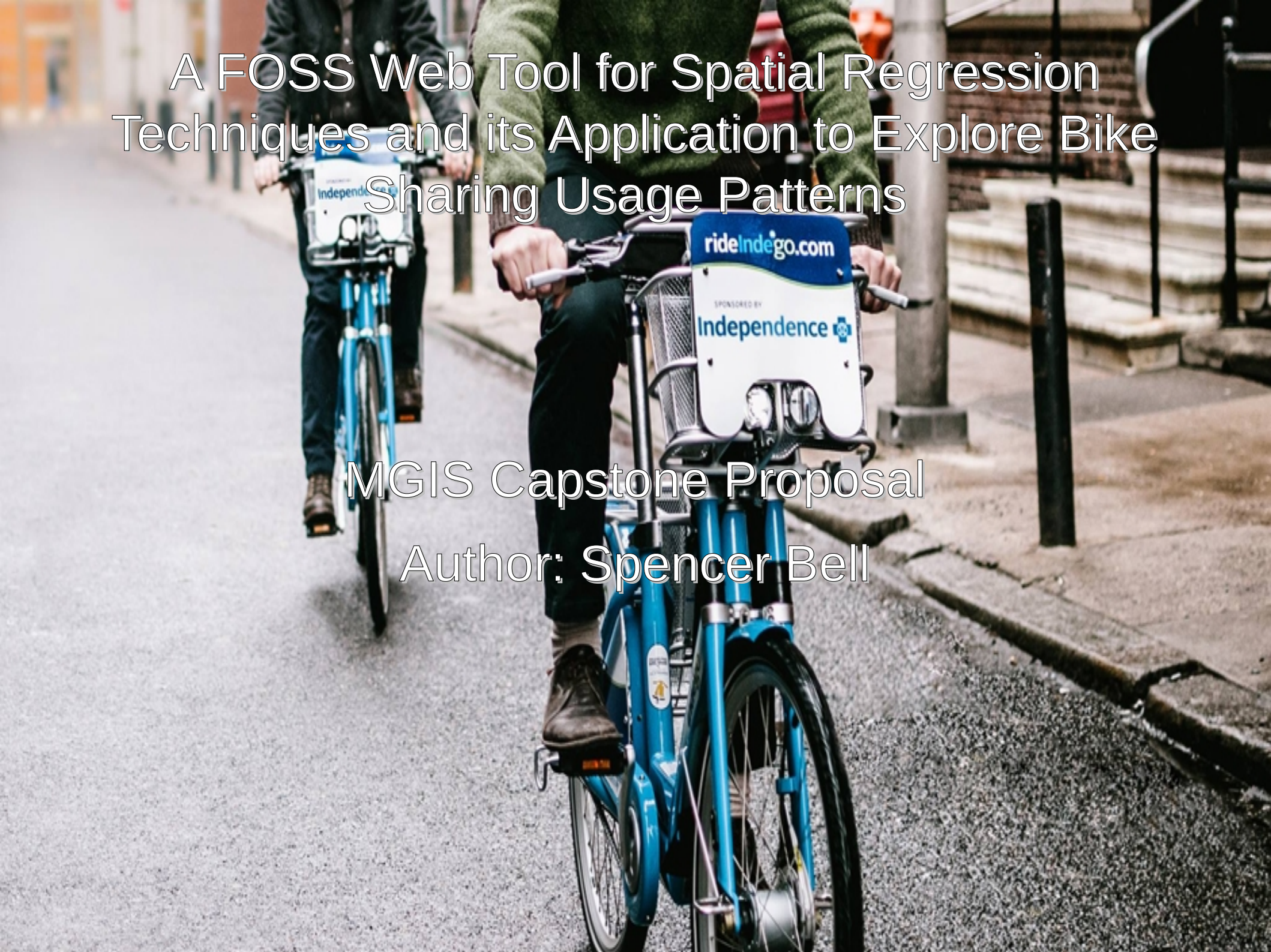
A FOSS Web Tool for Spatial Regression Techniques and its Application to Explore Bike Sharing Usage Patterns



MGIS Capstone Proposal

Author: Spencer Bell

Presentation Outline

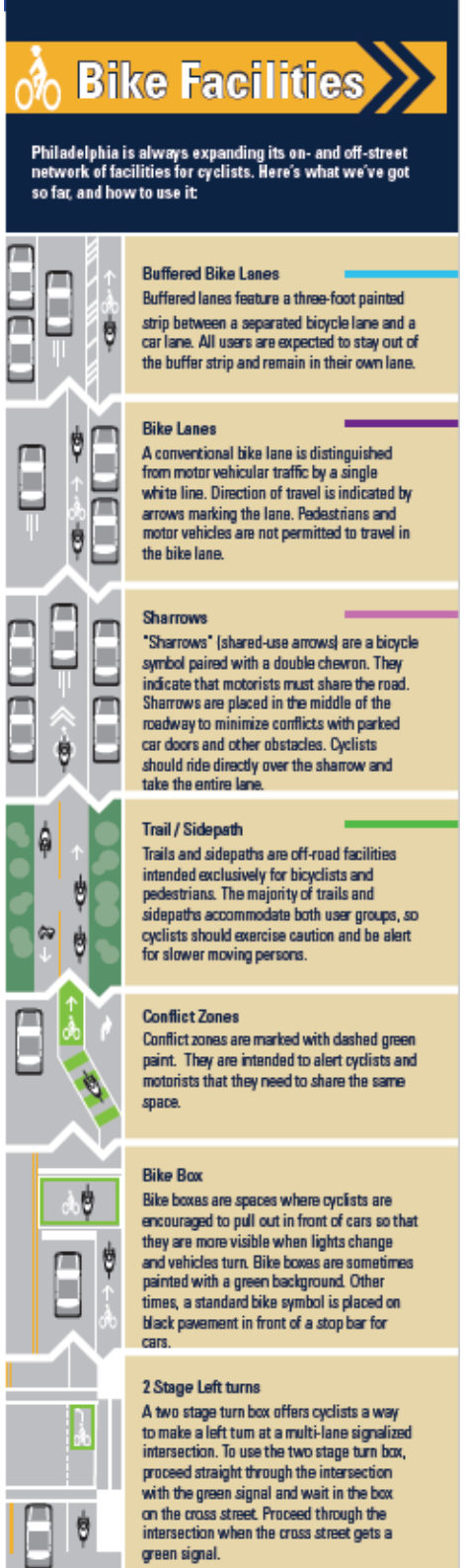
- Background
  - Bike Share
  - Spatial Regression
- Goals
  - Build a Web Tool to Explore Spatial Regression
  - Use Visual Analytics Techniques to present, explore, and disseminate results of Spatial Regression Analysis
  - Investigate and Explore Bike Share Hypothesis
- Approach & Timeline

Brief Overview of Bike Sharing

- Bike sharing has become increasingly popular in many large and medium sized urban areas
- This popularity is driven by the benefits of both the city and population

Bike Sharing Hypothesis

- The more roads with bike lanes around a given bike station, the greater the chance the station will have high bike usage
- Use the web tool to explore and prove/disprove hypothesis



Bike Data Sources

- Data sources for Indego Bike Share can be found on their website
- Variable Data is retrieved from ESRI's Business Analyst extension

THE DATA

Each .csv file contains data for one quarter of the year. Each file contains the following data points:

- Trip ID
- Duration (sec) – Trip times listed are calculated by taking the check-out and check-in times and rounding down to the minute. For example: checkout time = 4:09:14 PM, return time = 4:15:49 PM (6 minute and 35 second trip). The dataset records the trip time as 6 minutes or 360 seconds.
- Start Date, Time
- End Date, Time
- Start Station ID, Lat/Lon – The station name corresponding to the station to the station ID can be found in the Station Table.
- End Station ID, Lat/Lon
- Bike ID
- Plan Duration – This shows the type of pass by number of days (i.e., thirty-day pass shows '30')
- Trip Route Category – Round Trip or One Way
- Passholder Type – Walkup, Indego Flex or Indego30

2016 Esri Business Analyst Desktop Variable and Report List

Summary

Data and report listing for over 10,000 demographic and business variables.

Overview of Spatial Regression Analysis

- Spatial regression analysis helps you answer the question WHY
- Allows the user to model, examine, and explore spatial relationships
- Assists in predictions and forecasts to help make decisions

Ordinary Least Square (OLS)

- Models a dependent variable in terms of its relationship to a set of explanatory variables
- Is a global regression model

Geographically Weighted Regression (GWR)

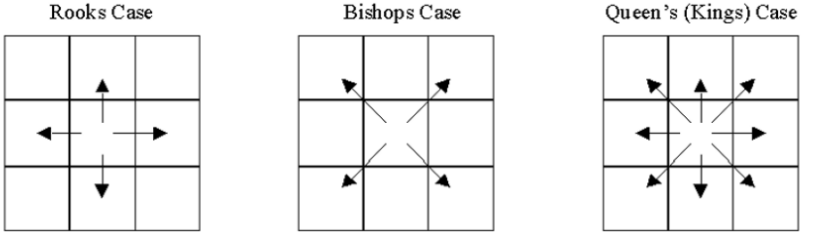
- Explore spatial non-stationarity
- Is a local regression model
- The equations incorporate the dependent and explanatory variables of features falling within the bandwidth of each target feature

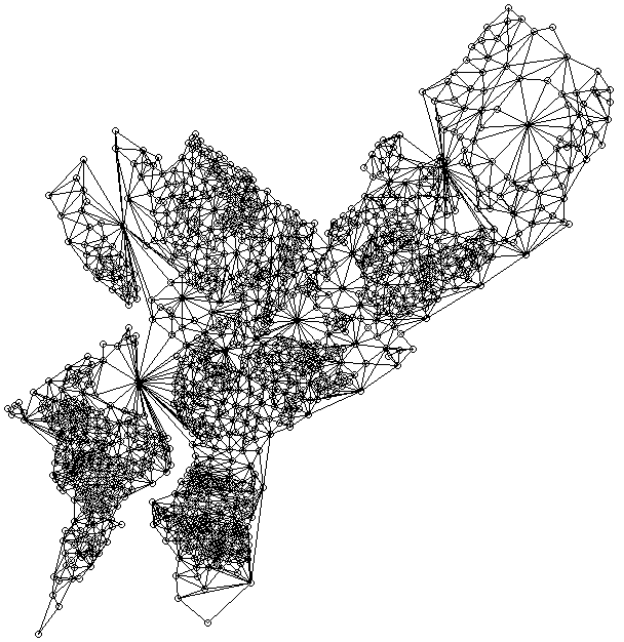
$$\hat{y}_i = \beta_0 + \sum_k \beta_k x_{ik} + \varepsilon_i \longrightarrow \hat{y}_i = \beta_0(u_i, v_i) + \sum_k \beta_k(u_i, v_i) x_{ik} + \varepsilon_i$$

Choosing Bandwidths for Localized Regression Models

- GWR constructs a separate equation for each target feature
- The features that fall within each target feature's separate equation is dependent upon the bandwidth
- Two types of bandwidth: Fixed distance or number of neighbors

Weight Matrix, Moran's I, and Spatial Autocorrelation





Checkerboard Pattern: Spatial Autocorrelation

Clustered Image Spatial Autocorrelation

Alternative Exploration Techniques

- Spatial Lag Models
- Spatial Error Models
- Structured Equation Models [5]

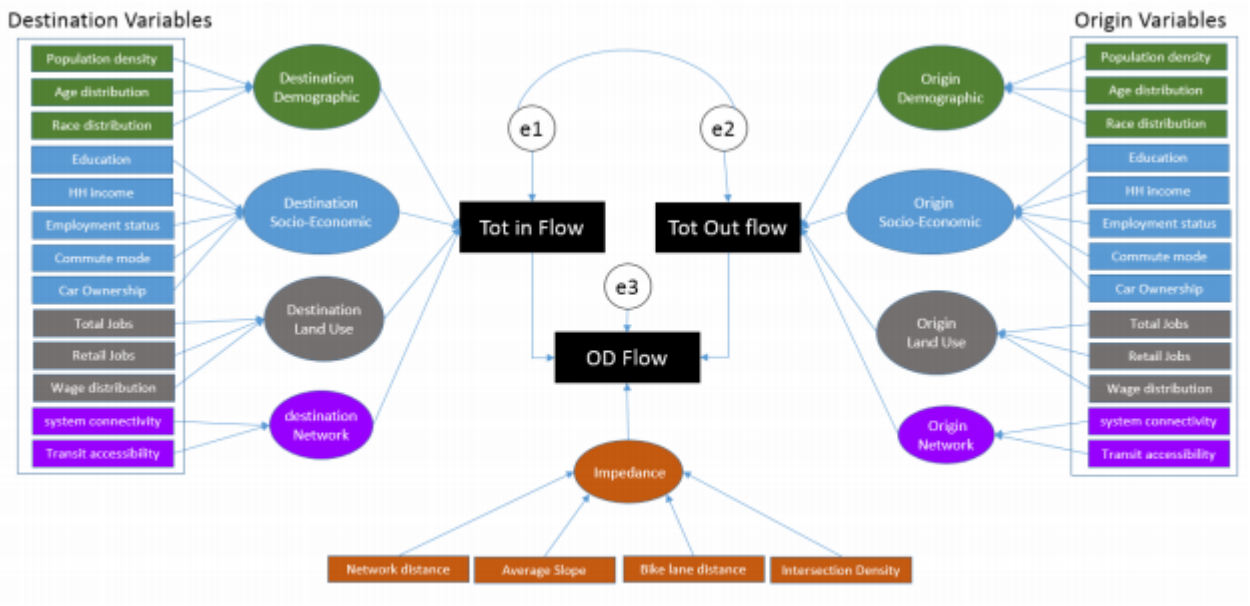
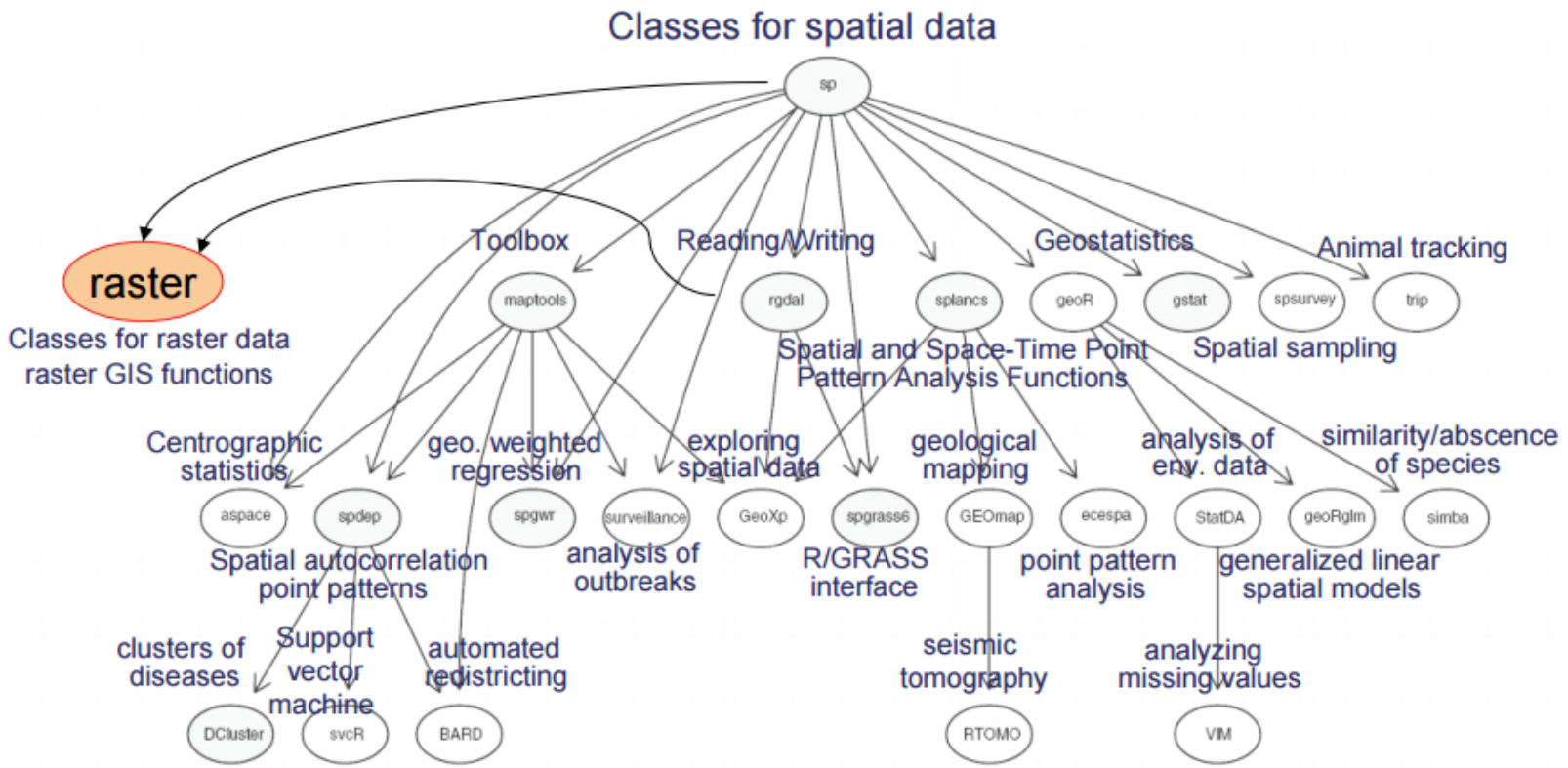


Figure 1.a BikeSEM Model

Introduction of R and Spatial Regression Packages



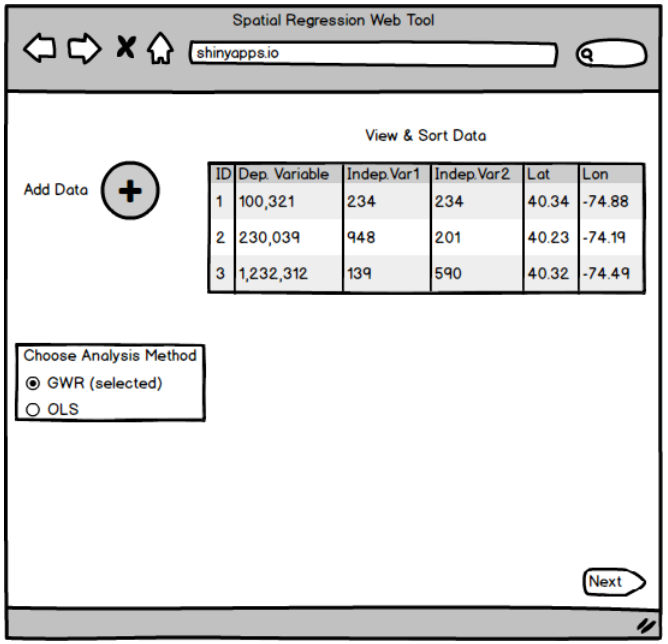
Presentation Outline

- Background
  - Bike Share
  - Spatial Regression
- Goals
  - Build a Web Tool to Explore Spatial Regression
  - Use Visual Analytics Techniques to present, explore, and disseminate results of Spatial Regression Analysis
  - Investigate and Explore Bike Share Hypothesis
- Approach & Timeline

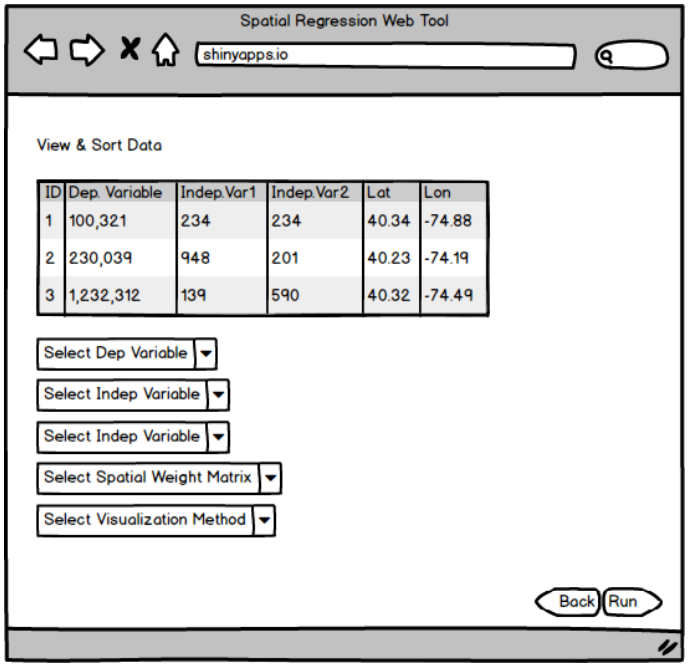
Project Goals

- Create a web tool that can run spatial regression analysis on a wide range of datasets
- Use visual analytics techniques to present, explore, and disseminate results of spatial regression analysis
- Investigate the bike share hypothesis using the web tool

Web Tool Design

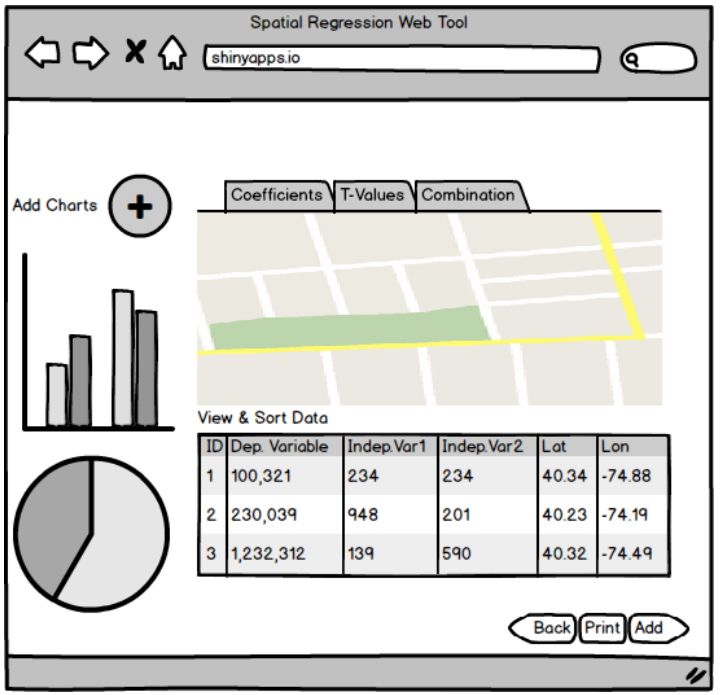


- Load data into web tool
- Ability to data wrangle
- Choose spatial regression



- Choose variables for analysis
- Select visualization method

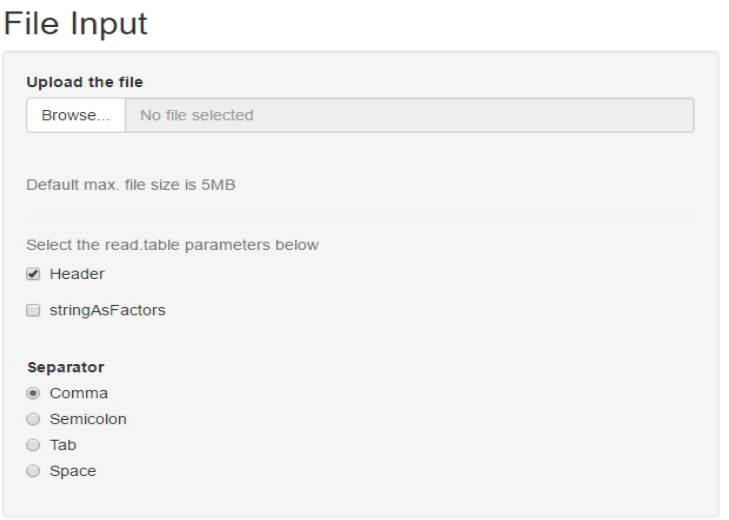
- Explore data via webmap
- Add supporting charts
- Print webmap for presentations
- Combine multiple layers for improved visualizations
- Layering and brushing



Simplifying Code

```
install.packages("rgdal")
install.packages("maptools")
install.packages("spdep")
library(rgdal)
library(maptools)
library(spdep)
```

Packages can be pre installed with shiny. Libraries can be ready without the need for the user to turn them on.




```
boston<-readOGR(dsn="F:/RShortcourse",layer="boston")
class(boston)
boston$LOGMEDV<-log(boston$CMEDV)

coords<-coordinates(boston)
IDs<-row.names(as(boston, "data.frame"))
bost_kn1<-knn2nb(knearneigh(coords, k=1), row.names=IDs)
dist<-unlist(nbdists(bost_kn1, coords))
summary(dist)

bost_kd1<-dnearneigh(coords, d1=0, d2=3.973, row.names=IDs)
plot(boston)
plot(bost_kd1, coords, add=T)

bost_kd1_w<- nb2listw(bost_kd1)

moran.test(boston$LOGMEDV, listw= bost_kd1_w)
moran.plot(boston$LOGMEDV, bost_kd1_w, labels=as.character(boston$ID), xlab="Log of Median Home Value", ylab="Spatially Lagged Median Home Value")
title("Moran scatterplot")

bostlm<-lm(LOGMEDV~RM + LSTAT + CRIM + ZN + CHAS + DIS, data=boston)
summary(bostlm)

boston$lmresid<-residuals(bostlm)
lm.morantest(bostlm,bost_kd1_w)
moran.plot(bostlm$resid,bost_kd1_w)
lm.LMtests(bostlm, bost_kd1_w, test="all")

library(lmtest)
bptest(bostlm)

bostlag<-lagsarlm(LOGMEDV~RM + LSTAT + CRIM + ZN + CHAS + DIS, data=boston, listw=bost_kd1_w)
summary(bostlag)
bptest.sarlm(bostlag)
bosterr<-errorsarlm(LOGMEDV~RM + LSTAT + CRIM + ZN + CHAS + DIS, data=boston, listw=bost_kd1_w)
summary(bosterr)
```

This equation that is repeated multiple times can be assigned as "Model 1" in the web tool.

Mennis [4] Example of Bivariate Choropleth Mapping

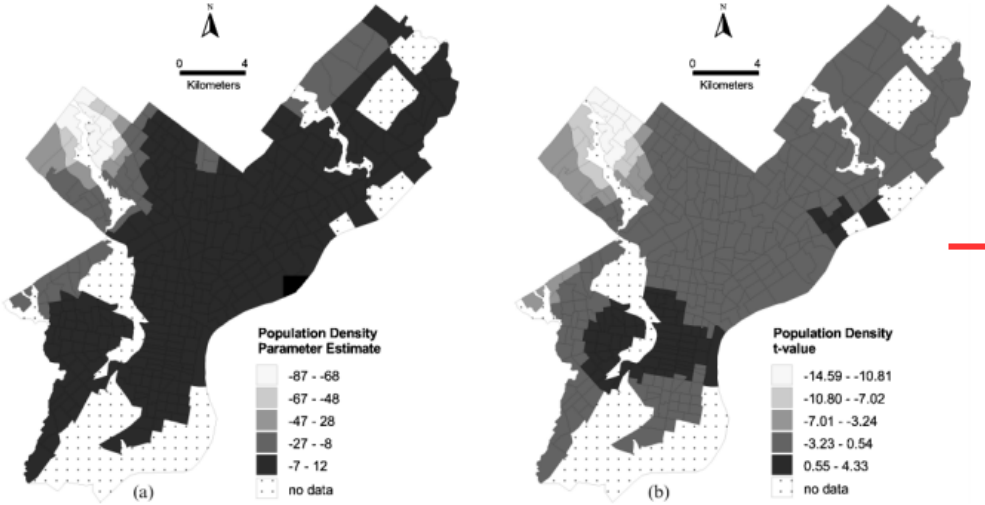


Figure 3. Choropleth maps of *a* parameter estimates and *b* t-values by census tract for the GWR of median home value using an equal step data classification and a sequential no-hue colour scheme for each map

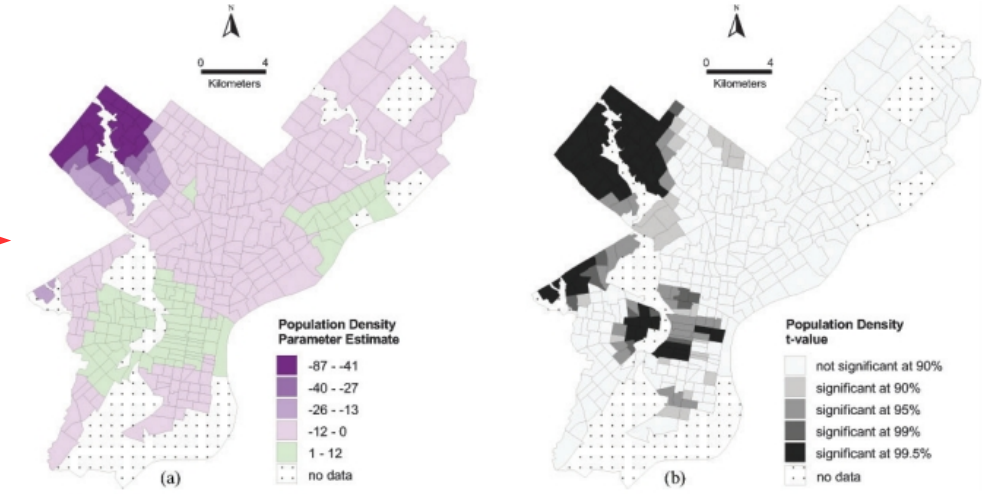
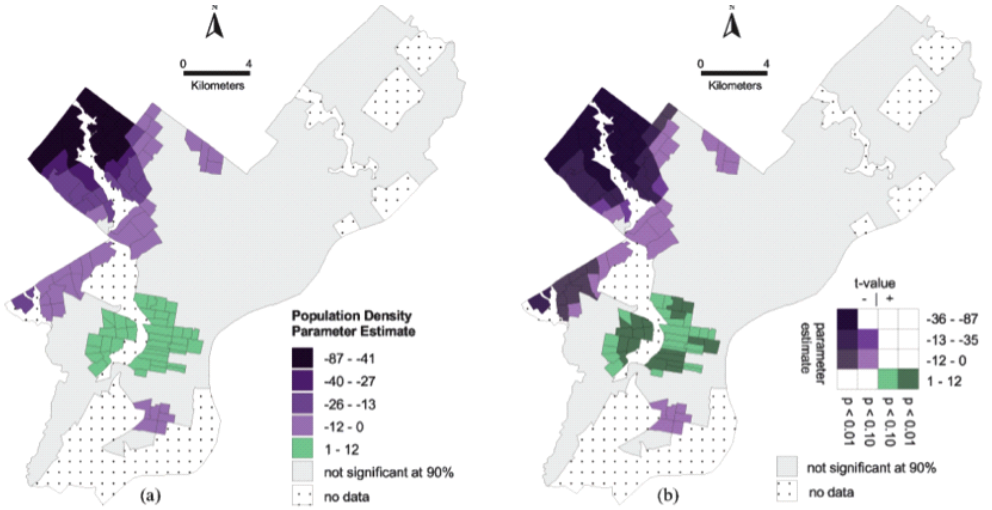


Figure 4. Choropleth maps of *a* parameter estimates and *b* t-values by census tract for the GWR of median home value. In the parameter estimate map, a modified standard deviation data classification and a diverging colour scheme is used whereas in the t-value map, an exogenous data classification based on commonly accepted significance thresholds and a sequential no-hue colour scheme is used



Matthews and Yang [3] Example of Isolines

Figure 1a: Social disadvantage local parameter estimate map

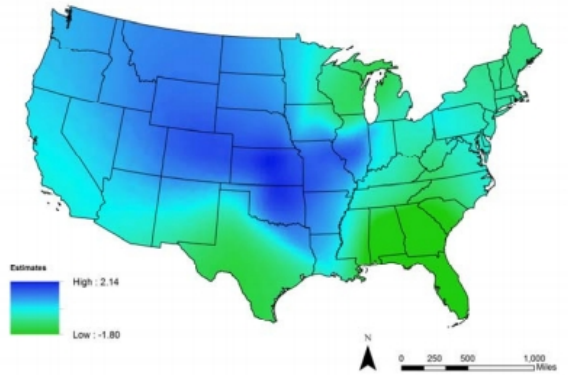
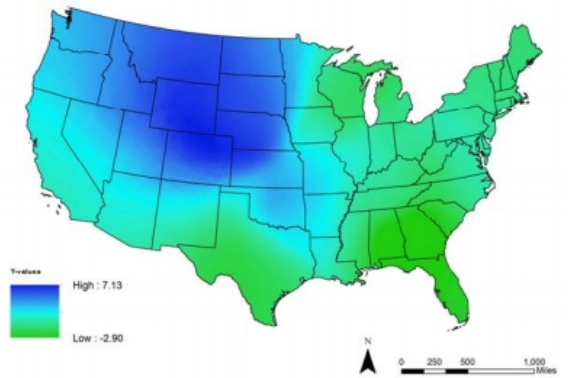


Figure 1b: Social disadvantage local t-value map



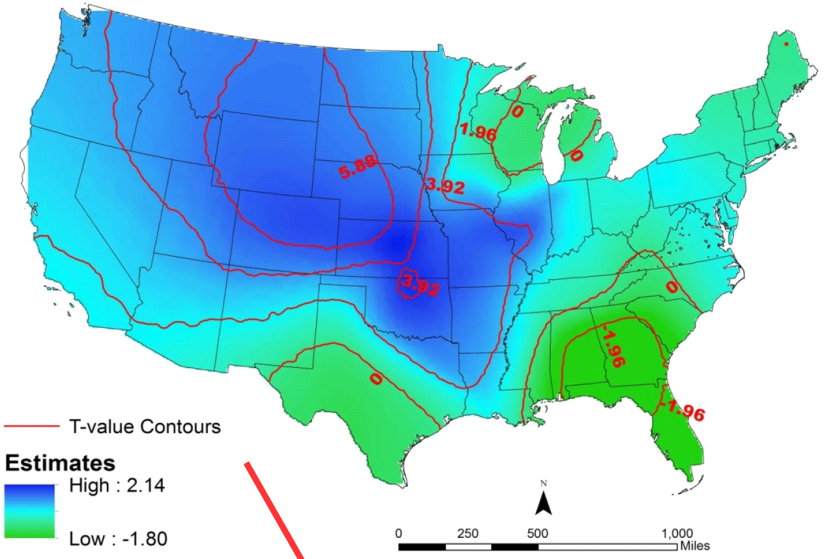
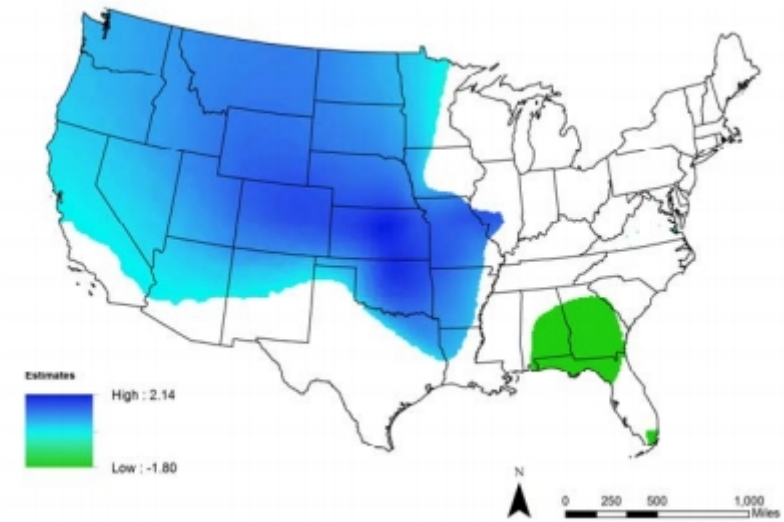


Figure 3: Social disadvantage with new mapping approach

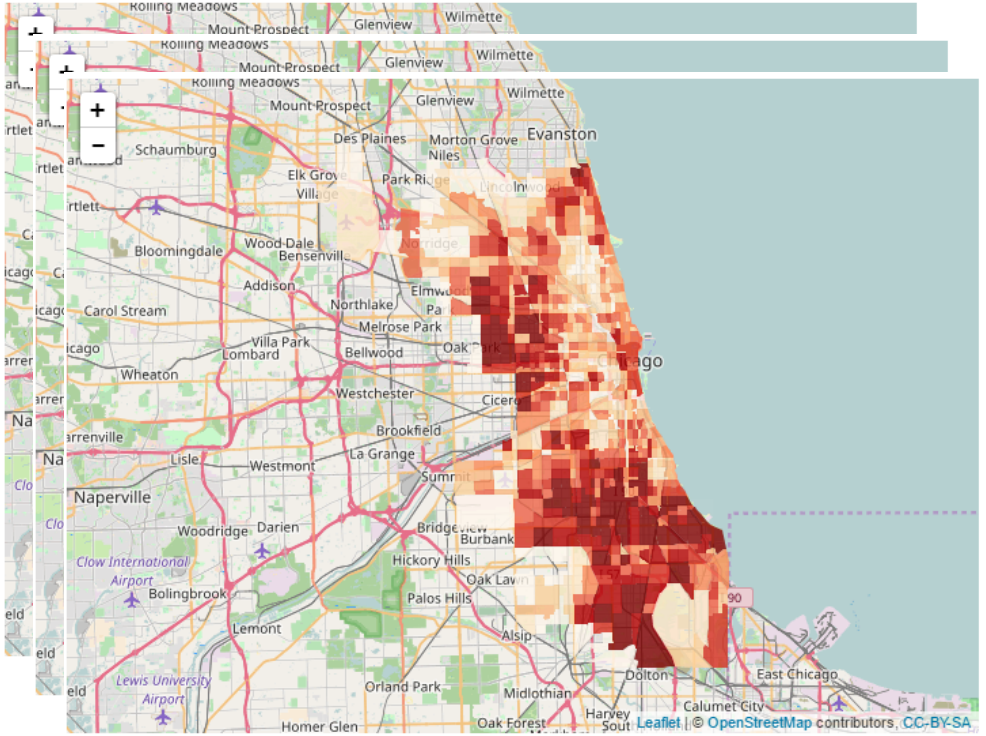


Presentation Outline

- Background
  - Bike Share
  - Spatial Regression
- Goals
  - Build a Web Tool to Explore Spatial Regression
  - Use Visual Analytics Techniques to present, explore, and disseminate results of Spatial Regression Analysis
  - Investigate and Explore Bike Share Hypothesis
- Approach & Timeline

Displaying Results on an Interactive Map

Static Map in Base R vs Interactive Map in R + Leaflet



- Interactive map allows for layering of regression outputs
- The ability to tab between models will help determine which model is the most accurate

Explanation of Shiny as a Web Framework

- Makes building interactive web applications with R possible through “reactivity”
- Htmlwidgets package allows for HTML, CSS, Javascript to be added
- Shinyapps.io is a server where shiny applications can be hosted

Advantages of Web Tool over Existing Software Solutions

- ArcGIS: Very expensive, not as much customization as other GWR tools listed

- Using base R: Steep learning curve to understanding the language. Without shiny it can not be shared easily on the web

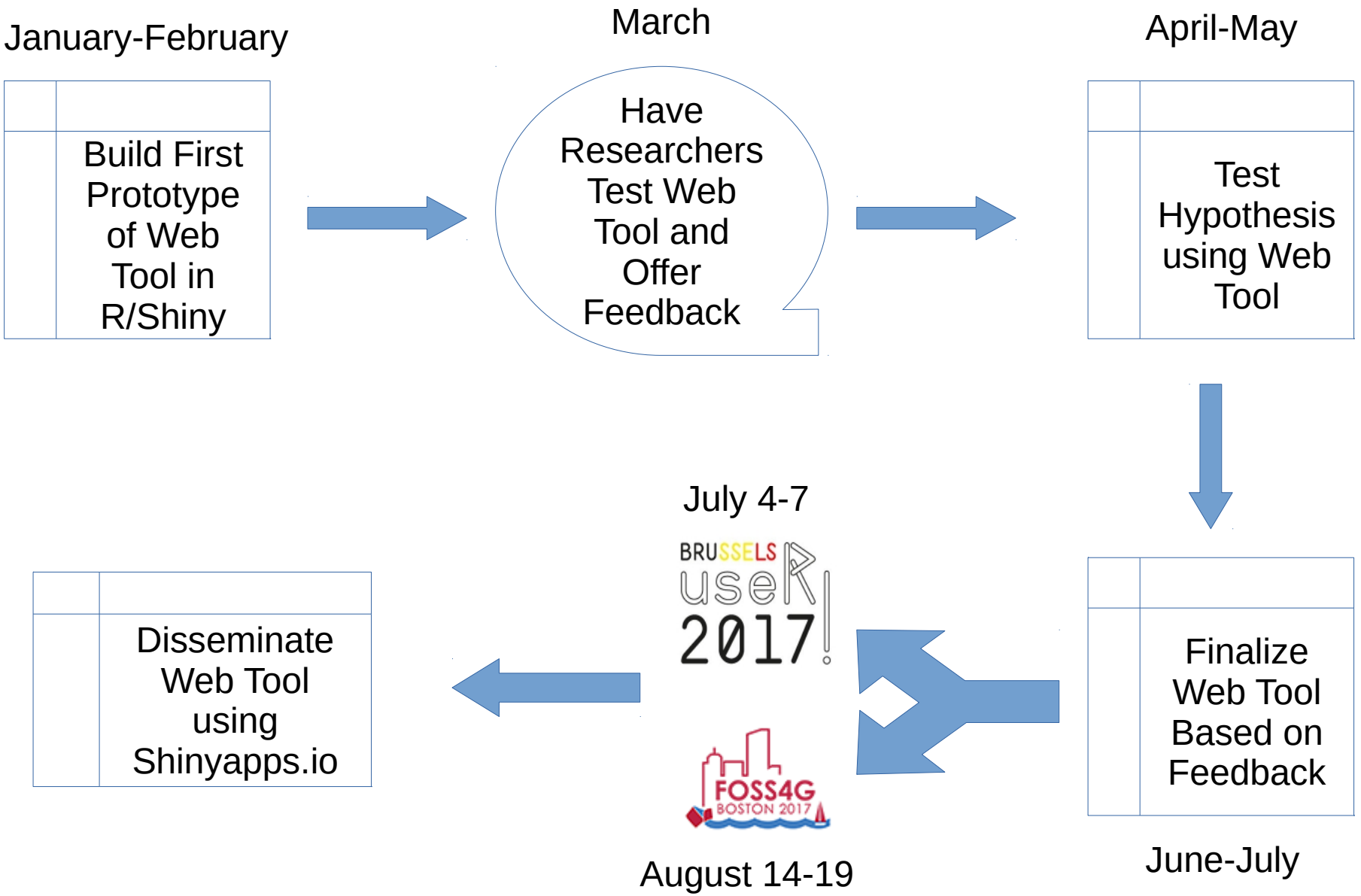
- Geoda: Unable to share results on the web

- GWR4: Great tool for setting up GWR model but there is no visual output and it can not be run on the web

Who Should Use this Web Tool?

- Students, Teachers, and Researchers
- Allow decision makers in low budget areas to make informed decisions based on solid data analysis

Project Timeline



Literature List

- [1] Forkel, Matthias. “Analysis of spatial data in R”. ftp://ftp.bgc-jena.mpg.de/pub/outgoing/mforkel/Rcourse/spatialR_2015.pdf
- [2] Ford, M. M., & Highfield, L. D. Exploring the Spatial Association between Social Deprivation and Cardiovascular Disease Mortality at the Neighborhood Level (2016). PLoS ONE, 11(1), e0146085. http://doi.org/10.1371/journal.pone.0146085
- [3] Matthews, Stephen A., and Tse-Chuan Yang. "Mapping the Results of Local Statistics." (2012). Demographic Research 26 : 151-66. Web.
- [4] Mennis, J.L. Mapping the results of geographically weighted regression (2006). The Cartographic Journal 43(2): 171-179. doi:10.1179/000870406X114658.
- [5] Ranaiefar, Fatemeh., Rixey, Alexander R. “Bike Sharing Ridership Forecast using Structural Equation Modeling” (2015). Retrieved October 26th, 2016.
- [6] Sarmiento-Barbieri, Ignacio. “An Introduction to Spatial Econometrics in R”. http://www.econ.uiuc.edu/~lab/workshop/Spatial_in_R.html.
- [7] https://www.rideindego.com/about/data/ Retrieved November 15th, 2016.

Thank You