdot.gov/projects/nc-147-extension/Pages/default.aspx

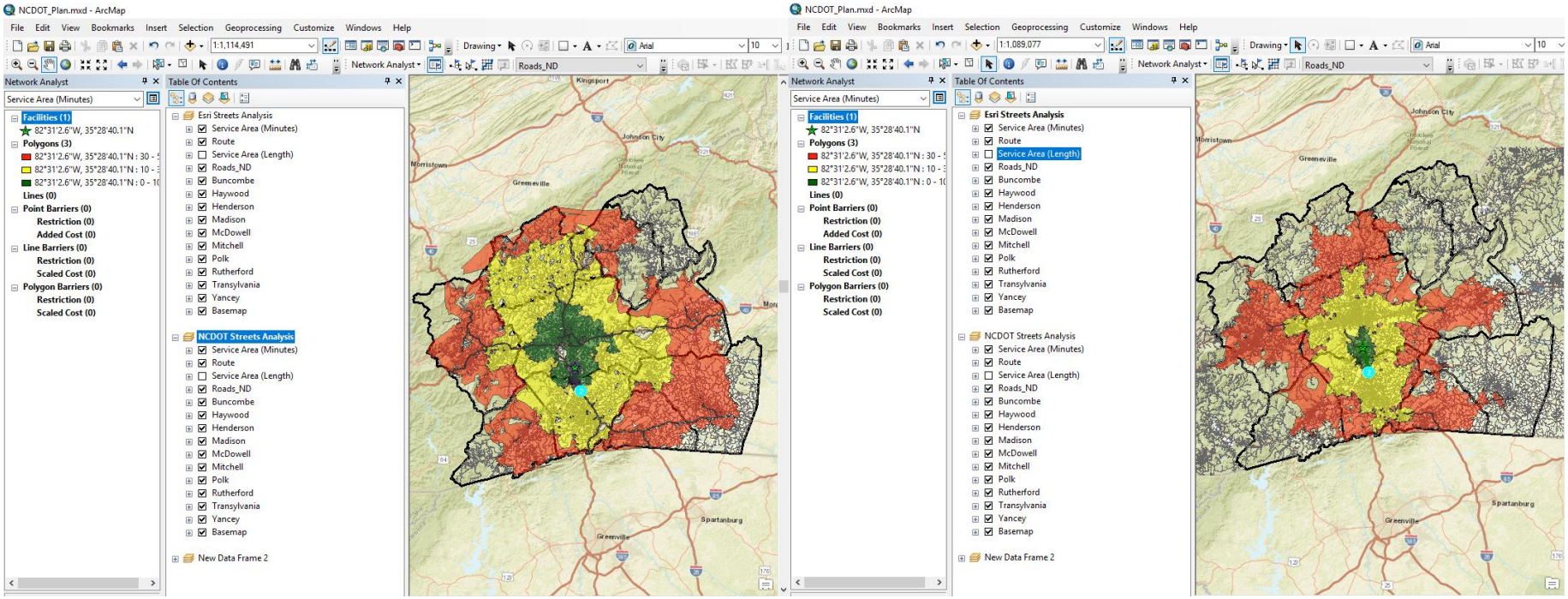
U.S. 117 Corridor Upgrade Near Goldsboro	Multiple	TBD	2027	TBD	November 29, 2018 & December 03-04, 2018	2019-2020 (Conceptual Designs) 2022 (Preliminary Design Maps)	U-3125	Temporarily suspended.	https://www.ncdot.gov/projects/us-117-goldsboro/Pages/default.aspx
Macy Grove Road Improvements	Multiple	$40.4 million (U-2800); estimated $19 million, currently unfunded (U-4734)	June 2013	TBD	August 2016	-	U-2800, U-4734	-	https://www.ncdot.gov/projects/macy-grove-road/Pages/default.aspx
N.C. 150 Widening Improvements	Multiple	$269.47 million	August 2019	TBD	August 2016	-	R-2307 and I-5717	-	https://www.ncdot.gov/projects/nc-150/Pages/default.aspx
I-26 Widening	Multiple	$6 million for right of way; $392 million for construction	October 2019	2024	October 13, 2016	April 16, 2018	I-4400, I-4700	-	https://www.ncdot.gov/projects/i-26-widening/Pages/default.aspx
U.S. 401/Ligon Mill Road/Mitchell Mill Road Intersection	Wake	$17.94 million	July 2020	TBD	December 4, 2018	May 6, 2019	U-5748	-	https://www.ncdot.gov/projects/us-401-improvements-wake/Pages/default.aspx
N.C. 62 Widening - Ramada Road to U.S. 70	Alamance	$11.4 million	November 2020	2022	Spring 2017 Fall 2017	April 26, 2018	U-5844	Temporarily suspended.	https://www.ncdot.gov/projects/nc-62-widening/Pages/default.aspx
I-95 Widening North of Fayetteville	Multiple	$708.9 million	Fall 2019	2024	October 18, 2018	November 8, 2018	I-5986A, I-5986B	-	https://www.ncdot.gov/projects/i-95-widening/Pages/default.aspx

U.S. 70 Havelock Bypass	Craven	$221.26 million	Fall 2019	2024	December 2011	-	R-1015	-	https://www.ncdot.gov/projects/us-70-havelock-bypass/Pages/default.aspx
Nashville-Rocky Mount Projects	Nash	$105 million	Fall 2020	Summer 2023	December 13, 2018	-	R-5720, U-5996, U-5026	-	https://www.ncdot.gov/projects/nashville-rocky-mount-projects/Pages/default.aspx
I-85 Widening - Gaston County	Gaston	$262.78 million	2024	2028	May 21-22, 2019	Winter 2020	I-5719, U-3608 & U-5800	Temporarily suspended.	https://www.ncdot.gov/projects/i-85-widening-gaston-county/Pages/default.aspx
Corridor K' Improvements	Multiple	$680.1 million	N/A	N/A	February 12, 2019 February 14, 2019	2020-2021	A-0009	-	https://www.ncdot.gov/projects/corridor-k/Pages/default.aspx
U.S. 158 Widening	Northampton	R-2582: $56.8 million,R-2584: $112.3 million	N/A	N/A	-	-	R-2582, R-2584	-	https://www.ncdot.gov/projects/us-158-widening/Pages/default.aspx
Mid-Currituck Bridge	Currituck	$491 million	Spring 2021	TBD	-	May 6, 2019	R-2576	-	https://www.ncdot.gov/projects/mid-currituck-bridge/Pages/default.aspx
U.S. 70 Improvements at Brier Creek Parkway & T.W. Alexander Drive	Multiple	$90 million	Spring 2021	TBD	April 6, 2017 October 30, 2018 November 1, 2018	May 6, 2019	U-5518	-	https://www.ncdot.gov/projects/us-70-brier-creek/Pages/default.aspx
U.S. 70 Improvements in Durham	Durham	$136.12 million	Spring 2024	TBD	-	-	U-5720	Temporarily suspended.	https://www.ncdot.gov/projects/us-70-durham/Pages/default.aspx
N.C. 42 Widening	Johnston	$117.4 million	Spring 2025	2028	May 10, 2018	-	R-3410	Temporarily suspended.	https://www.ncdot.gov/projects/nc-42-widening/Pages/default.aspx
I-485 Express Lanes	Mecklenburg	$289.5 million	Summer 2019	2022	July 25, 2018	June 27, 2019	I-5507	-	https://www.ncdot.gov/projects/i-485-express-lanes/Pages/default.aspx

					July 26, 2018				
U.S. 17 Business Improvements	Perquimans	NA	Summer 2019	2021	September 2013	June 28, 2019	R-4467	-	https://www.ncdot.gov/projects/us-17-business/Pages/default.aspx
Raeford Road Median (Fayetteville)	Cumberland	$147.8 million	Summer 2020	TBD	-	-	U-4405	Temporarily suspended.	https://www.ncdot.gov/projects/raeford-road-median/pages/default.aspx
Big Mill Farm/Hopkins Road Improvements	Forsyth	$27 million	Summer 2022	TBD	Aug. 24, 2017	-	U-5760	-	https://www.ncdot.gov/projects/big-mill-farm-hopkins/Pages/default.aspx
15th Street Improvements	Beaufort	$16.2 million	TBD	TBD	-	-	U-5860	Temporarily suspended.	https://www.ncdot.gov/projects/15th-street/Pages/default.aspx
Cape Fear Crossing	Multiple	$620 million to $995 million	TBD	TBD	April 29-30, 2019	-	U-4738	-	https://www.ncdot.gov/projects/cape-fear-crossing/Pages/default.aspx
Complete 540	Multiple	Approximately $2.2 billion	TBD	TBD	February 20-22, 2018	May 6, 2019	R-2721A, R-2721B, R-2828, R-2829	-	https://www.ncdot.gov/projects/complete-540/Pages/default.aspx
Carolina Bays Parkway Extension	Brunswick	$551.7 million ($185 million in S.C. and $366.7 million in N.C.)	TBD	TBD	Spring 2019	Summer 2020	R-5876 (N.C.), P029554 (S.C.)	-	https://www.ncdot.gov/projects/carolina-bays-parkway/Pages/default.aspx
I-440 Interchange Improvements at Glenwood Avenue	Wake	$231.3 Million	TBD	TBD	September 18, 2018 September 20, 2018 September 25, 2018 September 29, 2018	May 6, 2019 June 25, 2019	I-5870	-	https://www.ncdot.gov/projects/i-440-glenwood/Pages/default.aspx

N.C. 119 Relocation	Alamance	$109.9 million	TBD	TBD	-	-	U-3109A, U-3109B	-	https://www.ncdot.gov/projects/nc-119/Pages/default.aspx
N.C. 12 Improvements South of Rodanthe	Multiple	TBD	TBD	TBD	-	-	R-4070B	-	https://www.ncdot.gov/projects/nc-12-south/Pages/default.aspx
Amboy & Meadow Roads Widening	Buncombe	$49.3 million	Winter 2025	TBD	March 28, 2019	Spring 2020	U-4739	-	https://www.ncdot.gov/projects/amboy-meadow-roads/Pages/default.aspx

Appendix 6: Drive-Time Service Area Comparison - NCDOT vs ESRI Roadway Network



Appendix 7: Analysis Tools User Selection Options

A. Network Analysis Tool User Selection Options

Drive time tool parameter inputs:

- Using distance or time (miles or minutes)
- Distance/time range of interest (i.e., 15, 20, 25 minutes)
- Point location of interest (point within project area)

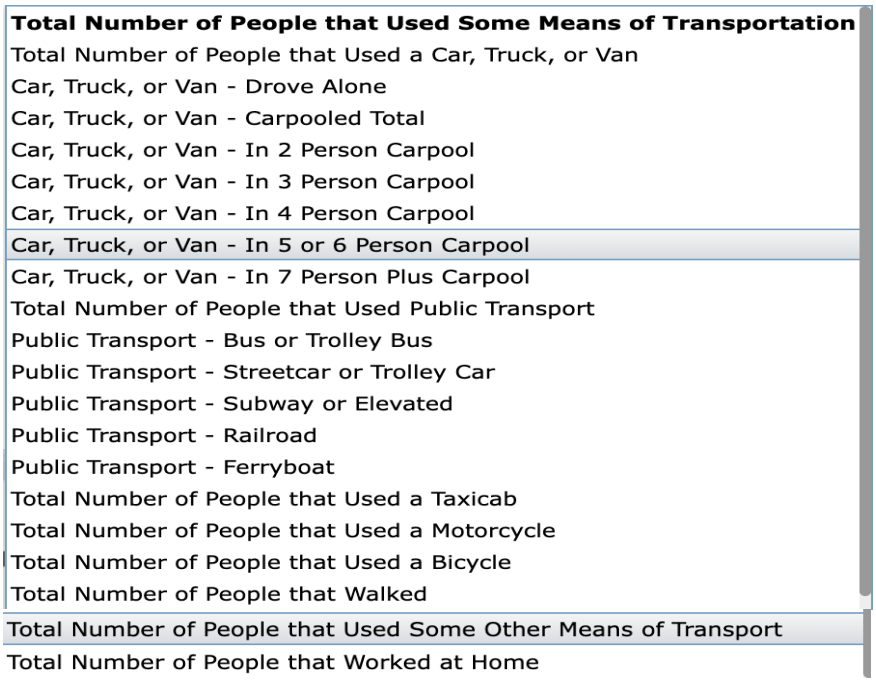
Demographic categories of interest:

- **Time Traveling to work**
  - Midnight to 5 am
  - 30-minute time ranges from 5am to 9am
  - 1 hour time ranges 9am to noon
  - Noon to 4pm
  - 4pm to midnight

Total Number of People who Traveled to Work Between 12:00 p.m. to 12:00 a.m.
12:00 a.m. to 4:59 a.m.
5:00 a.m. to 5:29 a.m.
5:30 a.m. to 5:59 a.m.
6:00 a.m. to 6:29 a.m.
6:30 a.m. to 6:59 a.m.
7:00 a.m. to 7:29 a.m.
7:30 a.m. to 7:59 a.m.
8:00 a.m. to 8:29 a.m.
8:30 a.m. to 8:59 a.m.
9:00 a.m. to 9:59 a.m.
10:00 a.m. to 10:59 a.m.
11:00 a.m. to 11:59 a.m.
12:00 p.m. to 3:59 p.m.
4:00 p.m. to 11:59 p.m.

- **Mode of Transportation**
  - Family/Personal vehicle (car, truck, van)
  - Vehicle carpool (car, truck, van)
    - 2 people
    - 3 people
    - 4 people
    - 5-6 people
    - more than 7 people
  - Public transportation
    - Bus
    - Streetcar
    - Subway
    - Railroad
    - Ferryboat
  - Walk

- Bicycle
- Taxicab
- Motorcycle
- Work from home
- Other



- **Language spoken and age**
  - Categories for each 5-17 years, 18-64 years, 65 plus
  - English
  - Asian
  - Spanish
  - Other Indo-European
  - Other language

- **Race**
  - Caucasian (ACS - white)
  - African American (ACS - Black or African American)
  - American Indian and Alaska Native
  - Asian
  - Native Hawaiian and Pacific Islander
  - Other Race
  - Two or More Races
  - Two or More Races and Part of Some Other Race
  - Two or More Races and Excluding Some Other Race
  -
- **Gender and age category**
  - All
  - All Male
  - All Female
  - Males under 20
  - Males 21-39
  - Males 40 to 59
  - Males 60 plus
  - Females under 20
  - Females 21-39
  - Females 40 to 59
  - Females 60 plus

B. Demographic/Hotspot Analysis Tool User Selection Options

- **Travel work time**
  - **Total Number of People who Traveled to Work Between 12:00 p.m. to 12:00 a.m.**
  - **12:00 a.m. to 4:59 a.m.**
  - **5:00 a.m. to 5:29 a.m.**
  - **5:30 a.m. to 5:59 a.m.**
  - **6:00 a.m. to 6:29 a.m.**
  - **6:30 a.m. to 6:59 a.m.**
  - **7:00 a.m. to 7:29 a.m.**
  - **7:30 a.m. to 7:59 a.m.**
  - **8:00 a.m. to 8:29 a.m.**
  - **8:30 a.m. to 8:59 a.m.**
  - **9:00 a.m. to 9:59 a.m.**
  - **10:00 a.m. to 10:59 a.m.**
  - **11:00 a.m. to 11:59 a.m.**
  - **12:00 p.m. to 3:59 p.m.**
  - **4:00 a.m. to 11:59 p.m.**

Total Number of People who Traveled to Work Between 12:00 p.m. to 12:00 a.m.
Total Number of People who Traveled to Work Between 12:00 p.m. to 12:00 a.m.
12:00 a.m. to 4:59 a.m.
5:00 a.m. to 5:29 a.m.
5:30 a.m. to 5:59 a.m.
6:00 a.m. to 6:29 a.m.
6:30 a.m. to 6:59 a.m.
7:00 a.m. to 7:29 a.m.
7:30 a.m. to 7:59 a.m.
8:00 a.m. to 8:29 a.m.
8:30 a.m. to 8:59 a.m.
9:00 a.m. to 9:59 a.m.
10:00 a.m. to 10:59 a.m.
11:00 a.m. to 11:59 a.m.
12:00 p.m. to 3:59 p.m.
4:00 p.m. to 11:59 p.m.

- **Transportation**
  - Total Number of People that Used a Car, Truck, or Van
  - Car, Truck, or Van - Drove Alone
  - Car, Truck, or Van - Carpooled Total
  - Car, Truck, or Van - In 2 Person Carpool
  - Car, Truck, or Van - In 3 Person Carpool
  - Car, Truck, or Van - In 4 Person Carpool
  - Car, Truck, or Van - In 5 or 6 Person Carpool
  - Car, Truck, or Van - In 7 Person Plus Carpool
  - Total Number of People that Used Public Transport
  - Public Transport - Bus or Trolley Bus
  - Public Transport - Streetcar or Trolley Car
  - Public Transport - Subway or Elevated
  - Public Transport - Railroad
  - Public Transport - Ferryboat
  - Total Number of People that Used a Taxicab
  - Total Number of People that Used a Motorcycle
  - Total Number of People that Used a Bicycle
  - Total Number of People that Walked
  - Total Number of People that Used Some Other Means of Transport
  - Total Number of People that Worked at Home

Transportation*

Car, Truck, or Van - Drove Alone
Total Number of People that Used Some Means of Transportation
Total Number of People that Used a Car, Truck, or Van
Car, Truck, or Van - Drove Alone
Car, Truck, or Van - Carpooled Total
Car, Truck, or Van - In 2 Person Carpool
Car, Truck, or Van - In 3 Person Carpool
Car, Truck, or Van - In 4 Person Carpool
Car, Truck, or Van - In 5 or 6 Person Carpool
Car, Truck, or Van - In 7 Plus Carpool
Total Number of People that Used Public Transport
Public Transport - Bus or Trolley Bus
Public Transport - Streetcar or Trolley Car
Public Transport - Railroad
Public Transport - Ferryboat
Total Number of People that Used a Taxicab
Total Number of People that Used Motorcycle
Total Number of People that Used a Bicycle
Total Number of People that Walked
Total Number of People that Used Some Other Means of Transportation
Total Number of People that Worked at Home

- **Language**

  Total Number of People that Spoke Some Language
  English Only, 5 to 17 Years
  English Only, 18 to 64 Years
  English Only, 65 Plus
  Spanish, 5 to 17 Years
  Spanish, 18 to 64 Years
  Spanish, 65 Plus
  Other Indo-European, 5 to 17 Years
  Other Indo-European, 18 to 64 Years
  Other Indo-European, 65 Plus
  Asian, 5 to 17 Years
  Asian, 18 to 64 Years
  Asian, 65 Plus
  Other Language, 5 to 17 Years
  Other Language, 18 to 64 Years
  Other Language, 65 Plus

Language*

Total Number of People that Spoke Some Language
Total Number of People that Spoke Some Language
English Only, 5 to 17 Years
English Only, 18 to 64 Years
English Only, 65 Plus
Spanish, 5 to 17 Years
Spanish, 18 to 64 Years
Spanish, 65 Plus
Other Indo-European, 5 to 17 Years
Other Indo-European, 18 to 64 Years
Other Indo-European, 65 Plus
Asian, 5 to 17 Years
Asian, 18 to 64 Years
Asian, 65 Plus
Other Language, 5 to 17 Years
Other Language, 18 to 64 Years
Other Language, 65 Plus

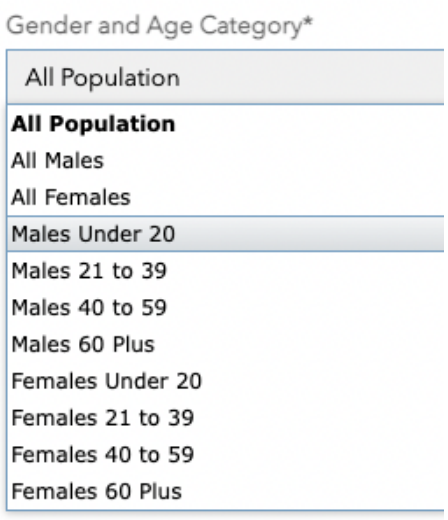
- **Race**
  Caucasian
  African American
  American Indian and Alaska Native
  Asian
  Native Hawaiian and Pacific Islander
  Other Race
  Two or More Races
  Two or More Races and Part of Some Other Race
  Two or More Races and Excluding Some Other Race

Race*

American Indian and Alaska Native
All Races
Caucasian
African American
American Indian and Alaska Native
Asian
Native Hawaiian and Pacific Islander
Other Race
Two or More Race
Two or More Races and Part of Some Other Race

- **Gender and Age Category**

All Population
All Males
All Females
Males Under 20
Males 21 to 39
Males 40 to 59
Males 60 Plus
Females Under 20
Females 21 to 39
Females 40 to 59
Females 60 Plus



- **Drive Polygon**

The service area layers created by the network analysis tool are intended to be used as input as the drive time polygon. This defines the area of interest for the analysis. The user has the option to select combined service areas as the input for this field (Linked SA) or the polygons defining each drive time distance (Service Area 1, 2, or 3).

Appendix 8: Network Analysis Tool Outputs

- Service Area 1
- Service Area 2
- Service Area 3
- Block Groups Intersecting Drive Polygon
- LinkedSA
- DriveOut.zip
- CensusStats.xls (See below for an example)
- PopAnalysisAll.txt (See below for an example)
- PopAnalysisGraphs.pdf (See below for an example)
- CensusGraphs.pdf (See below for an example)

CensusStats.xls:

OID	FromBreak	ToBreak	SUM_TotalPopEst	SUM_TotalPopEst_LowerMOE	SUM_TotalPopEst_UpperMOE	SUM_TrueTotal	SUM_TrueMOElow	SUM_TrueMOEup	SUM_Total RaceEst
1	30	50	1272597	1030022	1515208	1272597	1030022	1515208	1272597
2	10	30	1171249	955261	1387261	1171249	955261	1387261	1171249
3	0	10	142535	114612	170458	142535	114612	170458	142535

SUM_TotalRace_LowerMOE	SUM_TotalRace_UpperMOE	SUM_TrueTotal_1	SUM_TrueMOElow_1	SUM_TrueMOEup_1	SUM_TotalLangEst	SUM_TotalLang_LowerMOE	SUM_TotalLang_UpperMOE	SUM_TrueTotal_12	SUM_TrueMOElow_12
1030022	1515208	1272597	1030022	1515208	1190431	966162	1414736	1190431	966162
955261	1387261	1171249	955261	1387261	1095775	895800	1295774	1095775	895800
114612	170458	142535	114612	170458	132281	106902	157660	132281	106902

SUM_TrueMOEup_12	SUM_TotTransprtEst	SUM_TotTrnsprtEst_LowerMOE	SUM_TotTrnsprtEst_UpperMOE	SUM_TrueTotal_12_13	SUM_TrueMOElow_12_13	SUM_TrueMOEup_12_13	SUM_TotalTimeEst	SUM_TotalTimeEst_LowerMOE	SUM_TotalTimeEst_UpperMOE
1414736	599573	463328	735854	599573	463328	735854	563928	430472	697420
1295774	586478	458745	714240	586478	458745	714240	543387	418824	667979
157660	70335	54347	86323	70335	54347	86323	65423	49880	80966

SUM_TrueTotal_12_13_14	SUM_TrueMOElow_12_13_14	SUM_TrueMOEup_12_13_14
563928	430472	697420
543387	418824	667979
65423	49880	80966

PopAnalysisAll.txt

Predicting TotalPopEst Population (Y) based on Time (X)
Note: True Estimate Fields Only
Linear Regression Equation: Y = 14580.5 + 28251.55*x
r-squared: 0.816673583578
p-value: 0.281680530761

X-Values for Time:
OBJECTID
1 50
2 30
3 10
Name: ToBreak, dtype: int64

Predicted Y-Values:
OBJECTID
1 1427158.0
2 862127.0
3 297096.0
Name: ToBreak, dtype: float64

Actual Y-Values:
OBJECTID
1 1272597
2 1171249
3 142535
Name: SUM_TrueTotal, dtype: int64

Pearson's Correlation Coefficient Results:
Time with TotalPopEst: 0.903699941119

~~~*~~~
Predicting TotalRaceEst Population (Y) based on Time (X)
Note: True Estimate Fields Only
Linear Regression Equation: Y = 14580.5 + 28251.55*x
r-squared: 0.816673583578
p-value: 0.281680530761

X-Values for Time:
OBJECTID
1 50
2 30
3 10
Name: ToBreak, dtype: int64

Predicted Y-Values:
OBJECTID
1 1427158.0
2 862127.0
3 297096.0
Name: ToBreak, dtype: float64

Actual Y-Values:
OBJECTID
1 1272597
2 1171249
3 142535
Name: SUM_TrueTotal_1, dtype: int64

Pearson's Correlation Coefficient Results:
Time with TotalRaceEst: 0.903699941119
~~~*~~~
Predicting TotalLangEst Population (Y) based on Time (X)
Note: True Estimate Fields Only
Linear Regression Equation: Y = 12549.8333333 + 26453.75*x
r-squared: 0.816506207123
p-value: 0.281818198085

X-Values for Time:
OBJECTID
1 50
2 30
3 10
Name: ToBreak, dtype: int64

Predicted Y-Values:
OBJECTID
1 1.335237e+06
2 8.061623e+05
3 2.770873e+05

Name: ToBreak, dtype: float64

Actual Y-Values:
OBJECTID
1 1190431
2 1095775
3 132281
Name: SUM_TrueTotal_12, dtype: int64

Pearson's Correlation Coefficient Results:
Time with TotalLangEst: 0.903607330162
~~~*~~~
Predicting TotTrnsprtEst Population (Y) based on Time (X)
Note: True Estimate Fields Only
Linear Regression Equation: Y = 21866.8333333 + 13230.95*x
r-squared: 0.768545698783
p-value: 0.31952302046

X-Values for Time:
OBJECTID
1 50
2 30
3 10
Name: ToBreak, dtype: int64

Predicted Y-Values:
OBJECTID
1 683414.333333
2 418795.333333
3 154176.333333
Name: ToBreak, dtype: float64

Actual Y-Values:
OBJECTID
1 599573
2 586478
3 70335
Name: SUM_TrueTotal_12_13, dtype: int64

Pearson's Correlation Coefficient Results:
Time with TotTrnsprtEst: 0.876667382069
~~~*~~~
Predicting TotalTimeEst Population (Y) based on Time (X)
Note: True Estimate Fields Only
Linear Regression Equation: Y = 17033.9166667 + 12462.625*x
r-squared: 0.78084927365
p-value: 0.310148082323

X-Values for Time:

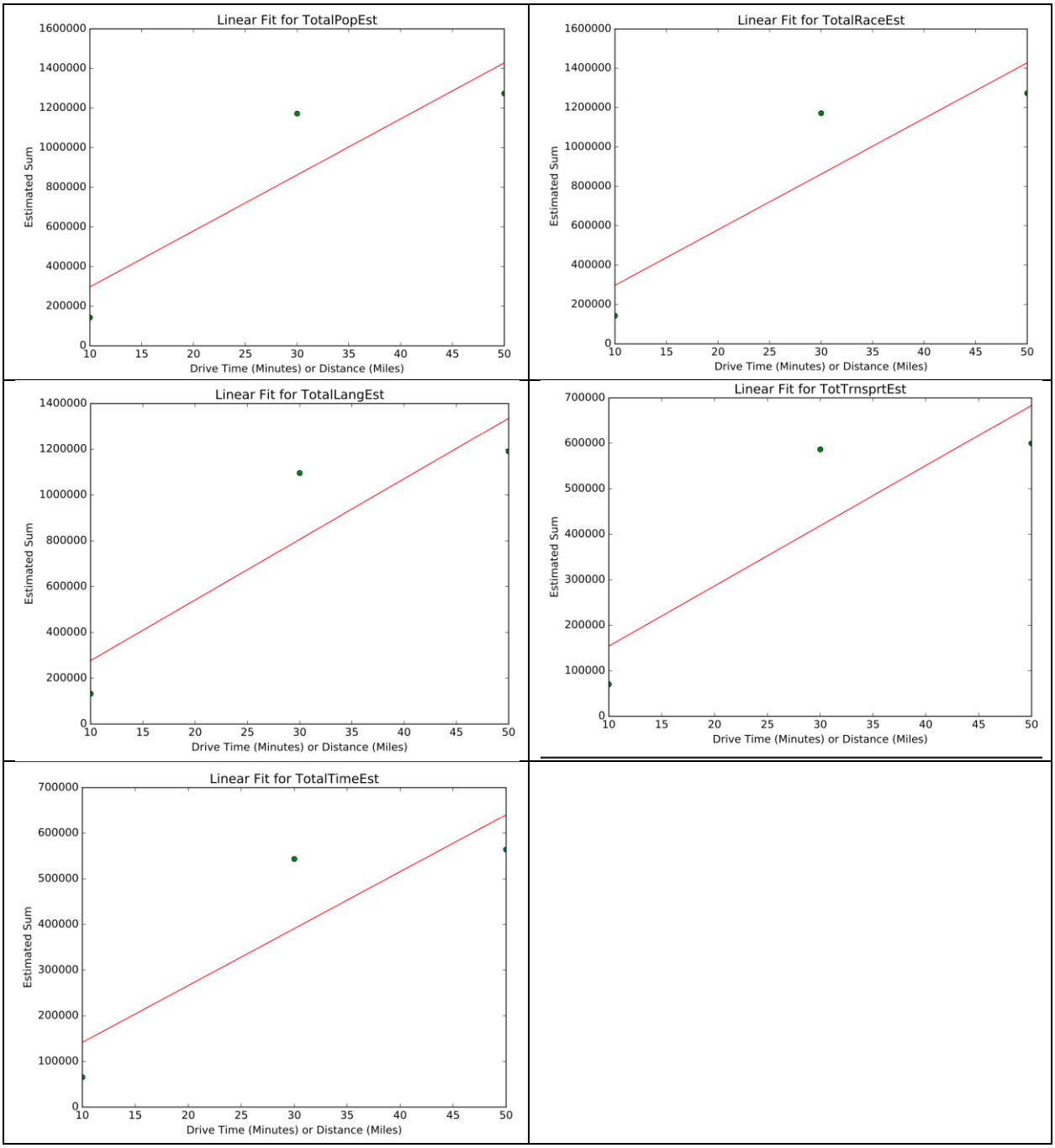
OBJECTID
1 50
2 30
3 10
Name: ToBreak, dtype: int64

Predicted Y-Values:
OBJECTID
1 640165.166667
2 390912.666667
3 141660.166667
Name: ToBreak, dtype: float64

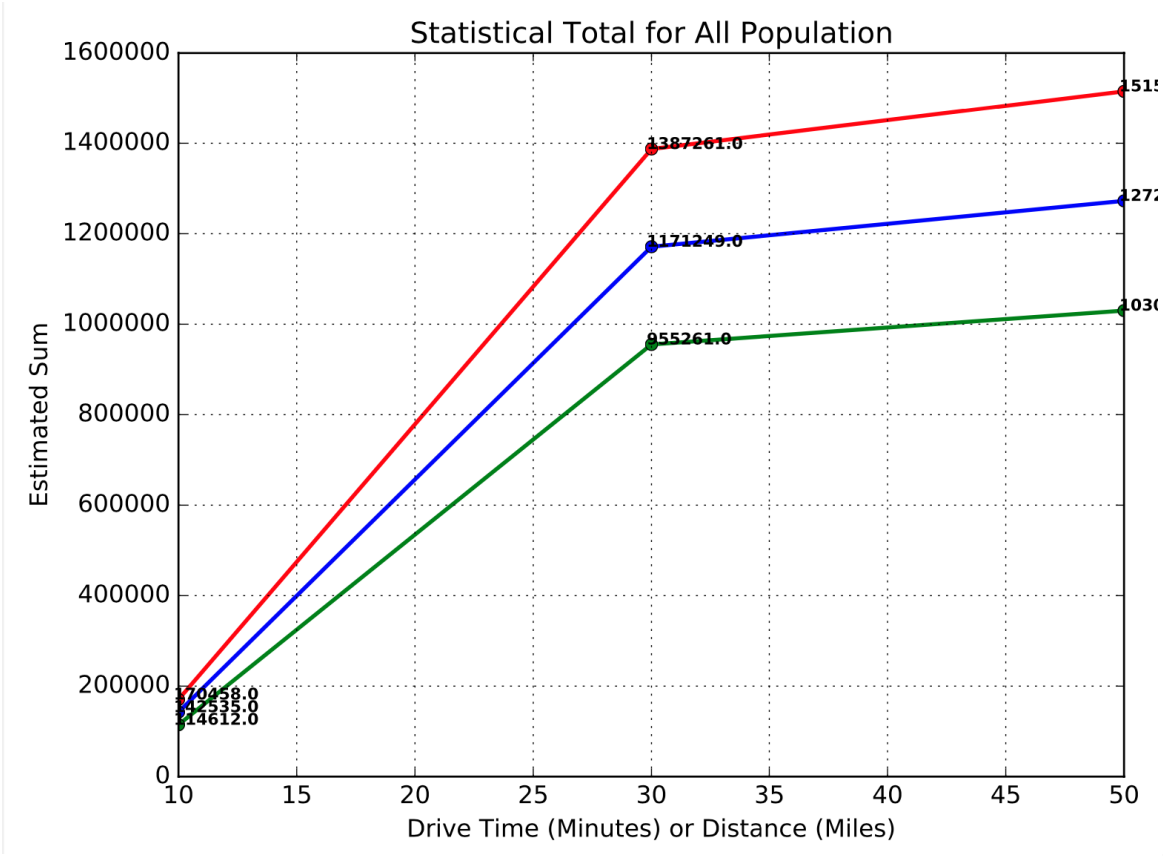
Actual Y-Values:
OBJECTID
1 563928
2 543387
3 65423
Name: SUM_TrueTotal_12_13_14, dtype: int64

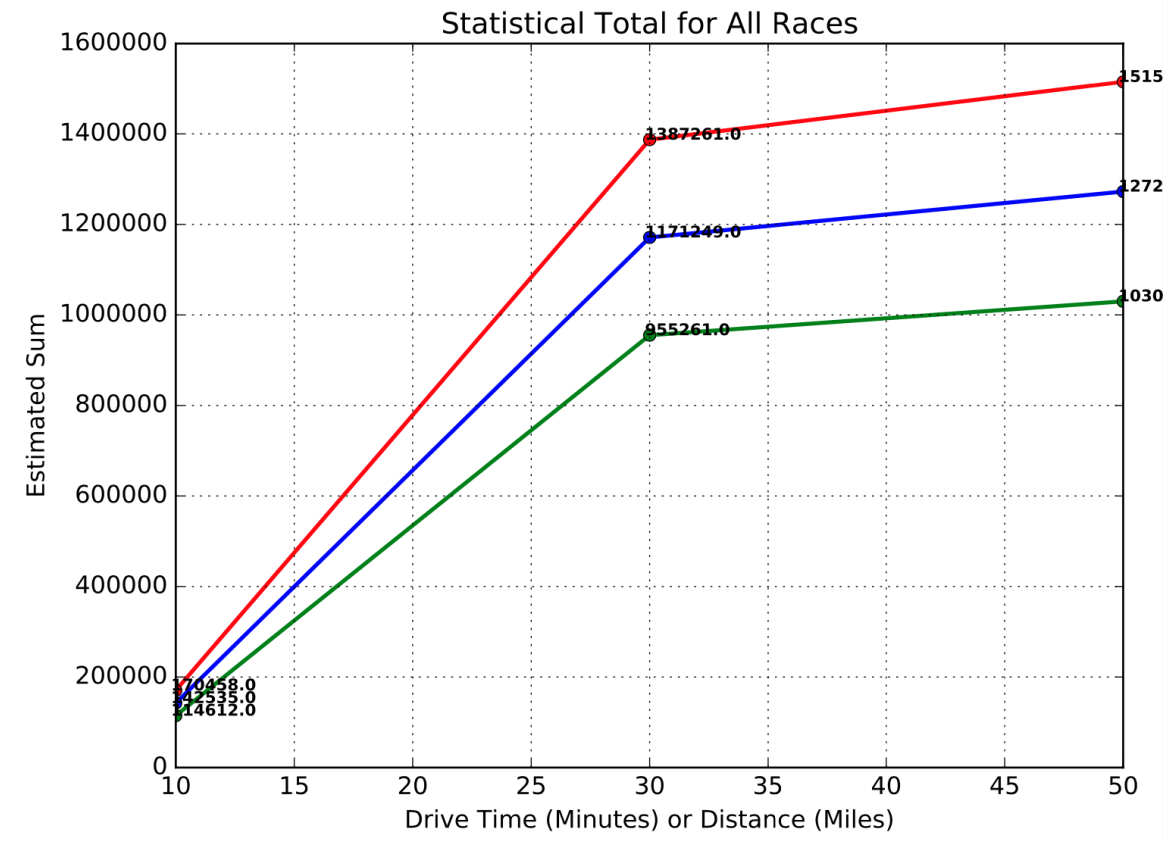
Pearson's Correlation Coefficient Results:
Time with TotalTimeEst: 0.883656762352

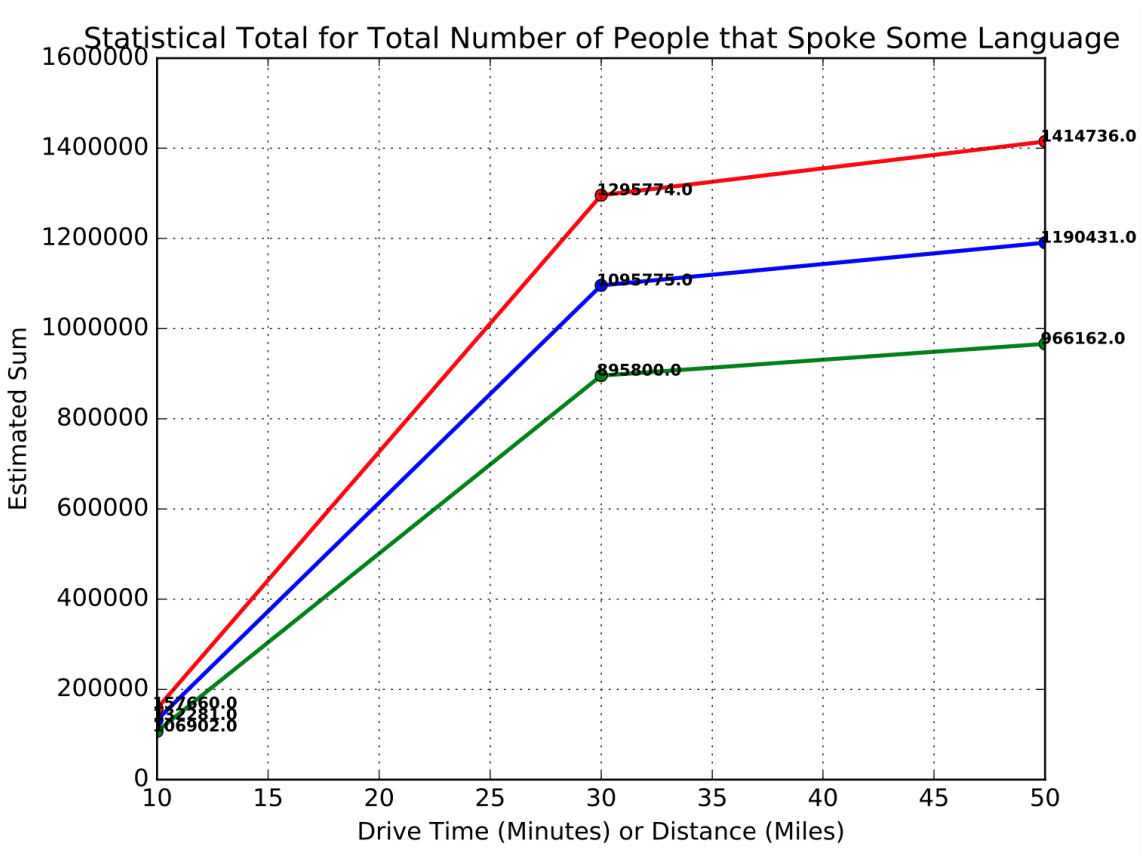
PopAnalysisGraphs.pdf



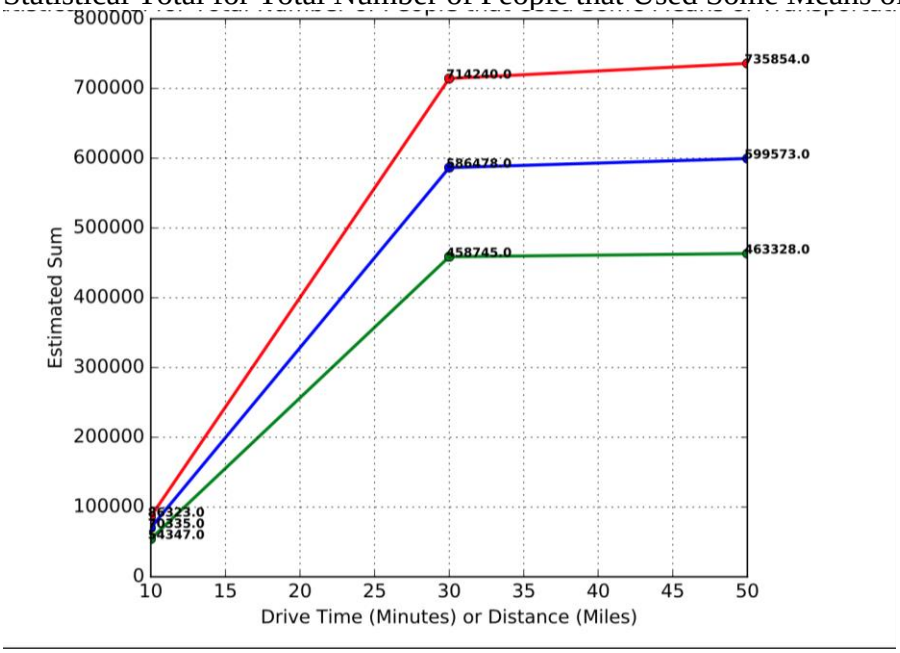
CensusGraphs.pdf



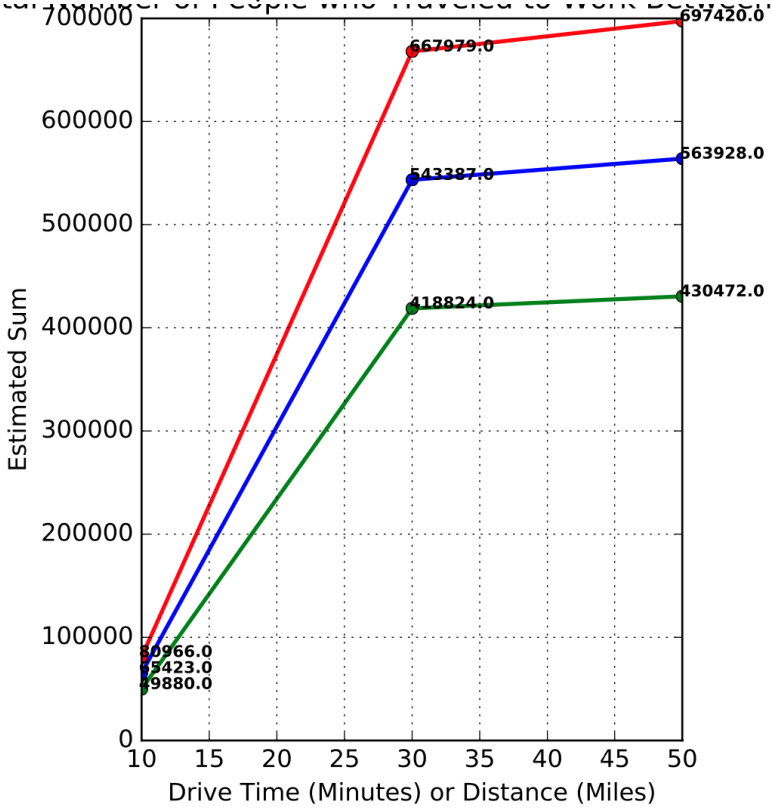




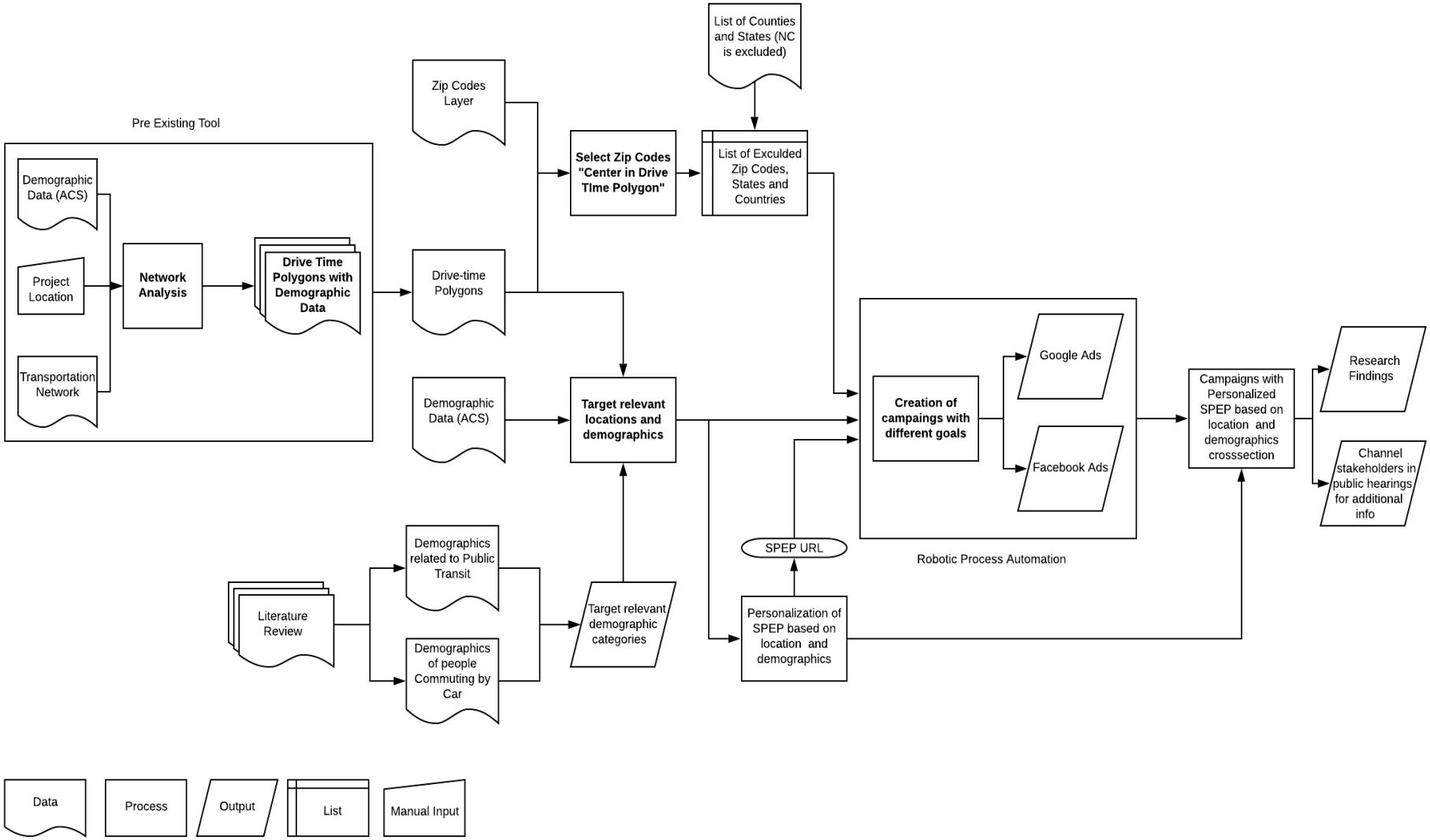
Statistical Total for Total Number of People that Used Some Means of Transportation:



Total for Total Number of People who Traveled to Work Between 12:00pm to 12:00am



Appendix 9: Detailed Process Flowchart (Enlarged)



Appendix 10: Python Scripts Used for Network Analysis Data and Tool Set Up

ACS_Modify.py:

Used during pre-processing to clean up select ACS 5-Year Estimates tables derived from American Fact Finder;

```
#--------------------------------------------------------------------------
# Name:         ACS Clean-up (ACS_Modify.py)
# Purpose:      To clean up select ACS 5-Year Estimates tables derived from
#               American Fact Finder
#
# Version:      Python 3.5
# Notes:        Script run in 'Anaconda Spyder'
#--------------------------------------------------------------------------

# Import packages
import pandas as pd

wkdir = "C:/Project/ACS_Cleanup/"
findir = "C:/Project/ACS_Cleanup/"

ACS_tables = ["B01003","B25001","B01001","B02001","B08008","B08301","B08302",
              "B09021","B11001","B11016","B15003","B16004","B19013","B23025",
              "B25002","B28001","B99051","C24010","C24030"]
ACS_pdList = [] # Values

# Append tables to lists
for itm in ACS_tables:
    ACS_Name = wkdir + "ACS_17_5YR_" + itm + "_with_ann.csv"
    ACS_pdList.append(ACS_Name)

ACS_pdList.sort()

csv_list = [] # Keys
df_list = [] # DataFrames
for num in range(1,20):
    df_name = "df" + str(num)
    csv_name = "csv" + str(num)
    df_list.append(df_name)
    csv_list.append(csv_name)

csv_list.sort()
df_list.sort()

# Make dictionary from keys and values lists
ACS_dict = dict(zip(csv_list, ACS_pdList))

# Read in csv files (4 at this point)
df1 = pd.read_csv(ACS_dict['csv1']) #B01001
df11 = pd.read_csv(ACS_dict['csv11']) #B02001
df19 = pd.read_csv(ACS_dict['csv19']) #B16004
df13 = pd.read_csv(ACS_dict['csv13']) #B08301
```

```
df14 = pd.read_csv(ACS_dict['csv14']) #B08302
############################################################
############################################################
# DF1 (CSV1)
# Retain relevant column names for reference
colName1 = df1.iloc[0] # Series
colEdit1 = pd.DataFrame(colName1) # DF
colConvert1 = colEdit1.rename(columns={0: "Ext"})
'''
*    Title: How to drop rows from pandas data frame that contains a
*           particular string in a particular column? [duplicate]
*    Author: Devarshi Mandal
*    Date: 2018
*    Code / Type version: 1.0
*    Code adapted from: https://stackoverflow.com/questions/28679930/
*                       how-to-drop-rows-from-pandas-data-frame-that-
*                       contains-a-particular-string-in-a-p/43399866
'''
colFin1 = colConvert1[~colConvert1.Ext.str.contains("Margin of Error")]
'''(Version 1.0) [Source code].
    https://stackoverflow.com/questions/28679930/how-to-drop-rows-from-
    pandas-data-frame-that-contains-a-particular-string-in-a-p/43399866'''

# Drop header
df1.drop(df1.index[:1], inplace=True)

a1 = [col for col in df1 if col.startswith('HD01_') or col.startswith('GEO.id2')]
a2 = df1[a1] # New DF - Middle point

b1 = [col for col in df1 if col.startswith('HD02_') or col.startswith('GEO.id2')]
b2 = df1[b1] # New  - All MOEs

# Find difference of the two dataframes (true value estimate with MOE)
c1 = a2.apply(pd.to_numeric) # Estimate columns
c2 = b2.apply(pd.to_numeric)  # MOE columns
c3 = pd.DataFrame(c1.values + c2.values, columns=c1.columns) # +MOE
c4 = pd.DataFrame(c1.values - c2.values, columns=c1.columns) # -MOE

# Summarize columns
c1.rename(columns={'GEO.id2':'GEO_id2',
                   'HD01_VD01':'TotalPopEst',
                   'HD01_VD02': 'MalePopEst',
                   'HD01_VD26':'FemPopEst'}, inplace=True)
c3.rename(columns={'GEO.id2':'GEO_id2',
                   'HD01_VD01':'TotalPopEst_UpperMOE',
                   'HD01_VD02': 'MalePopEst_UpperMOE',
                   'HD01_VD26':'FemPopEst_UpperMOE'}, inplace=True)
c4.rename(columns={'GEO.id2':'GEO_id2',
                   'HD01_VD01':'TotalPopEst_LowerMOE',
                   'HD01_VD02': 'MalePopEst_LowerMOE',
                   'HD01_VD26':'FemPopEst_LowerMOE'}, inplace=True)
# ESTIMATE
c1['MaleEst_UndEqto20'] = c1.iloc[:, 3:9].sum(axis=1) #HD01_VD03-HD01_VD08
      c1['MaleEst_21to39'] = c1.iloc[:, 9:14].sum(axis=1) #HD01_VD09-HD01_VD13
      c1['MaleEst_40to59'] = c1.iloc[:, 14:18].sum(axis=1) #HD01_VD14-HD01_VD17
      c1['MaleEst_60plus'] = c1.iloc[:, 18:26].sum(axis=1) #HD01_VD18-HD01_VD25
      c1['FemEst_UndEqto20'] = c1.iloc[:, 27:33].sum(axis=1) #HD01_VD27-HD01_VD32
      c1['FemEst_21to39'] = c1.iloc[:, 33:38].sum(axis=1) #HD01_VD33-HD01_VD37
      c1['FemEst_40to59'] = c1.iloc[:, 38:42].sum(axis=1) #HD01_VD38-HD01_VD41
      c1['FemEst_60plus'] = c1.iloc[:, 42:50].sum(axis=1) #HD01_VD42-HD01_VD49
      df1_est = c1.iloc[:, [0,1,2,26,50,51,52,53,54,55,56,57]]
```

```
108.
109.        # UPPER MOE
110.        c3['MaleUpperMOE_UndEqto20'] = c3.iloc[:, 3:9].sum(axis=1) #HD01_VD03-HD01_VD08
111.        c3['MaleUpperMOE_21to39'] = c3.iloc[:, 9:14].sum(axis=1) #HD01_VD09-HD01_VD13
112.        c3['MaleUpperMOE_40to59'] = c3.iloc[:, 14:18].sum(axis=1) #HD01_VD14-HD01_VD17
113.        c3['MaleUpperMOE_60plus'] = c3.iloc[:, 18:26].sum(axis=1) #HD01_VD18-HD01_VD25
114.        c3['FemUpperMOE_UndEqto20'] = c3.iloc[:, 27:33].sum(axis=1) #HD01_VD27-HD01_VD32
115.        c3['FemUpperMOE_21to39'] = c3.iloc[:, 33:38].sum(axis=1) #HD01_VD33-HD01_VD37
116.        c3['FemUpperMOE_40to59'] = c3.iloc[:, 38:42].sum(axis=1) #HD01_VD38-HD01_VD41
117.        c3['FemUpperMOE_60plus'] = c3.iloc[:, 42:50].sum(axis=1) #HD01_VD42-HD01_VD49
118.        c3['GEO_id2'] = c3['GEO_id2']/2 # Values were doubled from MOEs
119.        df1_upper = c3.iloc[:, [0,1,2,26,50,51,52,53,54,55,56,57]]
120.
121.        # LOWER MOE
122.        c4['MaleLowerMOE_UndEqto20'] = c4.iloc[:, 3:9].sum(axis=1) #HD01_VD03-HD01_VD08
123.        c4['MaleLowerMOE_21to39'] = c4.iloc[:, 9:14].sum(axis=1) #HD01_VD09-HD01_VD13
124.        c4['MaleLowerMOE_40to59'] = c4.iloc[:, 14:18].sum(axis=1) #HD01_VD14-HD01_VD17
125.        c4['MaleLowerMOE_60plus'] = c4.iloc[:, 18:26].sum(axis=1) #HD01_VD18-HD01_VD25
126.        c4['FemLowerMOE_UndEqto20'] = c4.iloc[:, 27:33].sum(axis=1) #HD01_VD27-HD01_VD32
127.        c4['FemLowerMOE_21to39'] = c4.iloc[:, 33:38].sum(axis=1) #HD01_VD33-HD01_VD37
128.        c4['FemLowerMOE_40to59'] = c4.iloc[:, 38:42].sum(axis=1) #HD01_VD38-HD01_VD41
129.        c4['FemLowerMOE_60plus'] = c4.iloc[:, 42:50].sum(axis=1) #HD01_VD42-HD01_VD49
130.        c4['GEO_id2'] = c3['GEO_id2']
131.        df1_lower = c4.iloc[:, [0,1,2,26,50,51,52,53,54,55,56,57]]
132.
133.        # Merge dataframes together - Have estimates and MOEs in one place
134.        df1_merge = pd.merge(df1_est, df1_upper, on='GEO_id2', how='outer')
135.        df1_fin = pd.merge(df1_merge, df1_lower, on='GEO_id2', how='outer')
136.
137.        # Convert all negative numbers to 0 (negative numbers don't make sense here)
138.        '''
139.        *    Title: How to replace negative numbers in Pandas Data Frame by zero
140.        *    Author: Stephen Rauch
141.        *    Date: 2018
142.        *    Code / Type version: 2.0
143.        *    Code adapted from: https://stackoverflow.com/questions/27759084/
144.        *                       how-to-replace-negative-numbers-in-pandas-data-
145.        *                       frame-by-zero/53147179#53147179
146.        '''
147.        df1_out = df1_fin.mask(df1_fin < 0, 0)
148.        '''(Version 2.0) [Source code]. https://stackoverflow.com/questions/
149.                                        27759084/how-to-replace-negative-numbers
150.                                        -in-pandas-data-frame-by-zero/53147179#
151.                                        53147179'''
152.
153.        # Convert to CSV
154.        #c6.columns.get_loc("FemEst")
155.        df1_out.to_csv(findir + "B01001.csv", index=False) #6155
156.        ############################################################
157.        ############################################################
158.        # DF11 (CSV11)
159.        # Retain relevant column names for reference
160.        colName11 = df11.iloc[0] # Series
161.        colEdit11 = pd.DataFrame(colName11) # DF
162.        colConvert11 = colEdit11.rename(columns={0: "Ext"})
163.        colFin11 = colConvert11[~colConvert11.Ext.str.contains("Margin of Error")]
164.        '''(Version 1.0) [Source code].
165.            https://stackoverflow.com/questions/28679930/how-to-drop-rows-from-
166.            pandas-data-frame-that-contains-a-particular-string-in-a-p/43399866'''
167.
168.        # Drop header
```

```
169.        df11.drop(df11.index[:1], inplace=True)
170.
171.        t1 = [col for col in df11 if col.startswith('HD01_') or col.startswith('GEO.id2')]
172.        t2 = df11[t1] # Estimate columns
173.
174.        u1 = [col for col in df11 if col.startswith('HD02_') or col.startswith('GEO.id2')]
175.        u2 = df11[u1] # MOE columns
176.
177.        # Find difference of the two dataframes (true value estimate with MOE)
178.        v1 = t2.apply(pd.to_numeric)
179.        v2 = u2.apply(pd.to_numeric)
180.        v3 = pd.DataFrame(v1.values + v2.values, columns=v1.columns) # +MOE
181.        v4 = pd.DataFrame(v1.values - v2.values, columns=v1.columns) # -MOE
182.
183.        # Summarize columns
184.        v1.rename(columns={'GEO.id2':'GEO_id2',
185.                           'HD01_VD01':'TotalRaceEst',
186.                           'HD01_VD02': 'CaucasEst',
187.                           'HD01_VD03':'AfricanAmericnEst',
188.                           'HD01_VD04':'AmericnIndnAkNtiveEst',
189.                           'HD01_VD05':'AsianEst',
190.                           'HD01_VD06':'NtiveHIPacificIsleEst',
191.                           'HD01_VD07':'OtherRaceEst',
192.                           'HD01_VD08':'TwoMoreRacesEst',
193.                           'HD01_VD09':'TwoMoreRaces_SOEst', #Including some other
194.                           'HD01_VD10':'TwoMoreRaces_SOTEst' #Including some other and 3 plus
195.                           }, inplace=True)
196.        # UPPER MOE
197.        v3.rename(columns={'GEO.id2':'GEO_id2',
198.                           'HD01_VD01':'TotalRace_UpperMOE',
199.                           'HD01_VD02': 'Caucas_UpperMOE',
200.                           'HD01_VD03':'AfricanAmericn_UpperMOE',
201.                           'HD01_VD04':'AmericnIndnAkNtive_UpperMOE',
202.                           'HD01_VD05':'Asian_UpperMOE',
203.                           'HD01_VD06':'NtiveHIPacificIsle_UpperMOE',
204.                           'HD01_VD07':'OtherRace_UpperMOE',
205.                           'HD01_VD08':'TwoMoreRaces_UpperMOE',
206.                           'HD01_VD09':'TwoMoreRaces_SO_UpperMOE',
207.                           'HD01_VD10':'TwoMoreRaces_SOT_UpperMOE'
208.                           }, inplace=True)
209.        v3['GEO_id2'] = v3['GEO_id2']/2 # Values were doubled from MOEs
210.
211.        # LOWER MOE
212.        v4.rename(columns={'GEO.id2':'GEO_id2',
213.                           'HD01_VD01':'TotalRace_LowerMOE',
214.                           'HD01_VD02': 'Caucas_LowerMOE',
215.                           'HD01_VD03':'AfricanAmericn_LowerMOE',
216.                           'HD01_VD04':'AmericnIndnAkNtive_LowerMOE',
217.                           'HD01_VD05':'Asian_LowerMOE',
218.                           'HD01_VD06':'NtiveHIPacificIsle_LowerMOE',
219.                           'HD01_VD07':'OtherRace_LowerMOE',
220.                           'HD01_VD08':'TwoMoreRaces_LowerMOE',
221.                           'HD01_VD09':'TwoMoreRaces_SO_LowerMOE',
222.                           'HD01_VD10':'TwoMoreRaces_SOT_LowerMOE'
223.                           }, inplace=True)
224.        v4['GEO_id2'] = v3['GEO_id2']
225.
226.        # Merge dataframes together - Have estimates and MOEs in one place
227.        df11_merge = pd.merge(v1, v3, on='GEO_id2', how='outer')
228.        df11_fin = pd.merge(df11_merge, v4, on='GEO_id2', how='outer')
229.
```

```
230.        # Convert all negative numbers to 0 (negative numbers don't make sense here)
231.        df11_out = df11_fin.mask(df11_fin < 0, 0)
232.        '''(Version 2.0) [Source code]. https://stackoverflow.com/questions/
233.                                        27759084/how-to-replace-negative-numbers
234.                                        -in-pandas-data-frame-by-zero/53147179#
235.                                        53147179'''
236.
237.        # Output final DataFrame and convert to CSV
238.        df11_out.to_csv(findir + "B02001.csv", index=False) #6155
239.        ############################################################
240.        ############################################################
241.        # DF19 (CSV19)
242.        # Retain relevant column names for reference
243.        colName19 = df19.iloc[0] # Series
244.        colEdit19 = pd.DataFrame(colName19) # DF
245.        colConvert19 = colEdit19.rename(columns={0: "Ext"})
246.        colFin19 = colConvert19[~colConvert19.Ext.str.contains("Margin of Error")]
247.        '''(Version 1.0) [Source code].
248.            https://stackoverflow.com/questions/28679930/how-to-drop-rows-from-
249.            pandas-data-frame-that-contains-a-particular-string-in-a-p/43399866'''
250.
251.        # Drop header
252.        df19.drop(df19.index[:1], inplace=True)
253.
254.        a_r1 = [col for col in df19 if col.startswith('HD01_') or col.startswith('GEO.id2')]
255.        a_r2 = df19[a_r1] # Estimate columns
256.
257.        a_s1 = [col for col in df19 if col.startswith('HD02_') or col.startswith('GEO.id2')]
258.        a_s2 = df19[a_s1] # MOE columns
259.
260.        # Find difference of the two dataframes (true value estimate with MOE)
261.        a_t1 = a_r2.apply(pd.to_numeric)
262.        a_t2 = a_s2.apply(pd.to_numeric)
263.        a_t3 = pd.DataFrame(a_t1.values + a_t2.values, columns=a_t1.columns) # +MOE
264.        a_t4 = pd.DataFrame(a_t1.values - a_t2.values, columns=a_t1.columns) # -MOE
265.
266.        # Summarize columns
267.        a_t1.rename(columns={'HD01_VD01':'TotalLangEst',
268.                             'GEO.id2':'GEO_id2',
269.                             'HD01_VD03': 'EngOnly5to17',
270.                             'HD01_VD04':'Spanish5to17',
271.                             'HD01_VD09': 'OtherIndoEuro5to17',
272.                             'HD01_VD14': 'Asian5to17',
273.                             'HD01_VD19': 'OtherLan5to17',
274.                             'HD01_VD25': 'EngOnly18to64',
275.                             'HD01_VD26': 'Spanish18to64',
276.                             'HD01_VD31': 'OtherIndoEuro18to64',
277.                             'HD01_VD36': 'Asian18to64',
278.                             'HD01_VD41': 'OtherLan18to64',
279.                             'HD01_VD47': 'EngOnly65Plus',
280.                             'HD01_VD48': 'Spanish65Plus',
281.                             'HD01_VD53': 'OtherIndoEuro65Plus',
282.                             'HD01_VD58': 'Asian65Plus',
283.                             'HD01_VD63': 'OtherLan65Plus'
284.                            }, inplace=True)
285.        df19_est = a_t1.iloc[:, [0,1,3,4,9,14,19,25,26,31,36,41,47,48,53,58,63]]
286.
287.        # UPPER MOE
288.        a_t3.rename(columns={'HD01_VD01':'TotalLang_UpperMOE',
289.                             'GEO.id2':'GEO_id2',
290.                             'HD01_VD03': 'EngOnly5to17_UpperMOE',
```

```
                            'HD01_VD04':'Spanish5to17_UpperMOE',
                            'HD01_VD09': 'OtherIndoEuro5to17_UpperMOE',
                            'HD01_VD14': 'Asian5to17_UpperMOE',
                            'HD01_VD19': 'OtherLan5to17_UpperMOE',
                            'HD01_VD25': 'EngOnly18to64_UpperMOE',
                            'HD01_VD26': 'Spanish18to64_UpperMOE',
                            'HD01_VD31': 'OtherIndoEuro18to64_UpperMOE',
                            'HD01_VD36': 'Asian18to64_UpperMOE',
                            'HD01_VD41': 'OtherLan18to64_UpperMOE',
                            'HD01_VD47': 'EngOnly65Plus_UpperMOE',
                            'HD01_VD48': 'Spanish65Plus_UpperMOE',
                            'HD01_VD53': 'OtherIndoEuro65Plus_UpperMOE',
                            'HD01_VD58': 'Asian65Plus_UpperMOE',
                            'HD01_VD63': 'OtherLan65Plus_UpperMOE'
                            }, inplace=True)
        a_t3['GEO_id2'] = a_t3['GEO_id2']/2 # Values were doubled from MOEs
        df19_upper = a_t3.iloc[:, [0,1,3,4,9,14,19,25,26,31,36,41,47,48,53,58,63]]

        # LOWER MOE
        a_t4.rename(columns={'HD01_VD01':'TotalLang_LowerMOE',
                            'GEO.id2':'GEO_id2',
                            'HD01_VD03': 'EngOnly5to17_LowerMOE',
                            'HD01_VD04':'Spanish5to17_LowerMOE',
                            'HD01_VD09': 'OtherIndoEuro5to17_LowerMOE',
                            'HD01_VD14': 'Asian5to17_LowerMOE',
                            'HD01_VD19': 'OtherLan5to17_LowerMOE',
                            'HD01_VD25': 'EngOnly18to64_LowerMOE',
                            'HD01_VD26': 'Spanish18to64_LowerMOE',
                            'HD01_VD31': 'OtherIndoEuro18to64_LowerMOE',
                            'HD01_VD36': 'Asian18to64_LowerMOE',
                            'HD01_VD41': 'OtherLan18to64_LowerMOE',
                            'HD01_VD47': 'EngOnly65Plus_LowerMOE',
                            'HD01_VD48': 'Spanish65Plus_LowerMOE',
                            'HD01_VD53': 'OtherIndoEuro65Plus_LowerMOE',
                            'HD01_VD58': 'Asian65Plus_LowerMOE',
                            'HD01_VD63': 'OtherLan65Plus_LowerMOE'
                            }, inplace=True)
        a_t4['GEO_id2'] = a_t3['GEO_id2']
        df19_lower = a_t4.iloc[:, [0,1,3,4,9,14,19,25,26,31,36,41,47,48,53,58,63]]

        # Merge dataframes together - Have estimates and MOEs in one place
        df19_merge = pd.merge(df19_est, df19_upper, on='GEO_id2', how='outer')
        df19_fin = pd.merge(df19_merge, df19_lower, on='GEO_id2', how='outer')

        # Convert all negative numbers to 0 (negative numbers don't make sense here)
        df19_out = df19_fin.mask(df19_fin < 0, 0)
        '''(Version 2.0) [Source code]. https://stackoverflow.com/questions/
                                        27759084/how-to-replace-negative-numbers
                                        -in-pandas-data-frame-by-zero/53147179#
                                        53147179'''

        # Output final DataFrame and convert to CSV
        df19_out.to_csv(findir + "B16004.csv", index=False) #6155
        ############################################################
        ############################################################
        # DF13 (CSV13)
        # Retain relevant column names for reference
        colName13 = df13.iloc[0] # Series
        colEdit13 = pd.DataFrame(colName13) # DF
        colConvert13 = colEdit13.rename(columns={0: "Ext"})
        colFin13 = colConvert13[~colConvert13.Ext.str.contains("Margin of Error")]
```

```
352.        '''(Version 1.0) [Source code].
353.            https://stackoverflow.com/questions/28679930/how-to-drop-rows-from-
354.            pandas-data-frame-that-contains-a-particular-string-in-a-p/43399866'''
355.
356.        # Drop header
357.        df13.drop(df13.index[:1], inplace=True)
358.
359.        u1 = [col for col in df13 if col.startswith('HD01_') or col.startswith('GEO.id2')]
360.        u2 = df13[u1] # New DF - Middle point
361.
362.        v1 = [col for col in df13 if col.startswith('HD02_') or col.startswith('GEO.id2')]
363.        v2 = df13[v1] # New  - All MOEs
364.
365.        # Find difference of the two dataframes (true value estimate with MOE)
366.        w1 = u2.apply(pd.to_numeric) # Estimate columns
367.        w2 = v2.apply(pd.to_numeric)  # MOE columns
368.        w3 = pd.DataFrame(w1.values + w2.values, columns=w1.columns) # +MOE
369.        w4 = pd.DataFrame(w1.values - w2.values, columns=w1.columns) # -MOE
370.
371.        # Summarize columns
372.        w1.rename(columns={'HD01_VD01':'TotTrnsprtEst',
373.                           'GEO.id2':'GEO_id2',
374.                           'HD01_VD02': 'CarTrkVanEst',
375.                           'HD01_VD03': 'CTVDrovealone',
376.                           'HD01_VD04':'CTVCarpoolEst',
377.                           'HD01_VD05': 'CTVcp2per',
378.                           'HD01_VD06': 'CTVcp3per',
379.                           'HD01_VD07': 'CTVcp4per',
380.                           'HD01_VD08': 'CTVcp5or6per',
381.                           'HD01_VD09': 'CTVcp7plus',
382.                           'HD01_VD10': 'PublicTrnsprtEst',
383.                           'HD01_VD11': 'PTBusTrolley',
384.                           'HD01_VD12': 'PTStCarTrolley',
385.                           'HD01_VD13': 'PTSubwayorElev',
386.                           'HD01_VD14': 'PTRailrd',
387.                           'HD01_VD15': 'PTFerry',
388.                           'HD01_VD16': 'TaxicabEst',
389.                           'HD01_VD17': 'MtrcycleEst',
390.                           'HD01_VD18': 'BicycleEst',
391.                           'HD01_VD19': 'WalkedEst',
392.                           'HD01_VD20': 'OtherEst',
393.                           'HD01_VD21': 'WorkedHomeEst'
394.                           }, inplace=True)
395.
396.        # UPPER MOE
397.        w3.rename(columns={'HD01_VD01':'TotTrnsprtEst_UpperMOE',
398.                           'GEO.id2':'GEO_id2',
399.                           'HD01_VD02': 'CarTrkVanEst_UpperMOE',
400.                           'HD01_VD03': 'CTVDrovealone_UpperMOE',
401.                           'HD01_VD04': 'CTVCarpoolEst_UpperMOE',
402.                           'HD01_VD05': 'CTVcp2per_UpperMOE',
403.                           'HD01_VD06': 'CTVcp3per_UpperMOE',
404.                           'HD01_VD07': 'CTVcp4per_UpperMOE',
405.                           'HD01_VD08': 'CTVcp5or6per_UpperMOE',
406.                           'HD01_VD09': 'CTVcp7plus_UpperMOE',
407.                           'HD01_VD10': 'PublicTrnsprtEst_UpperMOE',
408.                           'HD01_VD11': 'PTBusTrolley_UpperMOE',
409.                           'HD01_VD12': 'PTStCarTrolley_UpperMOE',
410.                           'HD01_VD13': 'PTSubwayorElev_UpperMOE',
411.                           'HD01_VD14': 'PTRailrd_UpperMOE',
412.                           'HD01_VD15': 'PTFerry_UpperMOE',
```

```
                            'HD01_VD16': 'TaxicabEst_UpperMOE',
                            'HD01_VD17': 'MtrcycleEst_UpperMOE',
                            'HD01_VD18': 'BicycleEst_UpperMOE',
                            'HD01_VD19': 'WalkedEst_UpperMOE',
                            'HD01_VD20': 'OtherEst_UpperMOE',
                            'HD01_VD21': 'WorkedHomeEst_UpperMOE'
                            }, inplace=True)
    w3['GEO_id2'] = w3['GEO_id2']/2 # Values were doubled from MOEs

    # LOWER MOE
    w4.rename(columns={'HD01_VD01':'TotTrnsprtEst_LowerMOE',
                            'GEO.id2':'GEO_id2',
                            'HD01_VD02': 'CarTrkVanEst_LowerMOE',
                            'HD01_VD03': 'CTVDrovealone_LowerMOE',
                            'HD01_VD04':'CTVCarpoolEst_LowerMOE',
                            'HD01_VD05': 'CTVcp2per_LowerMOE',
                            'HD01_VD06': 'CTVcp3per_LowerMOE',
                            'HD01_VD07': 'CTVcp4per_LowerMOE',
                            'HD01_VD08': 'CTVcp5or6per_LowerMOE',
                            'HD01_VD09': 'CTVcp7plus_LowerMOE',
                            'HD01_VD10': 'PublicTrnsprtEst_LowerMOE',
                            'HD01_VD11': 'PTBusTrolley_LowerMOE',
                            'HD01_VD12': 'PTStCarTrolley_LowerMOE',
                            'HD01_VD13': 'PTSubwayorElev_LowerMOE',
                            'HD01_VD14': 'PTRailrd_LowerMOE',
                            'HD01_VD15': 'PTFerry_LowerMOE',
                            'HD01_VD16': 'TaxicabEst_LowerMOE',
                            'HD01_VD17': 'MtrcycleEst_LowerMOE',
                            'HD01_VD18': 'BicycleEst_LowerMOE',
                            'HD01_VD19': 'WalkedEst_LowerMOE',
                            'HD01_VD20': 'OtherEst_LowerMOE',
                            'HD01_VD21': 'WorkedHomeEst_LowerMOE'
                            }, inplace=True)
    w4['GEO_id2'] = w3['GEO_id2']

    # Merge dataframes together - Have estimates and MOEs in one place
    df13_merge = pd.merge(w1, w3, on='GEO_id2', how='outer')
    df13_fin = pd.merge(df13_merge, w4, on='GEO_id2', how='outer')

    # Convert all negative numbers to 0 (negative numbers don't make sense here)
    df13_out = df13_fin.mask(df13_fin < 0, 0)
    '''(Version 2.0) [Source code]. https://stackoverflow.com/questions/
                                    27759084/how-to-replace-negative-numbers
                                    -in-pandas-data-frame-by-zero/53147179#
                                    53147179'''

    # Output final DataFrame and convert to CSV
    df13_out.to_csv(findir + "B08301.csv", index=False) #6155
    ############################################################
    ############################################################
    # DF14 (CSV14)
    # Retain relevant column names for reference
    colName14 = df14.iloc[0] # Series
    colEdit14 = pd.DataFrame(colName14) # DF
    colConvert14 = colEdit14.rename(columns={0: "Ext"})
    colFin14 = colConvert14[~colConvert14.Ext.str.contains("Margin of Error")]
    '''(Version 1.0) [Source code].
        https://stackoverflow.com/questions/28679930/how-to-drop-rows-from-
        pandas-data-frame-that-contains-a-particular-string-in-a-p/43399866'''

    # Drop header
```

```
474.        df14.drop(df14.index[:1], inplace=True)
475.
476.        x1 = [col for col in df14 if col.startswith('HD01_') or col.startswith('GEO.id2')]
477.        x2 = df14[x1] # New DF - Middle point
478.
479.        y1 = [col for col in df14 if col.startswith('HD02_') or col.startswith('GEO.id2')]
480.        y2 = df14[y1] # New  - All MOEs
481.
482.        # Find difference of the two dataframes (true value estimate with MOE)
483.        z1 = x2.apply(pd.to_numeric) # Estimate columns
484.        z2 = y2.apply(pd.to_numeric)  # MOE columns
485.        z3 = pd.DataFrame(z1.values + z2.values, columns=z1.columns) # +MOE
486.        z4 = pd.DataFrame(z1.values - z2.values, columns=z1.columns) # -MOE
487.
488.        # Summarize columns
489.        z1.rename(columns={'HD01_VD01':'TotalTimeEst',
490.                           'GEO.id2':'GEO_id2',
491.                           'HD01_VD02':'Tot12amto459am',
492.                           'HD01_VD03':'Tot5amto529am',
493.                           'HD01_VD04':'Tot530amto559am',
494.                           'HD01_VD05':'Tot6amto629am',
495.                           'HD01_VD06':'Tot630amto659am',
496.                           'HD01_VD07':'Tot7amto729am',
497.                           'HD01_VD08':'Tot730amto759am',
498.                           'HD01_VD09':'Tot8amto829am',
499.                           'HD01_VD10':'Tot830amto859am',
500.                           'HD01_VD11': 'Tot9amto959am',
501.                           'HD01_VD12': 'Tot10amto1059am',
502.                           'HD01_VD13': 'Tot11amto1159am',
503.                           'HD01_VD14': 'Tot12pmto359pm',
504.                           'HD01_VD15': 'Tot4pmto1159pm'
505.                           }, inplace=True)
506.
507.        # UPPER MOE
508.        z3.rename(columns={'HD01_VD01':'TotalTimeEst_UpperMOE',
509.                           'GEO.id2':'GEO_id2',
510.                           'HD01_VD02':'Tot12amto459am_UpperMOE',
511.                           'HD01_VD03':'Tot5amto529am_UpperMOE',
512.                           'HD01_VD04':'Tot530amto559am_UpperMOE',
513.                           'HD01_VD05':'Tot6amto629am_UpperMOE',
514.                           'HD01_VD06':'Tot630amto659am_UpperMOE',
515.                           'HD01_VD07':'Tot7amto729am_UpperMOE',
516.                           'HD01_VD08':'Tot730amto759am_UpperMOE',
517.                           'HD01_VD09':'Tot8amto829am_UpperMOE',
518.                           'HD01_VD10':'Tot830amto859am_UpperMOE',
519.                           'HD01_VD11': 'Tot9amto959am_UpperMOE',
520.                           'HD01_VD12': 'Tot10amto1059am_UpperMOE',
521.                           'HD01_VD13': 'Tot11amto1159am_UpperMOE',
522.                           'HD01_VD14': 'Tot12pmto359pm_UpperMOE',
523.                           'HD01_VD15': 'Tot4pmto1159pm_UpperMOE'
524.                           }, inplace=True)
525.        z3['GEO_id2'] = z3['GEO_id2']/2 # Values were doubled from MOEs
526.
527.        # LOWER MOE
528.        z4.rename(columns={'HD01_VD01':'TotalTimeEst_LowerMOE',
529.                           'GEO.id2':'GEO_id2',
530.                           'HD01_VD02':'Tot12amto459am_LowerMOE',
531.                           'HD01_VD03':'Tot5amto529am_LowerMOE',
532.                           'HD01_VD04':'Tot530amto559am_LowerMOE',
533.                           'HD01_VD05':'Tot6amto629am_LowerMOE',
534.                           'HD01_VD06':'Tot630amto659am_LowerMOE',
```

```
                        'HD01_VD07':'Tot7amto729am_LowerMOE',
                        'HD01_VD08':'Tot730amto759am_LowerMOE',
                        'HD01_VD09':'Tot8amto829am_LowerMOE',
                        'HD01_VD10':'Tot830amto859am_LowerMOE',
                        'HD01_VD11': 'Tot9amto959am_LowerMOE',
                        'HD01_VD12': 'Tot10amto1059am_LowerMOE',
                        'HD01_VD13': 'Tot11amto1159am_LowerMOE',
                        'HD01_VD14': 'Tot12pmto359pm_LowerMOE',
                        'HD01_VD15': 'Tot4pmto1159pm_LowerMOE'
                        }, inplace=True)
    z4['GEO_id2'] = z3['GEO_id2']

    # Merge dataframes together - Have estimates and MOEs in one place
    df14_merge = pd.merge(z1, z3, on='GEO_id2', how='outer')
    df14_fin = pd.merge(df14_merge, z4, on='GEO_id2', how='outer')

    # Convert all negative numbers to 0 (negative numbers don't make sense here)
    df14_out = df14_fin.mask(df14_fin < 0, 0)
    '''(Version 2.0) [Source code]. https://stackoverflow.com/questions/
                                    27759084/how-to-replace-negative-numbers
                                    -in-pandas-data-frame-by-zero/53147179#
                                    53147179'''

    # Output final DataFrame and convert to CSV
    df14_out.to_csv(findir + "B08302.csv", index=False) #6155
```

CensusTotal.py:

Allows the user to choose a demographic from census categories and output the statistical totals for each in a table;

```
#---------------------------------------------------------------------------
# Name:        Census Total (CensusTotal.py)
# Purpose:     To allow the user to choose a demographic from census categories
#              and output the statistical totals for each in a table
# Version:     Python 3.5
#---------------------------------------------------------------------------

# Import modules
import arcpy, os
from arcpy import env
import matplotlib.pyplot as plt

# Set environment settings
env.workspace = "C:/Project/data_lyrs/NCDOT_Plan.gdb"
env.scratchWorkspace = "C:/Project/scratch/scratch.gdb"
env.overwriteOutput = True

# Set local variables
outgdb = env.scratchGDB
outFol = env.scratchFolder
inPoly = arcpy.GetParameter(0) #CBsDriveFin

origPoly = os.path.join(outgdb, "serviceArea")
statsFin = os.path.join(outgdb, "statsFin")
recPoly = os.path.join(outgdb, "SAStats")
linkPoly = os.path.join(outgdb, "LinkedSA")
```

```
pdfPath = os.path.join(outFol, "CensusGraphs.pdf")

statsFinList = []
graphList = []
for num in range(1,6): # 5 values
    stat_Name = statsFin + str(num)
    graph_Name = "LineGraph" + str(num)
    pdf_Name = graph_Name + ".pdf"
    LineGraph_pdf = os.path.join(outFol, pdf_Name)
    statsFinList.append(stat_Name)
    graphList.append(LineGraph_pdf)

# Gender and Age
'''
*    Title: How to get position of key in a dictionary in python
*    Author: Steven C. Howell
*    Date: 2018
*    Code / Type version: 2.0
*    Code adapted from: https://stackoverflow.com/questions/36090175/how-to-
*                       get-position-of-key-in-a-dictionary-in-python
'''
GADict = {'TotalPopEst': ['All Population','TotalPopEst_UpperMOE',
                          'TotalPopEst_LowerMOE'],
    'MalePopEst': ['All Males','MalePopEst_UpperMOE','MalePopEst_LowerMOE'],
    'FemPopEst': ['All Females','FemPopEst_UpperMOE','FemPopEst_LowerMOE'],
    'MaleEst_UndEqto20': ['Males Under 20','MaleUpperMOE_UndEqto20',
                          'MaleLowerMOE_UndEqto20'],
    'MaleEst_21to39': ['Males 21 to 39','MaleUpperMOE_21to39',
                       'MaleLowerMOE_21to39'],
    'MaleEst_40to59': ['Males 40 to 59','MaleUpperMOE_40to59',
                       'MaleLowerMOE_40to59'],
    'MaleEst_60plus': ['Males 60 Plus','MaleUpperMOE_60plus',
                       'MaleLowerMOE_60plus'],
    'FemEst_UndEqto20': ['Females Under 20','FemUpperMOE_UndEqto20',
                         'FemLowerMOE_UndEqto20'],
    'FemEst_21to39': ['Females 21 to 39','FemUpperMOE_21to39',
                      'FemLowerMOE_21to39'],
    'FemEst_40to59': ['Females 40 to 59','FemUpperMOE_40to59',
                      'FemLowerMOE_40to59'],
    'FemEst_60plus': ['Females 60 Plus','FemUpperMOE_60plus',
                      'FemLowerMOE_60plus']}

# Race
RaceDict = {'TotalRaceEst': ['All Races','TotalRace_UpperMOE',
                             'TotalRace_LowerMOE'],
    'CaucasEst': ['Caucasian','Caucas_UpperMOE','Caucas_LowerMOE'],
    'AfricanAmericnEst': ['African American','AfricanAmericn_UpperMOE',
                          'AfricanAmericn_LowerMOE'],
    'AmericnIndnAkNtiveEst': ['American Indian and Alaska Native',
                              'AmericnIndnAkNtive_UpperMOE',
                              'AmericnIndnAkNtive_LowerMOE'],
    'AsianEst': ['Asian','Asian_UpperMOE','Asian_LowerMOE'],
    'NtiveHIPacificIsleEst': ['Native Hawaiian and Pacific Islander',
                              'NtiveHIPacificIsle_UpperMOE',
                              'NtiveHIPacificIsle_LowerMOE'],
    'OtherRaceEst': ['Other Race','OtherRace_UpperMOE','OtherRace_LowerMOE'],
    'TwoMoreRacesEst': ['Two or More Races','TwoMoreRaces_UpperMOE',
                        'TwoMoreRaces_LowerMOE'],
    'TwoMoreRaces_SOEst': ['Two or More Races and Part of Some Other Race',
                           'TwoMoreRaces_SO_UpperMOE',
                           'TwoMoreRaces_SO_LowerMOE'],
```

```
    'TwoMoreRaces_SOTEst': ['Two or More Races and Excluding Some Other Race',
                            'TwoMoreRaces_SOT_UpperMOE',
                            'TwoMoreRaces_SOT_LowerMOE']}

# Language Spoken
LADict = {'TotalLangEst': ['Total Number of People that Spoke Some Language',
                           'TotalLang_UpperMOE','TotalLang_LowerMOE'],
    'EngOnly5to17': ['English Only, 5 to 17 Years','EngOnly5to17_UpperMOE',
                     'EngOnly5to17_LowerMOE'],
    'EngOnly18to64': ['English Only, 18 to 64 Years','EngOnly18to64_UpperMOE',
                      'EngOnly18to64_LowerMOE'],
    'EngOnly65Plus': ['English Only, 65 Plus','EngOnly65Plus_UpperMOE',
                            'EngOnly65Plus_LowerMOE'],
          'Spanish5to17': ['Spanish, 5 to 17 Years','Spanish5to17_UpperMOE',
                           'Spanish5to17_LowerMOE'],
          'Spanish18to64': ['Spanish, 18 to 64 Years','Spanish18to64_UpperMOE',
                            'Spanish18to64_LowerMOE'],
          'Spanish65plus': ['Spanish, 65 Plus','Spanish65Plus_UpperMOE',
                            'Spanish65Plus_LowerMOE'],
          'OtherIndoEuro5to17': ['Other Indo-European, 5 to 17 Years',
                                 'OtherIndoEuro5to17_UpperMOE',
                                 'OtherIndoEuro5to17_LowerMOE'],
          'OtherIndoEuro18to64': ['Other Indo-European, 18 to 64 Years',
                                  'OtherIndoEuro18to64_UpperMOE',
                                  'OtherIndoEuro18to64_LowerMOE'],
          'OtherIndoEuro65Plus': ['Other Indo-European, 65 Plus',
                                  'OtherIndoEuro65Plus_UpperMOE',
                                  'OtherIndoEuro65Plus_LowerMOE'],
          'Asian5to17': ['Asian, 5 to 17 Years','Asian5to17_UpperMOE',
                         'Asian5to17_LowerMOE'],
          'Asian18to64': ['Asian, 18 to 64 Years','Asian18to64_UpperMOE',
                          'Asian18to64_LowerMOE'],
          'Asian65Plus': ['Asian, 65 Plus','Asian65Plus_UpperMOE',
                          'Asian65Plus_LowerMOE'],
          'OtherLan5to17': ['Other Language, 5 to 17 Years','OtherLan5to17_UpperMOE',
                            'OtherLan5to17_LowerMOE'],
          'OtherLan18to64': ['Other Language, 18 to 64 Years',
                             'OtherLan18to64_UpperMOE','OtherLan18to64_LowerMOE'],
          'OtherLan65Plus': ['Other Language, 65 Plus','OtherLan65Plus_UpperMOE',
                             'OtherLan65Plus_LowerMOE']}

      # Transportation Means
      TMDict = {'TotTrnsprtEst': [
              'Total Number of People that Used Some Means of Transportation',
              'TotTrnsprtEst_UpperMOE','TotTrnsprtEst_LowerMOE'],
          'CarTrkVanEst': ['Total Number of People that Used a Car, Truck, or Van',
                           'CarTrkVanEst_UpperMOE','CarTrkVanEst_LowerMOE'],
          'CTVDrovealone': ['Car, Truck, or Van - Drove Alone',
                            'CTVDrovealone_UpperMOE','CTVDrovealone_LowerMOE'],
          'CTVCarpoolEst': ['Car, Truck, or Van - Carpooled Total',
                            'CTVCarpoolEst_UpperMOE','CTVCarpoolEst_LowerMOE'],
          'CTVcp2per': ['Car, Truck, or Van - In 2 Person Carpool',
                        'CTVcp2per_UpperMOE','CTVcp2per_LowerMOE'],
          'CTVcp3per': ['Car, Truck, or Van - In 3 Person Carpool',
                        'CTVcp3per_UpperMOE','CTVcp3per_LowerMOE'],
          'CTVcp4per': ['Car, Truck, or Van - In 4 Person Carpool',
                        'CTVcp4per_UpperMOE','CTVcp4per_LowerMOE'],
          'CTVcp5or6per': ['Car, Truck, or Van - In 5 or 6 Person Carpool',
                           'CTVcp5or6per_UpperMOE','CTVcp5or6per_LowerMOE'],
          'CTVcp7plus': ['Car, Truck, or Van - In 7 Person Plus Carpool',
                         'CTVcp7plus_UpperMOE','CTVcp7plus_LowerMOE'],
```

```
149.          'PublicTrnsprtEst': ['Total Number of People that Used Public Transport',
150.                               'PublicTrnsprtEst_UpperMOE',
151.                               'PublicTrnsprtEst_LowerMOE'],
152.          'PTBusTrolley': ['Public Transport - Bus or Trolley Bus',
153.                           'PTBusTrolley_UpperMOE','PTBusTrolley_LowerMOE'],
154.          'PTStCarTrolley': ['Public Transport - Streetcar or Trolley Car',
155.                             'PTStCarTrolley_UpperMOE','PTStCarTrolley_LowerMOE'],
156.          'PTSubwayorElev': ['Public Transport - Subway or Elevated',
157.                             'PTSubwayorElev_UpperMOE','PTSubwayorElev_LowerMOE'],
158.          'PTRailrd': ['Public Transport - Railroad','PTRailrd_UpperMOE',
159.                       'PTRailrd_LowerMOE'],
160.          'PTFerry': ['Public Transport - Ferryboat','PTFerry_UpperMOE',
161.                      'PTFerry_LowerMOE'],
162.          'TaxicabEst': ['Total Number of People that Used a Taxicab',
163.                         'TaxicabEst_UpperMOE','TaxicabEst_LowerMOE'],
164.          'MtrcycleEst': ['Total Number of People that Used a Motorcycle',
165.                          'MtrcycleEst_UpperMOE','MtrcycleEst_LowerMOE'],
166.          'BicycleEst': ['Total Number of People that Used a Bicycle',
167.                         'BicycleEst_UpperMOE','BicycleEst_LowerMOE'],
168.          'WalkedEst': ['Total Number of People that Walked','WalkedEst_UpperMOE',
169.                        'WalkedEst_LowerMOE'],
170.          'OtherEst': [
171.                 'Total Number of People that Used Some Other Means of Transport',
172.                 'OtherEst_UpperMOE','OtherEst_LowerMOE'],
173.          'WorkedHomeEst': ['Total Number of People that Worked at Home',
174.                            'WorkedHomeEst_UpperMOE','WorkedHomeEst_LowerMOE']}
175.
176.      # Travel Work Time
177.      TimeDict = {'TotalTimeEst':[
178.              'Total Number of People who Traveled to Work Between 12 p.m. to 12 a.m.',
179.              'TotalTimeEst_UpperMOE','TotalTimeEst_LowerMOE'],
180.          'Tot12amto459am': ['12:00 a.m. to 4:59 a.m.','Tot12amto459am_UpperMOE',
181.                             'Tot12amto459am_LowerMOE'],
182.          'Tot5amto529am': ['5:00 a.m. to 5:29 a.m.','Tot5amto529am_UpperMOE',
183.                            'Tot5amto529am_LowerMOE'],
184.          'Tot530amto559am': ['5:30 a.m. to 5:59 a.m.','Tot530amto559am_UpperMOE',
185.                              'Tot530amto559am_LowerMOE'],
186.          'Tot6amto629am': ['6:00 a.m. to 6:29 a.m.','Tot6amto629am_UpperMOE',
187.                            'Tot6amto629am_LowerMOE'],
188.           'Tot630amto659am': ['6:30 a.m. to 6:59 a.m.','Tot630amto659am_UpperMOE',
189.                               'Tot630amto659am_LowerMOE'],
190.          'Tot7amto729am': ['7:00 a.m. to 7:29 a.m.','Tot7amto729am_UpperMOE',
191.                            'Tot7amto729am_LowerMOE'],
192.          'Tot730amto759am': ['7:30 a.m. to 7:59 a.m.','Tot730amto759am_UpperMOE',
193.                              'Tot730amto759am_LowerMOE'],
194.          'Tot8amto829am': ['8:00 a.m. to 8:29 a.m.','Tot8amto829am_UpperMOE',
195.                            'Tot8amto829am_LowerMOE'],
196.          'Tot830amto859am': ['8:30 a.m. to 8:59 a.m.','Tot830amto859am_UpperMOE',
197.                              'Tot830amto859am_LowerMOE'],
198.          'Tot9amto959am': ['9:00 a.m. to 9:59 a.m.','Tot9amto959am_UpperMOE',
199.                            'Tot9amto959am_LowerMOE'],
200.          'Tot10amto1059am': ['10:00 a.m. to 10:59 a.m.','Tot10amto1059am_UpperMOE',
201.                              'Tot10amto1059am_LowerMOE'],
202.          'Tot11amto1159am': ['11:00 a.m. to 11:59 a.m.','Tot11amto1159am_UpperMOE',
203.                              'Tot11amto1159am_LowerMOE'],
204.          'Tot12pmto359pm': ['12:00 p.m. to 3:59 p.m.','Tot12pmto359pm_UpperMOE',
205.                             'Tot12pmto359pm_LowerMOE'],
206.          'Tot4pmto1159pm': ['4:00 p.m. to 11:59 p.m.','Tot4pmto1159pm_UpperMOE',
207.                             'Tot4pmto1159pm_LowerMOE']}
208.      '''(Version 2.0) [Source code]. https://stackoverflow.com/questions/36090175/
209.                                      how-to-get-position-of-key-in-a-dictionary-in
```

```
                                        -python'''

    # Input demographic of choice from census categories
    GAFid = arcpy.GetParameter(1) # Gender and Age
    RaceFid = arcpy.GetParameter(2) # Race
    LangFid = arcpy.GetParameter(3) # Language Spoken
    TMFid = arcpy.GetParameter(4) # Transportation Means
    TimeFid = arcpy.GetParameter(5) # Travel Work Time

    # Write a function that calculates statistical totals for each census category
    def categoryCensus(dict, categoryFid, statTab, outGraph):
        for key, value in dict.items():
            if value[0] == categoryFid:
                '''Replace demographic chosen with field name in census polygon'''
                arcpy.AddMessage("Replacing demographic input with table fields.")
                categoryRep = categoryFid.replace(categoryFid, key)
                MOElower = categoryFid.replace(categoryFid, value[2]) # Lower MOE
                MOEupper = categoryFid.replace(categoryFid, value[1]) # Upper MOE
                '''Find the amount of area that overlaps the original census blocks
                for percentage multipliers'''
                selectExp = "!PcntMltplier!*!{0}!".format(categoryRep)
                MOElowExp = "!PcntMltplier!*!{0}!".format(MOElower)
                MOEupExp = "!PcntMltplier!*!{0}!".format(MOEupper)
                '''Get true population count by multipling percentage multipliers
                to the original census totals'''
                arcpy.AddMessage("Calculating true totals from area overlap.")
                calcStat = arcpy.CalculateField_management(inPoly, "TrueTotal",
                                                           selectExp, "PYTHON")
                calclower = arcpy.CalculateField_management(inPoly, "TrueMOElow",
                                                            MOElowExp, "PYTHON")
                calcupper = arcpy.CalculateField_management(inPoly, "TrueMOEup",
                                                            MOEupExp, "PYTHON")
                statsFields = [[categoryRep,"SUM"],[MOElower,"SUM"],
                               [MOEupper,"SUM"],["TrueTotal","SUM"],
                               ["TrueMOElow","SUM"],["TrueMOEup","SUM"]]
                caseFid = ["FromBreak","ToBreak"]
                '''Output statistical sums of demographic chosen within each drive
                time interval'''
                outFin = arcpy.Statistics_analysis(inPoly, statTab, statsFields,
                                                   caseFid)
                '''Join table to original drive polygon'''
                arcpy.AddMessage("Summary statistics completed and joined to SA.")
                polyTabJoin = arcpy.JoinField_management(origPoly, "ToBreak",
                                                         statTab, "ToBreak")
                '''Create a graph of true value results'''
                '''
                *    Title: TableToNumPyArray
                *    Author: Esri / ArcGIS Pro Help
                *    Date: 2019
                *    Code / Type version: 2.4
                *    Code adapted from: https://pro.arcgis.com/en/pro-app/arcpy/
                *                       data-access/tabletonumpyarray.htm
                '''
                array = arcpy.da.TableToNumPyArray(statTab,('FromBreak','ToBreak',
                                                            'SUM_TrueTotal',
                                                            'SUM_TrueMOElow',
                                                            'SUM_TrueMOEup'))
                xFid = array["ToBreak"]
                yFid1 = array["SUM_TrueTotal"]
                yFid2 = array["SUM_TrueMOElow"]
                yFid3 = array["SUM_TrueMOEup"]
```

```
                '''(Version 2.4) [Source code]. https://pro.arcgis.com/en/pro-app/
                                                 arcpy/data-access/tabletonumpyarray
                                                 .htm'''
                fig, ax = plt.subplots()
                plt.title('Statistical Total for {0}'.format(categoryFid))
                plt.xlabel('Drive Time (Minutes) or Distance (Miles)')
                plt.ylabel('Estimated Sum')
                plt.xlim(xmin=min(xFid),xmax=max(xFid))
                ax.plot(xFid,yFid1,linestyle='-',marker='o',markersize=6,
                        linewidth=2,color='blue',label="True Total")
                ax.plot(xFid,yFid2,linestyle='-',marker='o',markersize=6,
                        linewidth=2,color='green',label="True Lower MOE")
                ax.plot(xFid,yFid3,linestyle='-',marker='o',markersize=6,
                        linewidth=2,color='red',label="True Upper MOE")
                '''Put labels over points'''
                '''
                *    Title: python - how to show values on top of bar plot
                *                     [duplicate]
                *    Author: Marianne Halloran
                *    Date: 2018
                *    Code / Type version: 2.0
                *    Code adapted from: https://stackoverflow.com/questions/
                *                       53066633/python-how-to-show-values-on-top-
                *                       of-bar-plot
                '''
                for i, v in enumerate(yFid1):
                    plt.text(xFid[i] - 0.2, v + 0.2, str(round(v)),
                             fontweight='bold',fontsize=8)
                for i, v in enumerate(yFid2):
                    plt.text(xFid[i] - 0.2, v + 0.2, str(round(v)),
                             fontweight='bold',fontsize=8)
                for i, v in enumerate(yFid3):
                    plt.text(xFid[i] - 0.2, v + 0.2, str(round(v)),
                             fontweight='bold',fontsize=8)
                '''(Version 2.0) [Source code]. https://stackoverflow.com/questions
                                                 /53066633/python-how-to-show-values
                                                 -on-top-of-bar-plot'''
                plt.grid(True)
                plt.legend(loc='upper left',ncol=3,prop={'size': 8})
                plt.tight_layout()
                '''Save the graph as a pdf'''
                plt.savefig(outGraph, dpi=300)
                plt.close()
                del fig
                arcpy.AddMessage("Created pdf graph for demographic.")
            else:
                pass

        # Run the functions to output the summary statistic tables
        categoryCensus(GADict, GAFid, statsFinList[0], graphList[0])
        categoryCensus(RaceDict, RaceFid, statsFinList[1], graphList[1])
        categoryCensus(LADict, LangFid, statsFinList[2], graphList[2])
        categoryCensus(TMDict, TMFid, statsFinList[3], graphList[3])
        categoryCensus(TimeDict, TimeFid, statsFinList[4], graphList[4])

        # Merge each pdf file into one pdf file
        '''
        *    Title: PDFDocument
        *    Author: Esri / ArcGIS Desktop Help
        *    Date: 2019
        *    Code / Type version: 10.7
```

```
        *    Code adapted from: http://desktop.arcgis.com/en/arcmap/latest/analyze/
        *                       arcpy-mapping/pdfdocument-class.htm
        '''
        pdfDoc = arcpy.mapping.PDFDocumentCreate(pdfPath)
        pdfDoc.appendPages(graphList[0])
        pdfDoc.appendPages(graphList[1])
        pdfDoc.appendPages(graphList[2])
        pdfDoc.appendPages(graphList[3])
        pdfDoc.appendPages(graphList[4])
        pdfDoc.saveAndClose()
        del pdfDoc
        '''(Version 10.7) [Source code]. http://desktop.arcgis.com/en/arcmap/
                                        latest/analyze/arcpy-mapping/pdfdocument-
                                        class.htm'''
        arcpy.AddMessage("Merged all pdfs into one pdf file.")

        # Copy the joined drive polygon to a new feature class to keep joined fields
        polyFin = arcpy.CopyFeatures_management(origPoly, linkPoly)

        # Copy the joined drive polygon's records to a table
        polyRec = arcpy.CopyRows_management(linkPoly, recPoly)

        # Delete unnecessary table fields and keep only relevant ones
        arcpy.AddMessage("Cleaning output table fields.")
        delFid = arcpy.DeleteField_management(linkPoly,["FacilityID","Name",
        "FacilityOID","Name_1","FromBreak_1","ToBreak_1","FREQUENCY",
        "FromBreak_12","ToBreak_12","FREQUENCY_1","FromBreak_12_13",
        "ToBreak_12_13","FREQUENCY_12","FromBreak_12_13_14","ToBreak_12_13_14",
        "FREQUENCY_12_13","FromBreak_12_13_14_15","ToBreak_12_13_14_15",
        "FREQUENCY_12_13_14"])

        delRec = arcpy.DeleteField_management(recPoly,["FacilityID","Name",
        "FacilityOID","Name_1","FromBreak_1","ToBreak_1","FREQUENCY",
        "FromBreak_12","ToBreak_12","FREQUENCY_1","FromBreak_12_13",
        "ToBreak_12_13","FREQUENCY_12","FromBreak_12_13_14","ToBreak_12_13_14",
        "FREQUENCY_12_13","FromBreak_12_13_14_15","ToBreak_12_13_14_15",
        "FREQUENCY_12_13_14","Shape_Area","Shape_Length"])

        # Output the final table containing all statistical sums for the chosen
        # demographics
        arcpy.AddMessage("Script completed successfully.")
        polyOut = arcpy.SetParameter(6, linkPoly) # Stat SA polygon
        recOut = arcpy.SetParameter(7, recPoly) # Stat Table
        pdfchartOut = arcpy.SetParameter(8,pdfPath) # Census Graphs PDF
```

DriveTotal.py:

Allows the user pick a point along any street on the map, input three drive time/distance thresholds and it's units, and output the drive polygon on the map

```
#---------------------------------------------------------------------------
# Name:         Drive Total (DriveTotal.py)
# Purpose:      To allow the user to pick a point along any street on the map,
#               input three drive time / distance thresholds and its units, and
#               output the drive polygon on the map
```

```
# Version:     Python 3.5
#-------------------------------------------------------------------------------

# Import modules
import arcpy, os
from arcpy import env

# Set environment settings
env.workspace = "C:/xhong2_Project/data_lyrs/NCDOT_Plan.gdb"
env.scratchWorkspace = "C:/xhong2_Project/scratch/scratch.gdb"
env.overwriteOutput = True

# Check out the Network Analyst extension license
arcpy.CheckOutExtension("Network")

# Set local variables
outgdb = env.scratchGDB
savePoint = os.path.join(outgdb, "SelectedPoint")
serviceArea = os.path.join(outgdb, "serviceArea")
RoadsND = "Roads/Roads_ND"

# Create a new feature set with same schema as Facilities parameter in
# Generate Service Areas tool.
facilities = arcpy.GetParameter(0)
facilities.load(facilities)

breakValues = arcpy.GetParameter(1) # 10, 20, 30
breakUnits = arcpy.GetParameter(2) # Minutes, Miles

# Set limit on number of facilities entered - 1
maxFacilities = 1
fac_count = arcpy.GetCount_management(facilities)
fac_str = str(fac_count)
fac_int = int(fac_str)

'''
*    Title: GenerateServiceAreas_Workflow.py
*    Author: Esri
*    Date: 2019
*    Code / Type version: 10.7
*    Code adapted from: ArcToolbox Script / ArcMap Search
'''
if fac_int > maxFacilities:
    arcpy.Delete_management(facilities)
    arcpy.AddIDMessage("ERROR", 30096,"Facilities", maxFacilities)
    sys.exit(0)
elif facilities == '#' or not facilities:
    arcpy.Delete_management(facilities)
    arcpy.AddMessage("ERROR. Select a point on the map.")
    sys.exit(0)
elif arcpy.Exists(facilities):
    arcpy.Delete_management(facilities)
else:
    pass
'''(Version 10.7) [Source code].
    "ArcMap Search: Generate Service Areas (Network Analyst)'''

pt_out = arcpy.CopyFeatures_management(facilities,savePoint)

# Set limit on number of break values entered - 3
res = [x.strip() for x in breakValues.split(',')]
```

```
res_convert = list(map(int,res))
maxbreakValues = 3
bv_count = len(res_convert)
if bv_count > maxbreakValues or bv_count < maxbreakValues:
    arcpy.AddMessage("ERROR. Enter exactly 3 break values.")
    sys.exit(0)
else:
    #Get the max value from breakValues
    res_max = max(res_convert)
    res_buf = str(res_max) + " Miles"

# Create an empty feature class with same spatial reference as network dataset
facility_id = "FacilityOID" #long
frombreak_fid = "FromBreak" #double
tobreak_fid = "ToBreak" #double

# Generate service area around the input point and copy the output service area
# to a new feature class
'''
*    Title: Generate Service Areas
*    Author: Esri / ArcGIS Desktop Help
*    Date: 2019
*    Code / Type version: 10.7
*    Code adapted from: http://desktop.arcgis.com/en/arcmap/latest/tools/
*                       network-analyst-toolbox/generate-service-areas.htm
'''
arcpy.AddMessage("Generating service area around point.")
if breakUnits == 'Minutes':
    arcpy.na.GenerateServiceAreas(facilities,breakValues,breakUnits,RoadsND,
                                  serviceArea,"TRAVEL_FROM","", "NO_UTURNS",
                                  "","","","","","","","","","","","","","",
                                  "NO_OVERLAP","RINGS","DETAILED_POLYS","","",
                                  1,3,"","","",res_max,"")
    else:
        arcpy.na.GenerateServiceAreas(facilities,breakValues,breakUnits,RoadsND,
                                      serviceArea,"TRAVEL_FROM","", "NO_UTURNS",
                                      "","","","","","","","","","","","","","",
                                      "NO_OVERLAP","RINGS","DETAILED_POLYS","","",
                                      1,3,"","","","",res_max)
    '''(Version 10.7) [Source code]. http://desktop.arcgis.com/en/arcmap/latest/
                                    tools/network-analyst-toolbox/generate-
                                    service-areas.htm'''

    # Make feature layer of drive polygon
    SAlyr = arcpy.MakeFeatureLayer_management(serviceArea, "SA_lyr")

    # Copy each row of drive polygon to individual fcs (e.g., 5 min = fc1,
    # 10 min = fc2..)
    for num in range(1,maxbreakValues + 1):
        SAName = "ServicePoly" + str(num)
        arcpy.AddMessage("Creating separate feature classes for drive thresholds.")
        '''
        *    Title: GenerateServiceAreas_Workflow.py
        *    Author: Esri / ArcGIS Desktop Help
        *    Date: 2016
        *    Code / Type version: 10.3
        *    Code adapted from: http://desktop.arcgis.com/en/arcmap/10.3/tools/
        *                       network-analyst-toolbox/generate-service-areas.htm
        '''
        outSA = arcpy.management.CreateFeatureclass(outgdb, SAName, "POLYGON","",
                                                    "","",RoadsND)
```

```
            arcpy.management.AddField(outSA, facility_id, "LONG")
            arcpy.management.AddField(outSA, frombreak_fid, "DOUBLE")
            arcpy.management.AddField(outSA, tobreak_fid, "DOUBLE")
            # Extract new fc by OID
            arcpy.SelectLayerByAttribute_management("SA_lyr", "NEW_SELECTION",
                                                    '"OBJECTID" = {0}'.format(num))
            # Open an insert cursor on the new feature class to add polygon info
            cursor = arcpy.da.InsertCursor(outSA, ("SHAPE@", facility_id,
                                                   frombreak_fid, tobreak_fid))
            # Get the shape from the temp service area and copy to separate polygons
            arcpy.AddMessage("Copying row info to each feature class.")
            with arcpy.da.SearchCursor("SA_lyr",("SHAPE@", facility_id, frombreak_fid,
                                                 tobreak_fid)) as inputRows:
                for row in inputRows:
                    cursor.insertRow((row[0],row[1], row[2], row[3]))
            del cursor
            '''(Version 10.3) [Source code]. http://desktop.arcgis.com/en/arcmap/10.3/
                                            tools/network-analyst-toolbox/generate-
                                            service-areas.htm'''
            arcpy.SelectLayerByAttribute_management("SA_lyr", "CLEAR_SELECTION")

        # Append each drive polygon to a list
        SA1 = os.path.join(outgdb, "ServicePoly1")
        SA2 = os.path.join(outgdb, "ServicePoly2")
        SA3 = os.path.join(outgdb, "ServicePoly3")
        outSA_list = [SA1, SA2, SA3]

        # Output all parameters
        fac_out = arcpy.SetParameter(3,savePoint)
        SA1_out = arcpy.SetParameter(4,outSA_list[0]) # SA1: e.g., 0-10min
        SA2_out = arcpy.SetParameter(5,outSA_list[1]) # SA2: e.g., 10-20min
        SA3_out = arcpy.SetParameter(6,outSA_list[2]) # SA3: e.g., 20-30min
        poly_out = arcpy.SetParameter(7, serviceArea) # e.g., 0-30min

        # Add completed script message
        arcpy.AddMessage("Script completed successfully.")
```

Fill_Speeds.py:

Used for replacing null speed limit values based on NCDOT route characteristics metadata

```
#-------------------------------------------------------------------------------
# Name:        Null Speed Limit Replacements (Fill_Speeds.py)
# Purpose:     To replace null speed limit values based on NCDOT route
#              characteristics metadata
# Version:     Python 3.5
#-------------------------------------------------------------------------------

with arcpy.da.UpdateCursor("Streets",["TF_Minutes","FT_Minutes","Miles","TownCode","MPH"]) as
cursor:
    for row in cursor:
        if row[0] == None and row[3] == None:
        '''speed limit is 55 outside of municipalties'''
            row[4] = 55
            row[0] = row[2]/55
            row[1] = row[2]/55
            cursor.updateRow(row)
        elif row[0] == None and row[3] != None:
```

```
        '''speed limit is 35 in municipalities'''
            row[4] = 35
            row[0] = row[2]/35
            row[1] = row[2]/35
            cursor.updateRow(row)
        else:
            pass
    del row
```

LRPredict.py:

Used to predict population values using time as a function.

```
#---------------------------------------------------------------------------
# Name:        Linear Regression Predict (LRPredict.py)
# Purpose:     To predict population values using time as a function
# Version:     Python 3.5
# Notes:       Script run in 'Anaconda Spyder'
#---------------------------------------------------------------------------

# Import packages
import arcpy, os
from arcpy import env
from scipy import stats
import pandas as pd
import matplotlib.pyplot as plt

# Set environment settings
env.workspace = "C:/xhong2_Project/data_lyrs/NCDOT_Plan.gdb"
env.scratchWorkspace = "C:/xhong2_Project/scratch/scratch.gdb"
env.overwriteOutput = True

# Set local variables
outgdb = env.scratchGDB
outFol = env.scratchFolder
Excelfile = arcpy.GetParameter(0) #CensusStats_loc1a.xls
ExcelFin = r"{0}".format(Excelfile)

# Read in datasets
df1 = pd.read_excel(ExcelFin, index_col=0, engine='xlrd')
df1 = df1.fillna(method='ffill')

# Set local variables
timecol = ["FromBreak","ToBreak"]
cols_all = list(df1.columns.values) # all columns
cols_tot = [col for col in df1.columns if 'SUM_True' not in col
             and col not in timecol and 'MOE' not in col] # SUM cols w/out MOE
cols_true = [col for col in df1.columns if 'SUM_True' in col
             and col not in timecol and 'MOE' not in col] # True cols w/out MOE
pdfPath = os.path.join(outFol, "PopAnalysisGraphs.pdf")
graphList = []
txtList = []

for num in range(1,6): # 5 values
    graph_Name = "Graph" + str(num)
    txt_base = "PopAnalysis" + str(num)
    pdf_Name = graph_Name + ".pdf"
    txt_Name = txt_base + ".txt"
    Graph_Out = os.path.join(outFol, pdf_Name)
    txt_Out = os.path.join(outFol, txt_Name)
```

```
    graphList.append(Graph_Out)
    txtList.append(txt_Out)

for txt in txtList:
    f = open(txt, "w")
    f.close()

# Translate true value column names for easier interpretation
cols_convert = {cols_true[0]: cols_tot[0][4:],
                cols_true[1]: cols_tot[1][4:],
                cols_true[2]: cols_tot[2][4:],
                cols_true[3]: cols_tot[3][4:],
                cols_true[4]: cols_tot[4][4:]}

# Goal: Predict Population (Y) based on Time(X)
# Read in each population parameter
X1 = df1['ToBreak']#.values.reshape(-1,1)
Y1 = df1[cols_true[0]]
Y2 = df1[cols_true[1]]
Y3 = df1[cols_true[2]]
Y4 = df1[cols_true[3]]
Y5 = df1[cols_true[4]]

# Solve linear regression equation
def LRSolve(yVar,yName,outGraph,txt_file):
    '''
    *    Title: scipy.stats.linregress
    *    Author: The SciPy community
    *    Date: 2019
    *    Code / Type version: 1.3.3
    *    Code adapted from: https://docs.scipy.org/doc/scipy/reference/
    *                       generated/scipy.stats.linregress.html
    '''
    slope, intercept, r_value, p_value, std_err = stats.linregress(X1,yVar)
    yx = intercept + slope*X1 #y=b0+b1x1
    '''Graph output with fitted line'''
    fig, ax = plt.subplots()
    plt.title('Linear Fit for {0}'.format(yName))
    plt.xlabel('Drive Time (Minutes) or Distance (Miles)')
    plt.ylabel('Estimated Sum')
    plt.plot(X1, yVar, 'go', label='original')
    plt.plot(X1, intercept + slope*X1, 'r', label='fitted')
    plt.tight_layout()
    '''Save the graph as a pdf'''
    plt.savefig(outGraph, dpi=300)
    plt.close()
    del fig
    '''Solve Pearson's Correlation Coefficient for each parameter'''
    ''''=Note: Time * Population Parameter, * = correlation with'''
    corr1 = X1.corr(yVar,method="pearson",min_periods=1) #if Y1 then Y2
    '''(Version 1.3.3) [Source code]. https://docs.scipy.org/doc/scipy/
                                        reference/generated/scipy.stats.
                                               linregress.html'''
        '''Output statistical interpretations to text file'''
        g = open(txt_file,"a")
        g.write('Predicting {0} Population (Y) based on Time (X) \n'.format(yName))
        g.write('Note: True Estimate Fields Only\n')
        g.write('Linear Regression Equation: ')
        g.write('Y = {0} + {1}*x\n'.format(intercept,slope))
        g.write('r-squared: {0}\n'.format(r_value**2))
        g.write('p-value: {0}\n\n'.format(p_value))
```

```
            g.write('X-Values for Time:\n')
            g.write('{0}\n\n'.format(X1))
            g.write('Predicted Y-Values:\n')
            g.write('{0}\n\n'.format(yx))
            g.write('Actual Y-Values:\n')
            g.write('{0}\n\n'.format(yVar))
            g.write("Pearson's Correlation Coefficient Results:\n")
            g.write('Time with {0}: {1}\n'.format(yName,corr1))
            g.write('~~~*~~~\n')
            g.close()

        # Run function
        LRSolve(Y1, cols_tot[0][4:],graphList[0],txtList[0])
        LRSolve(Y2, cols_tot[1][4:],graphList[1],txtList[1])
        LRSolve(Y3, cols_tot[2][4:],graphList[2],txtList[2])
        LRSolve(Y4, cols_tot[3][4:],graphList[3],txtList[3])
        LRSolve(Y5, cols_tot[4][4:],graphList[4],txtList[4])

        # Write text file results to one text file
        txtMain = os.path.join(outFol,"PopAnalysisAll.txt")
        with open(txtMain, 'w') as outfile:
            for txtfile in txtList:
                with open(txtfile) as infile:
                    for line in infile:
                        outfile.write(line)

        # Merge each pdf file into one pdf file
        '''
        *    Title: PDFDocument
        *    Author: Esri / ArcGIS Desktop Help
        *    Date: 2019
        *    Code / Type version: 10.7
        *    Code adapted from: http://desktop.arcgis.com/en/arcmap/latest/analyze/
        *                       arcpy-mapping/pdfdocument-class.htm
        '''
        pdfDoc = arcpy.mapping.PDFDocumentCreate(pdfPath)
        pdfDoc.appendPages(graphList[0])
        pdfDoc.appendPages(graphList[1])
        pdfDoc.appendPages(graphList[2])
        pdfDoc.appendPages(graphList[3])
        pdfDoc.appendPages(graphList[4])
        pdfDoc.saveAndClose()
        del pdfDoc
        '''(Version 10.7) [Source code]. http://desktop.arcgis.com/en/arcmap/
                                         latest/analyze/arcpy-mapping/pdfdocument-
                                         class.htm'''

        # Output parameters
        LROut = arcpy.SetParameter(1, txtMain) # Text file of stat results
        LRRes = arcpy.SetParameter(2, pdfPath) # Analyzed graph results
```

Appendix 11: ArcGIS Pro Script to identify Zip Codes for exclusion

```
import arcpy
arcpy.env.workspace = "c:\\Users\\NCDOT_User\\Documents\\ArcGIS\\Projects\\NCDOT\\NCDOT.gdb"
#selects all the Zip Codes that are for exclusion
arcpy.SelectLayerByLocation_management("NC_ZipCodes","have_their_center_in", "Service
Area\Polygons",invert_spatial_relationship="INVERT")

#export it as a table within the arcgis pro environment for processing
arcpy.TableToTable_conversion("NC_ZipCodes", "C:\\Users\\NCDOT_User
\\Documents\\ArcGIS\\Projects\\NCDOT\\NCDOT.gdb", "ExcludedZipCodes")

#delete most of the unnecessary fields
arcpy.DeleteField_management("C:\\Users\\NCDOT_User
\\Documents\\ArcGIS\\Projects\\NCDOT\\NCDOT.gdb\\ExcludedZipCodes.dbf",  [ "OBJECTID", "ZCTA5CE10",
"AFFGEOID10", "ALAND10", "AWATER10", "ShapeSTAre","ShapeSTLen"])

#export as a CSV file to be read by the RPA
arcpy.TableToTable_conversion("ExcludedZipCodes", "C:\\Users\\ NCDOT_User
\\Documents\\ArcGIS\\Projects\\NCDOT", "ExcludedZipCodes.csv")
```

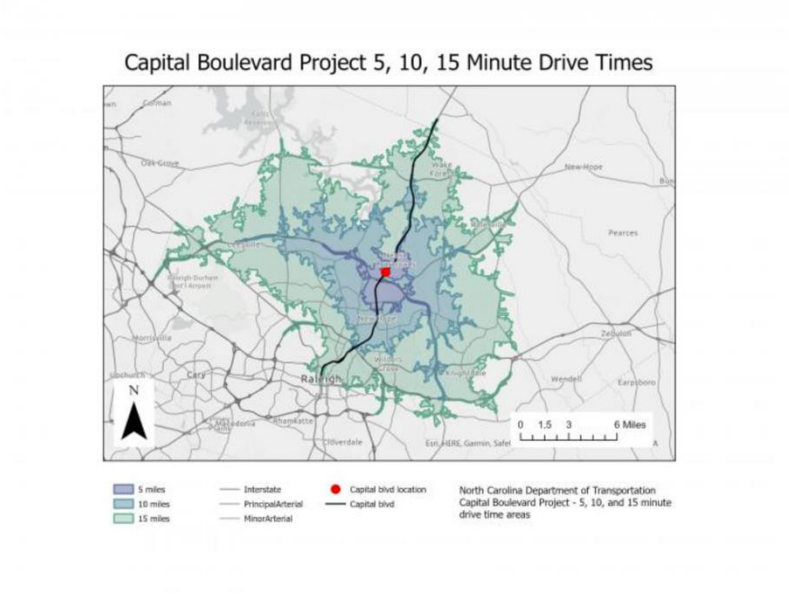
Appendix 12: Surveys Administered to Project Staff

U-5307 Capital Blvd:

NCDOT Project Manager Opinion Survey

What stage is the project currently at? What are the milestones and expected/planned dates in the next 6 months.

How would you delineate distance categories of interest for analysis (in drive time minutes)? Below is 5, 15 and 15 minute drive times for reference.



Inner area in close proximity	
Middle range distance/drive time	
Outermost boundary (farthest meaningful stakeholder distance)	

Has there been a public meeting for this project?

- ○ Yes
- ○ No

Answer the following questions regarding the meetings which have already been held (to the best of your knowledge):

Number of meetings already held?	
Number of remaining meetings planned?	

Date of the first meeting?	
Was meeting held in-person or remotely?	
About how many people attended the first meeting?	
How would you describe the demographic breakdown of the attendants? Please be specific.	
Approximate percentage of attendees which live/work in the close proximity?	
Approximate percentage of attendees which live/work in the middle distance group?	
Approximate percentage of attendees which live/work in the outermost drive time area?	
Please elaborate about any details regarding the feedback provided by the public.	

Answer the following questions regarding the meetings which are planned (to the best of your knowledge):

Number of meetings planned?	
Planned date of first meeting?	
Will meetings be in-person or held remotely?	
Estimated turnout at the first meeting?	
Estimated demographic breakdown of the attendants? Please be specific.	
Approximate percentage of attendees which live/work in close proximity?	
Approximate percentage of attendees which live/work in the middle range distance?	
Approximate percentage of attendees which live/work in the outermost drive time area?	

What is the level of public feedback **received** for the project up to this point in the public outreach effort?

	Little	Some	Moderate	Elevated	Overwhelming	N/A
In favor	○	○	○	○	○	○
Against	○	○	○	○	○	○

Please provide comments regarding the public feedback received up to this point

What is the **expected** level of public feedback for the project as a part of next public outreach milestone (Public Info Meeting, etc..) ?

	Little to none	Some	Moderate	Elevated	Overwhelming	N/A
In favor	○	○	○	○	○	○
Against	○	○	○	○	○	○

Feel free to provide comments regarding the public feedback expected

Select the categories that are of interest for analysis (select all that apply).
Time traveling to work:

- ☐ 30 minute time ranges from 5am to 9am
- ☐ 1 hour time ranges 9am to noon
- ☐ Noon to 4pm
- ☐ 4pm to midnight
- ☐ Midnight to 5 am

Select the categories that are of interest for analysis (select all that apply).
Time traveling to home:

- [ ] 30 minute time ranges from 5am to 9am
- [ ] 1 hour time ranges 9am to noon
- [ ] Noon to 4pm
- [ ] 4pm to midnight
- [ ] Midnight to 5 am

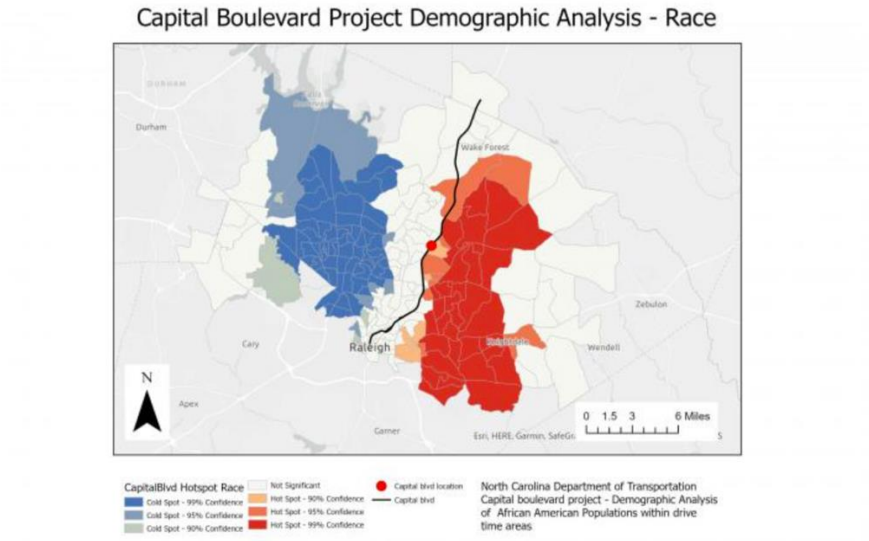
Select all the categories of **mode of transportation** which are of interest for analysis purposes (select all that apply):

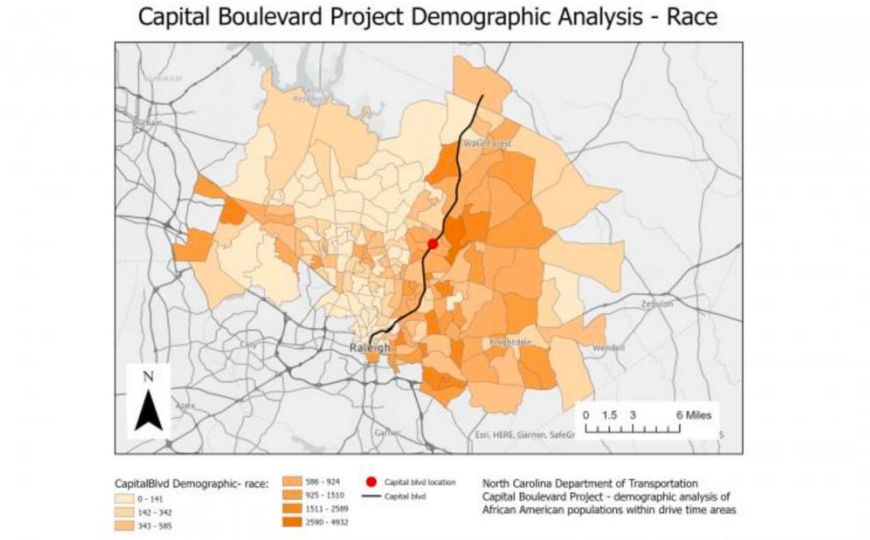
- [ ] Family/Personal vehicle (car, truck, van)
- [ ] Vehicle carpool (car, truck, van) 2 people
- [ ] Vehicle carpool (car, truck, van) 3 people
- [ ] Vehicle carpool (car, truck, van) 4 people
- [ ] Vehicle carpool (car, truck, van) 5-6 people
- [ ] Vehicle carpool (car, truck, van) more than 7 people
- [ ] Public transportation
- [ ] Walk
- [ ] Bicycle
- [ ] Taxicab
- [ ] Motorcycle
- [ ] Work from home
- [ ] Other

Select all the categories of **languages spoken** which are of interest for analysis purposes (select all that apply, to the best of your knowledge):

- ○ English
- ○ Spanish
- ○ Asian
- ○ Other Indo-European Languages
- ○ All other languages

Below are two example demographic analyses focusing on race. First image below shows statistical hot spots/cold spots for African American demographic group within the drive time areas. Second image reflects African American population numbers within the drive time areas.

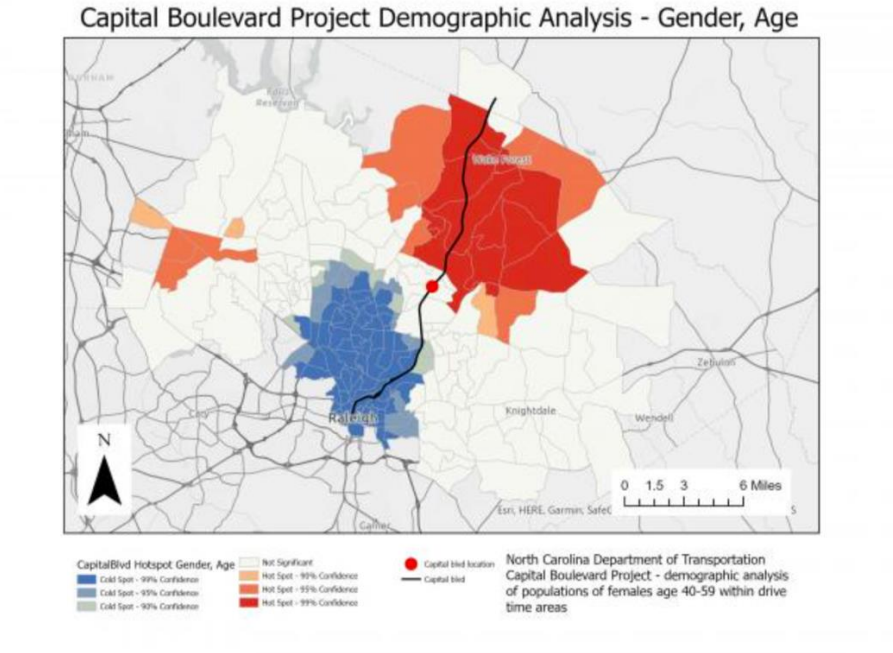


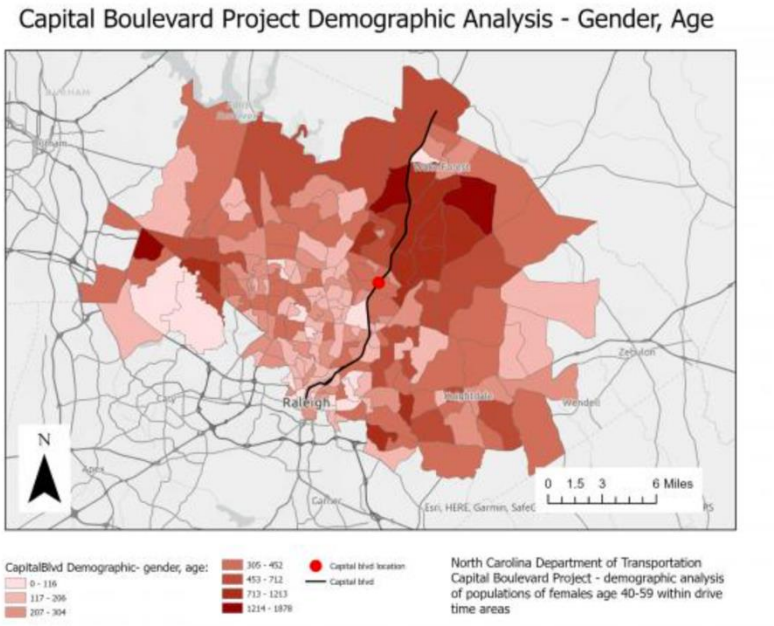


We will create more detailed analysis on various race groups based on your feedback in order to help maximize the public input. Please select all the categories of **race** which are of interest for analysis purposes (select all that apply, to the best of your knowledge):

- [ ] African American or Black
- [ ] American Indian or Alaskan Native
- [ ] Asian
- [ ] Caucasian (white or non-Hispanic)
- [ ] Caucasian (Hispanic or Latino)
- [ ] Native Hawaiian or Pacific Islander
- [ ] Other

Below are two example demographic analyses focusing on gender and age groups. First image below shows statistical hot spots/cold spots for females age 40-59 within the drive time areas. Second image reflects population numbers for females age 40-59 within the drive time areas.





We will create more detailed analysis on various gender and age groups based on your feedback in order to help maximize the public input. Please select all the categories of **gender and age category** which are of interest for analysis purposes (select all that apply, to the best of your knowledge):

- ☐ Male (<20)
- ☐ Male (21 to 39)
- ☐ Male (40 to 59)
- ☐ Male (60+)
- ☐ Female (<20)
- ☐ Female (21 to 39)
- ☐ Female (40 to 59)
- ☐ Female (60+)

Select what you believe are the benefits our approach provides over exisiting or prior approaches (can select more than one)

- ☐ Increased public participation
- ☐ Earlier public participation
- ☐ Targeting key demographics
- ☐ Reaching members of the public beyond the immediate vicinity of the project (commuters)
- ☐ Other

Answer following questions relating to the accuracy and usefulness of the analysis tools

	Strongly Disagree	Disagree	Somewhat Disagree	Neither agree or disagree	Somewhat Agree	Agree	St A
I believe the drive-time analysis results are/will be accurate	○	○	○	○	○	○	
I believe the demographic analysis results are/will be accurate	○	○	○	○	○	○	
I am likely to incorporate drive-time analyses into future work	○	○	○	○	○	○	
I am likely to incorporate demographic analyses into future work	○	○	○	○	○	○	
The demographic analysis helped identify participants likely to provide input	○	○	○	○	○	○	

Answer the following questions relating the success of the outreach process

	Strongly Disagree	Disagree	Somewhat Disagree	Neither agree or disagree	Somewhat Agree	Agre
Targeted online advertising helps engage participants likely to provide input	○	○	○	○	○	○

	Strongly Disagree	Disagree	Somewhat Disagree	Neither agree or disagree	Somewhat Agree	Agre
The public information portal engages and informs stakeholders	○	○	○	○	○	○
The public information helps elicit feedback from stakeholders	○	○	○	○	○	○
I am likely to incorporate alternative forms of outreach (targeted online ads) into future work	○	○	○	○	○	○

What privacy concerns do you have regarding the targeted online advertising? Has this been an issue in the past for this project or other projects you were involved in?

Use this space to provide us any comments about the project which has not been addressed in the previous questions.