# Bicycle Kiosk Locations in Madison, WI

University of Wisconsin at Madison
Geography 578: GIS Applications Project Final Paper
Spring 2011: May 13, 2011

Kolin Erickson (**kaerickson2@wisc.edu**)
Jonathan Spencer (**jaspencer2@wisc.edu**)
Andrew Wilson (**awilson3@wisc.edu**)

## Introduction

Our initial motivation for this project came from an article found in the *Badger Herald*, a University of Wisconsin student newspaper; the article asserted that the City of Madison allocate funds for a bicycle-sharing program with Trek Bicycle Company to begin in Spring 2011. A bicycle-sharing program consists of the installation of several kiosk sites throughout the city where professionals, residents, students, and tourists can rent bicycles for their personal use and return them at a later time. The overarching goal behind this project is to promote alternative modes of transportation to residents and visitors of Madison, where multi-modal transportation with buses can be utilized.

Formally, our capstone statement is to "create a suitability map for bicycle-sharing kiosk locations, facilitating bicycle transportation and multi-modal short distance travel for a variety of users in Madison, WI." The goal of our finished map is to identify ideal locations for potential bicycle-sharing kiosks throughout Madison, based on a set criteria met by our key concepts of accessibility, site connectivity, and bicycle barriers which will be explained in more detail in the body of this report.

## Conceptualization

Identifying the optimal sites of potential locations in Madison, Wisconsin for bicycle-sharing kiosks has fundamentally three key concepts: accessibility, site-connectivity and barriers to bicycling. Accessibility can be thought of as the consumer factor, more specifically, where the potential customers live and work. Site-connectivity can be described as the multi-modal factor, in that these variables represent infrastructure in support of an alternative to personal driving. Barriers to bicycling can be viewed as the major obstacles and deterrents to bicycle commuting, which either prohibit bicycle use, like interstate highways and their major intersections, or it includes features impossible to physically traverse, such as water bodies including lakes and rivers.

The variables associated with these key concepts are as follows: accessibility includes the distances to bicycle routes and bicycle “friendly” roads (roads with bicycle lanes) and both the population and job density of the potential locations. The site-connectivity variables include the infrastructure already in existence, supporting multi-modal short distance travel. The barriers to bicycling variables are comprised of water bodies, like lakes and rivers, and interstate highways and their major intersections. See figure 1.

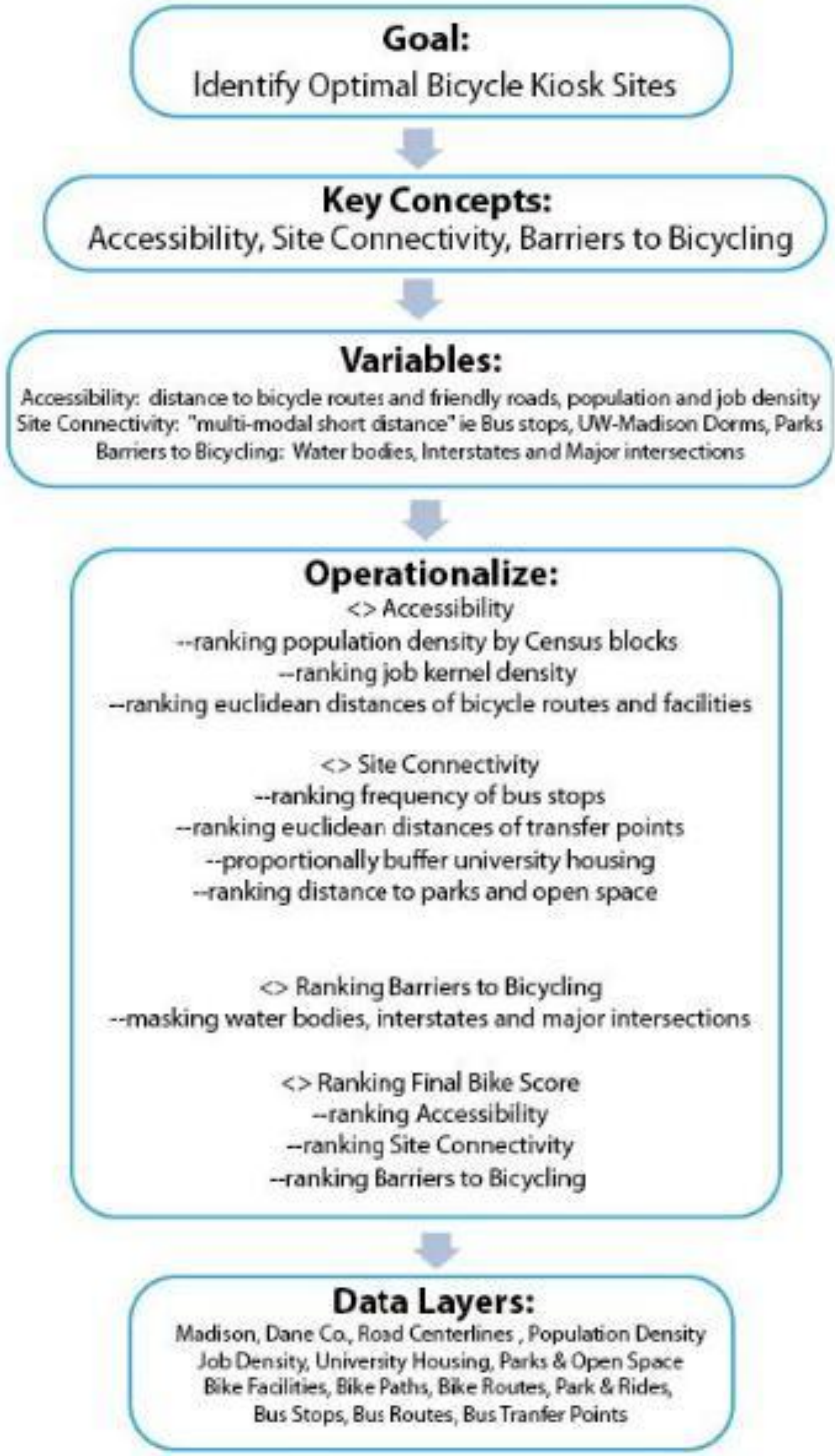


Figure 1. Conceptualization Diagram shows how to achieve our goal to identify optimal bicycle kiosk sites.

| Data Layer: | Description: |
|---|---|
| **1. Bicycle facilities** | --city infrastructure in support of, and promoting bicycle commuting. |
| **2. Bicycle routes** | -- either roadways with bicycle designated lanes AND/OR paved non-motorized trials. |
| **3. Bicycle paths** | -- either an unpaved non-motorized trail AND/OR a paved non-motorized trail. |
| **4. Transfer points** | -- several locations around the perimeter of the city limits which acts as mini-bus stations allowing patrons to use bus connections to travel though out the city. |
| **5. Bus stops** | -- simply the locations where a certain bus stops along its route. |
| **6. Park and rides** | -- designated parking lot areas outside the major city limits, which promote public transportation and multi-modal commuting to and from home and work. |
| **7. Parks** | -- city open green spaces unavailable for construction of any kind, including low impact or seasonal. |
| **8. Job density** | -- a measure of the density of employment in the neighborhoods around Madison, Wisconsin. |
| **9. Population density** | -- the measure of the amount of people in the cities smallest enumeration unit; blocks. |
| **10. University Housing** | --unique data layer of resident populations in dorms |

Table 1. All data layers and meaningful definitions.

In order to operationalize these variables of the key concepts, we will implore a GIS technique called a *Weighted Sum Raster* analysis like previous concept studies (Philadelphia 2010: 42 , Seattle 2010: 21). This procedure requires raster data layer inputs, (our particular case ranging from various demographic data to city infrastructure,) and adds the user-specified ranking classifications into a summed raster layer containing all of the information. All facets of the data went into the *Weighted Sum Raster* equation. This *Weighted Sum Raster* equation can be manipulated by the weighting model and, like an algebraic formula, the weights of the raster inputs can be structured so that some layers can have more or less influence. The data leads us to our scenarios; scenario one will increase the weights of our concepts of accessibility (where potential bike-riders live and work) and scenario two will increase the weights of site-connectivity (where multi-modal support exists) variables.

The data layers used in the process of operationalization of variables was in the format of GIS data layers. For the accessibility layers, we ranked the population density at US Census block level and created a raster layer. We also ranked the job density inside the city of Madison, WI city limits, and, finally, we ranked the Euclidean distance of bicycle routes and bicycle facilities. For the site-connectivity variables, we ranked the frequency of bus routes stopping at a single location, as well as ranked the Euclidean distances of the transfer points and parks and open space. Finally, the university housing, based on the student resident population, was buffered proportionally. For the barriers to bicycling, we ranked the Euclidian distances of "unfriendly" bicycle lanes (roads without designated bicycle lanes) and erased the water bodies from the resulting *Weighted Sum Raster* layer. See table 1. for the data layer names and their specific descriptions.

## Implementation

The majority of data layers used in our analysis came from the Arthur H. Robinson Map Library on the UW-Madison Campus (UW), with the only exceptions being the Job and Population Density layers and the UW dorms layer. The Job Density layer was derived from the U.S. Census Bureau and the U.S. Bureau of Labor Statistics. Information for our Population Density layer was accessed from the U.S. Census FactFinder Website and the census block shapefile was obtained through ESRI's Tiger files database. Finally, the UW dorms layer was a unique data layer that we created using statistical information from the UW Housing Division. Please refer to Figure 2, which is our full Implementation Diagram for this section, as the next paragraphs will explain our implementation diagram and processes in more detail.

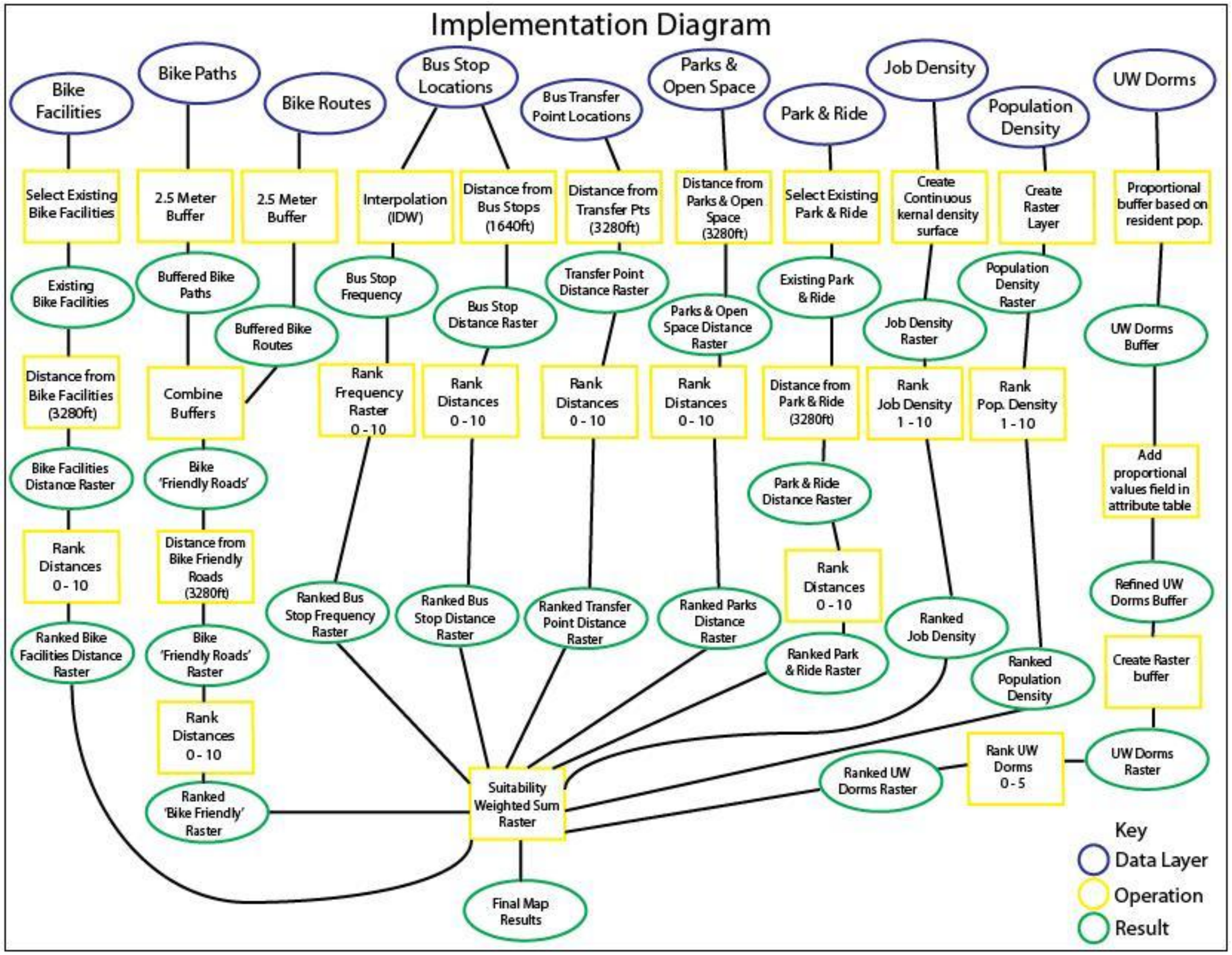


Figure 2. Implementation diagram displays the basic GIS methodology involved in the analysis.

Our general implementation workflow with most of the data layers was an iterative process, with the bulk of our time being spent gathering the data layers and preparing them for analysis. Once the data layers were in usable formats, the three main GIS operations used were the creation of buffers, calculating Euclidean distances from particular data inputs (more on this later), and reclassifying the data into a ranking system. Once these operations were performed, the final suitability map for bicycle kiosk locations could be created. Here is a brief summary of our implementation methods.

The Bike Facilities data layer were infrastructure items strictly related to bike paths, such as bridge overpasses and bridge underpasses. For the Bike Facilities data layer, as well as all other data layers used, we decided to focus our attention on existing infrastructure items only and did not include future or planned items. Once we obtained only existing bike facilities, we performed a straight line or Euclidean Distance calculation from the bike facilities point data, out to a maximum distance of 3,280 feet, which is approximately 1000 meters. To put this into perspective, this distance is about the same as traveling from the Memorial Union on the UW Campus to the Edgewater Hotel. The 3,280 feet was determined from the Philadelphia Bikesharing Concept Study, which used 500 meters (0.31 miles); our group decided to double that number to a distance of 1000 meters (0.62 miles) (Philadelphia Bikesharing Concept Study 2010: 43). Next, we reclassified the resulting Euclidean Distance layer into an eleven class system from 0 – 10, where a value of '0' corresponded to 'No Data', '1' being least favorable, (farthest distance) and '10' being most favorable (closest distance) (Philadelphia Bikesharing Concept Study 2010: 90). The ranked bike facilities layer was then ready for the final suitability analysis, which will be explained more in our results and discussion section.

The procedures described above were identical for the Bike Paths, Bike Routes, Bus Stop Locations, Bus Transfer Point Locations, Parks & Open Space, and Park & Ride data layers. The only difference for Bus Stop Locations was that we chose to use 1,640 feet (500 meters) like the Philadelphia Study because we wanted to emphasize the importance of multi-modal transportation with the local bus system. Also, the Bike Paths and Bike Routes had a few additional steps. We created a 'Bicycle Friendly' layer which is composed of the Bike Paths and Bike Routes layers, both of which were buffered at 2.5 meters (the length of a two lane road). The rest of the analysis for the Bicycle Friendly layer was then carried out the same as previously described.

Additionally, we decided to incorporate a second analysis with the Bus Stop Locations data layer. The idea behind creating a bus stop frequency layer was that the group wanted to emphasize the importance of multi-modal transportation with the bus system. To highlight its importance, we implemented an interpolated frequency surface that displayed the density of the number of bus stops throughout the greater Madison Metro area. An Inverse Distance Weighting (IDW) interpolation was used. Numerous other interpolation methods were attempted, but based on visual inspection, the IDW method proved to be the most spatially accurate for our purposes.

Our Job and Population Density layers were used with the assumption that bike kiosks will be used where a majority of people live and work. For example, people may be inclined to use a bicycle at a kiosk to run errands on their lunch break or to go get lunch at a nearby restaurant. The population density was important because we wanted to target denser populated areas; the closer the kiosks are to people, hopefully, the more likely that they will actually use the public bicycle system.

The Job Density data from the U.S. Census Bureau originally came to us as a thermal heat map image which we had to create a continuous kernel density surface in the ArcGIS software. Once this step was completed, we were then able to rank job density in a similar scale as used above, the only exception being that it was a 1 – 10 scale because there were no areas within this surface without job density. The Population Density (people/sq. mile) layer was derived through a number of field calculations within the ArcGIS software and corresponding attribute tables. The enumeration units used for the population density calculations were at the population block level, also with a ranking of 1 – 10.

Our final layer that was unique to this project was the creation of the UW dorms/housing data layer. We wanted to highlight the bicycle kiosks for the UW Campus because college students fit an ideal profile as potential users of a bicycle kiosk system. The Philadelphia Study indicated that professionals, students, residents, and tourists are the most likely users of this type of system (Philadelphia Bikesharing Concept Study 2010: 40). The UW dorms were proportionally weighted by their resident populations, with greater numbers receiving more importance than lesser ones. Again, the strategy was similar to that of our job and population density data layers: reach the vast majority of people. The resulting UW dorms raster layer was ranked 0 – 5; ‘0’ representing ‘No Data,’ ‘1’ being the least populous dorms, and ‘5’ being the most populous dorms such as Sellery, Witte, and Chadbourne residential halls.

Once all ten data layers were ranked accordingly to our scales, they were compiled into a weighted sum raster based off of similar designs by the Philadelphia Study (Philadelphia Bikesharing Concept Study 2010: 43). The results of the final suitability map will be discussed in greater depth in our results section, but we ran three trials by changing the weights of different data layers. One trial was an evenly weighted scenario with all data layers receiving a weighted score of 1.0. A second trial looked at our key concept of accessibility, weighing those variables more heavily. Finally, we ran a third trial that emphasized multi-modal transportation and greater connectivity in the Madison Metro area. Please see our Results and Discussion Section and Tables 2-3 for more information.

## Results and Discussion

The results of our analysis were observed through three separate output maps. The first map weighed each input factor evenly, while the other two applied additional weight to factors pertaining to accessibility and site connectivity. To assess our results, the final outputs were classified in order to separate the most optimal locations. For each of the outputs the highest scoring areas were all located in the downtown campus area. The top ten site locations are highlighted in Table 2.

| Rank | Location |
|---|---|
| **1** | Sellery Hall |
| **2** | Chadbourne Hall |
| **3** | Lakeshore Dorms |
| **4** | East Campus Mall |
| **5** | College Library |
| **6** | Brittington Apartments |
| **7** | Spring and Park Streets |
| **8** | Smith and Ogg Dorms |
| **9** | Observatory and Charter |
| **10** | West Washington St. |

Table 2. This table shows specific locations with the highest suitability scores in the Madison downtown area.

In order to separate levels of optimal scores, a phase implementation was used to divide each area that was considered acceptable. For each final raster there was a natural peak in the histogram of final scores. All values ranked above this peak were considered acceptable and were classified into nine classes. The top third of these classes were labeled phase one locations. These locations were the highest scoring and would therefore be ideal locations to begin implementation of bicycle kiosks in the city. The sites mentioned above were all ranked phase one along with surrounding areas and additional campus locations. The next three classes were labeled phase two and included additional downtown areas as well as areas to the east and west of Madison including Middleton and Verona. The lowest three classes displayed are the areas with the lowest scores. These areas would be useful to build phase one and two areas as well as connect the two.

While many of the general trends remained constant through the multiple weighting schemes, site connectivity and accessibility each emphasized different areas. Accessibility, presumably due to the population statistic, had an emphasized area of optimal locations centered in the downtown area. The site connectivity output, which placed additional weight on factors that encourage multi-modal transportation, emphasized areas on the west side of Madison. While a phase implementation was not determined for site connectivity or accessibility outputs, it is presumed that the location and size of phase areas would be similar to the equal weight output. The differences in weighting schemes would be most useful for site specific analysis as individual locations may differ in scores across inputs while general trends remain consistent.

The results obtained in this analysis were helpful as they were easily divided into classes, distributed throughout the study area, and contained feasible locations for bicycle kiosks. This study confirms that the downtown campus area is the most optimal location to begin installations and also identifies specific locations that most effectively cater to the needs of potential users. In addition to specific downtown locations, the classification of our results reveals the best areas to expand outside of the downtown areas. Further analysis could identify specific high scoring locations within the phase two and three areas in order to plan for further kiosk installation and expansion.

When contemplating a spatial problem in a GIS environment, many limitations exist; in our case, we encountered several issues. First, Euclidean distance is a set of ordinal buffers around the feature according to a maximum distance specified by the user. The Euclidean distance calculates, for each cell, the Euclidean distance to the closest source involving the hypotenuse, with the x-max and y-max. Network distance is involved with measuring distance, cost, time, etc. across a network consisting of polylines, nodes and some topology. Network distance would account for the bicycle paths, friendly and unfriendly roads (with and without bicycle lanes) along with bus routes. Considering bicycling is primarily focused on predetermined paths and routes, as opposed to open space and free-range riding in front yards, through parks and parking lots. Euclidean distance would not account for barriers to bicycling like buildings, water and busy intersections. A network distance would absorb the issue of operationlization of the barriers to bicycling.

Second, the issue of rasterizing vector data is common, but generally when rasterizing vector data there is a loss of spatial topology; this loss of information does not account for basic spatial references such as next to, contained by or unique overlapping entities. The generalization of rasterizing a point into a pixel creates enormous error when dealing with large pixels and a small area, but in our case we are rasterizing into 10 meter pixels over a localized area. The size of a bicycle-sharing kiosk containing more than ten bikes is approximately greater than 30 feet and thus a single kiosk could be contained inside two pixels, theoretically speaking.

A third variable is, the lack of stakeholder motivations and their influence on the weights involved with the *Weighted Sum Raster*. Doing this type of heavy data preparation for analysis, the powers that be, will be clear to mention their motivations and your duty for influencing the weights in the final ranking model. Without stakeholder input, the process of finding suitable locations in Madison, WI for bicycle-sharing kiosks is missing a key element of influence which drives the entire spatial analysis procedure.

Fourth, the university housing data layer only includes UW-Madison dormitories. The use of University of Wisconsin-Madison housing is only natural, but does not include the heavily populated university sponsored and privately-owned apartments, nor did we include the surrounding community colleges housing facilities. Limiting our university housing to only downtown UW campus limits the total student population accessible to the bicycle-sharing kiosk location in Madison, WI.

Fifth, the last major limitation is selecting optimal sites was our inability to operationalize bicycle barriers. The ranking of the bicycle barriers seem to be troublesome when Euclidian distancing bicycle “unfriendly” roads and water bodies, but simply masking the obstacles over the results, provides a visual display of the barriers to bicycle commuting. Although this is inconsistent with other variables, it is completely necessary to account for bicycle deterrents, thus a limitation of concern.

## Conclusion

Upon reviewing our final set of bicycle suitability maps, we feel validated that our implementation methods and assumptions were well-thought through and discussed amongst our group members. We sought to find the most suitable locations to build bicycle kiosks sites in the Madison Metro area and our maps have accomplished this task. Visual inspection of our maps confirms the high use areas where bicycle transportation should be most utilized. The UW Campus area, Capitol Square, and pockets of Madison's East Side are the most ideal locations, also reaffirming our key concepts of accessibility and site connectivity, see figure 3.

From a geographic viewpoint, our results conform to the traditional isthmus and lakes of Madison. There were no unknown outliers in our data such as highly suitable regions in the middle of Lake Mendota or Monona. Through completion of this project we gained a better understanding of the complexities that are part and parcel to GIS. We learned how to conceptualize a geographic topic and, more importantly, implement a number of plausible solutions.

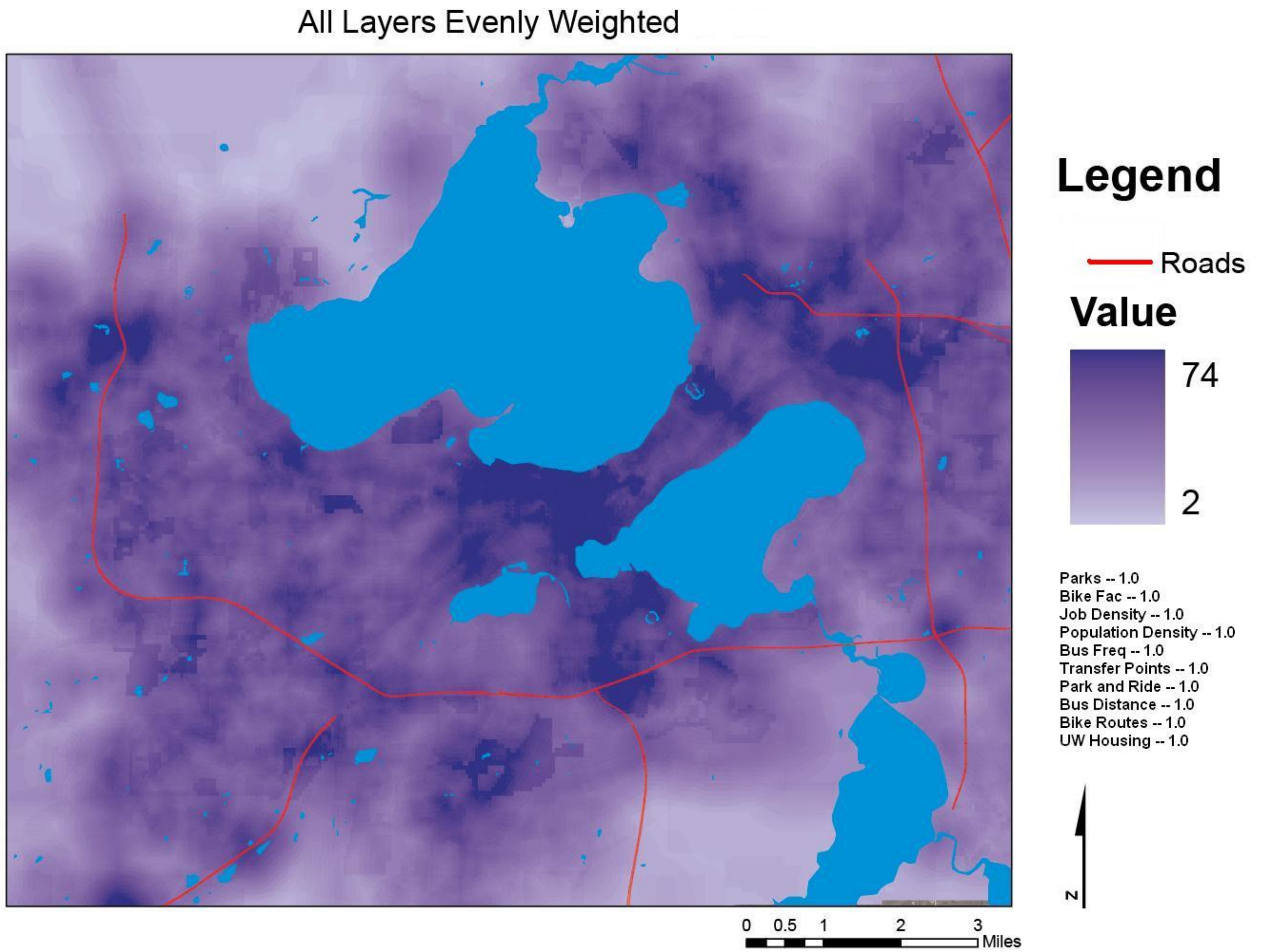


Figure 3. This map is output from a *Weighted Sum Raster* analysis, where all input variables were evenly weighted. The Final Bike Score is represented by the shade of blue and range in values between 2 and 74, calculated by data layers.

## Accessibility

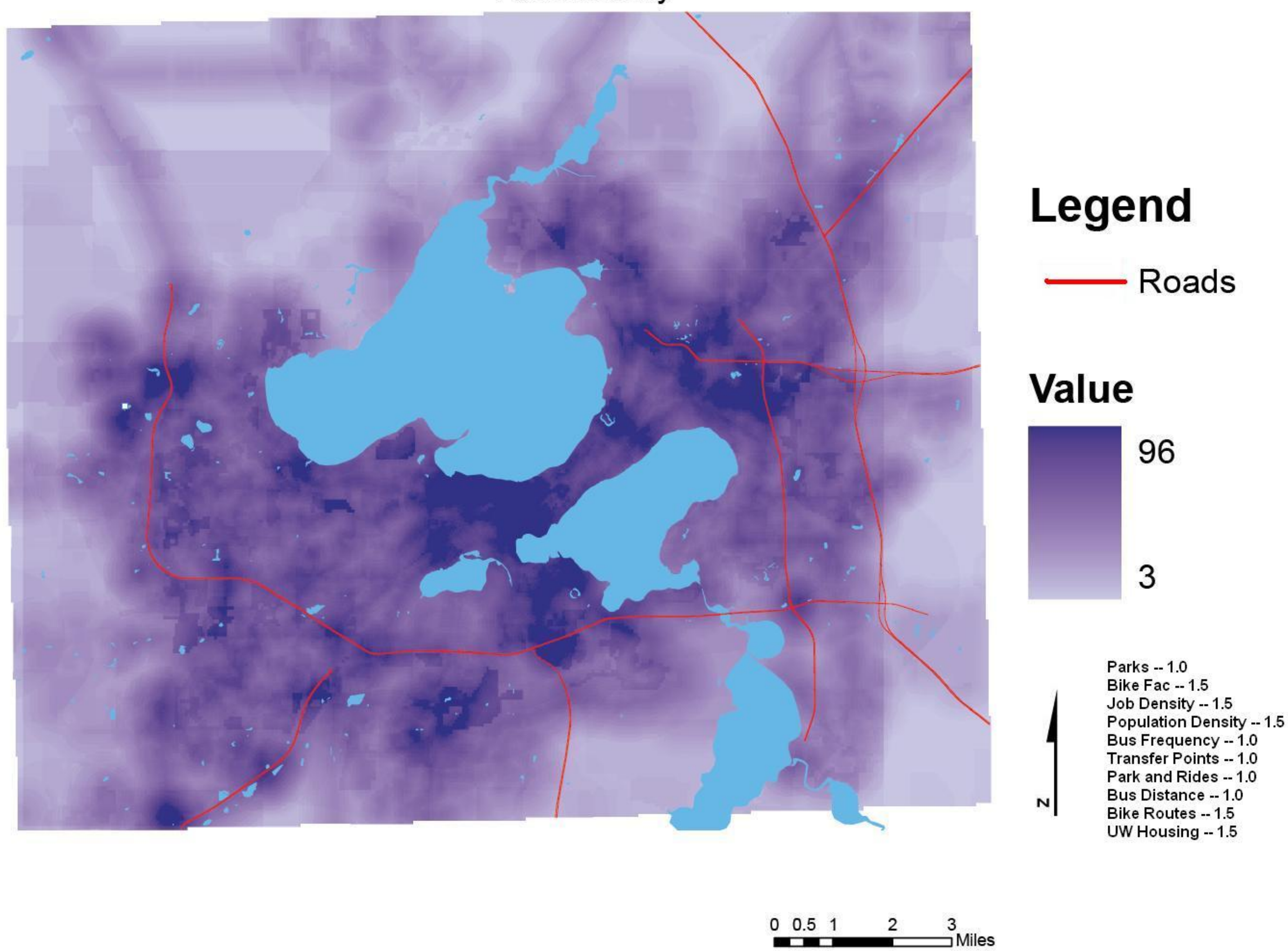


Figure 4. This map is another *Weighted Sum Raster* analysis where only input variables associated with population demographics were weighted with more influence. The Final Bike Score is represented by the shade of blue and range in values between 3 and 96, calculated by data layers.

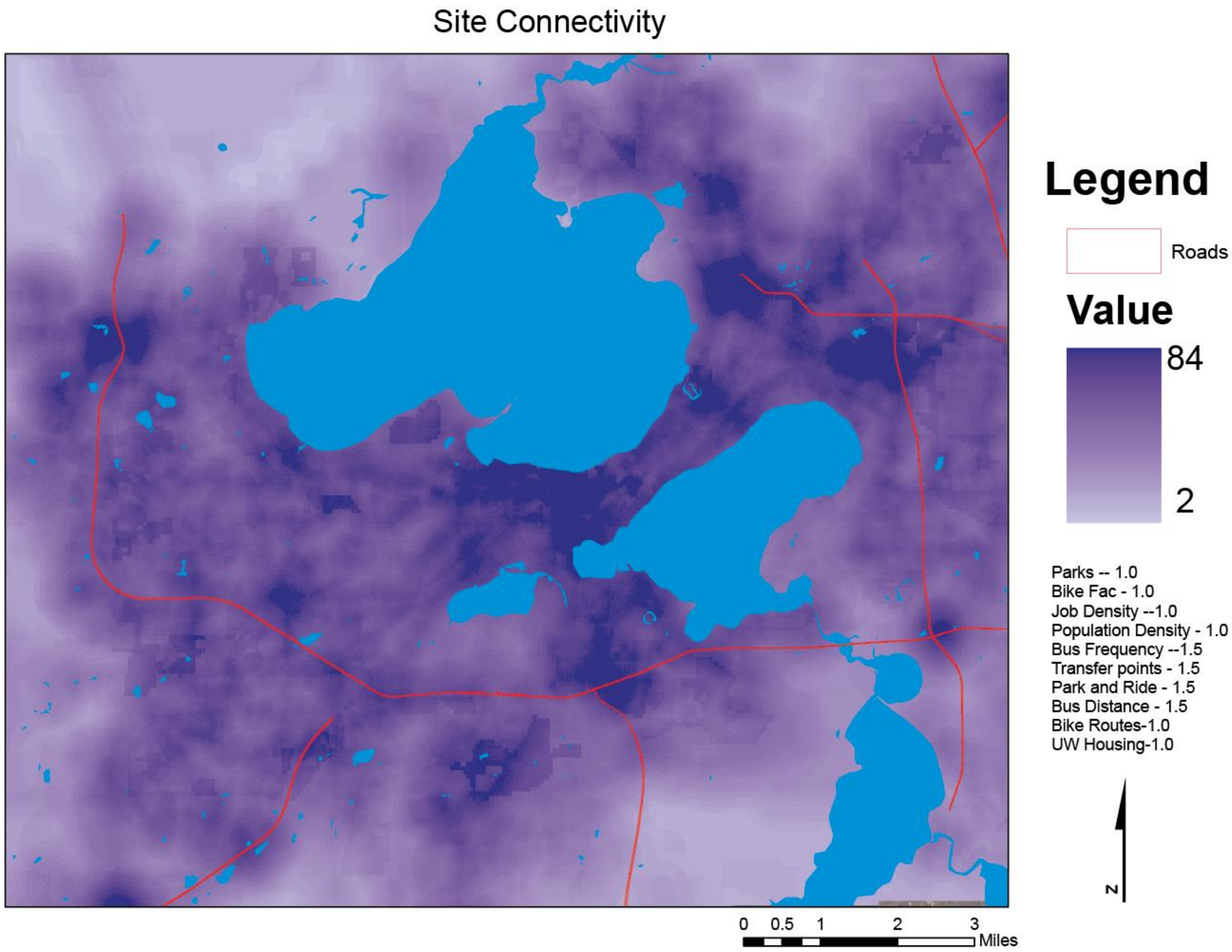


Figure 5. This is another output from a *Weighted Sum Raster* analysis, where only input variables associated with multi-modal short distance travel were weighted with more influence. The Final Bike Score is represented by the shade of blue and range in values between 2 and 84, calculated by data layers.

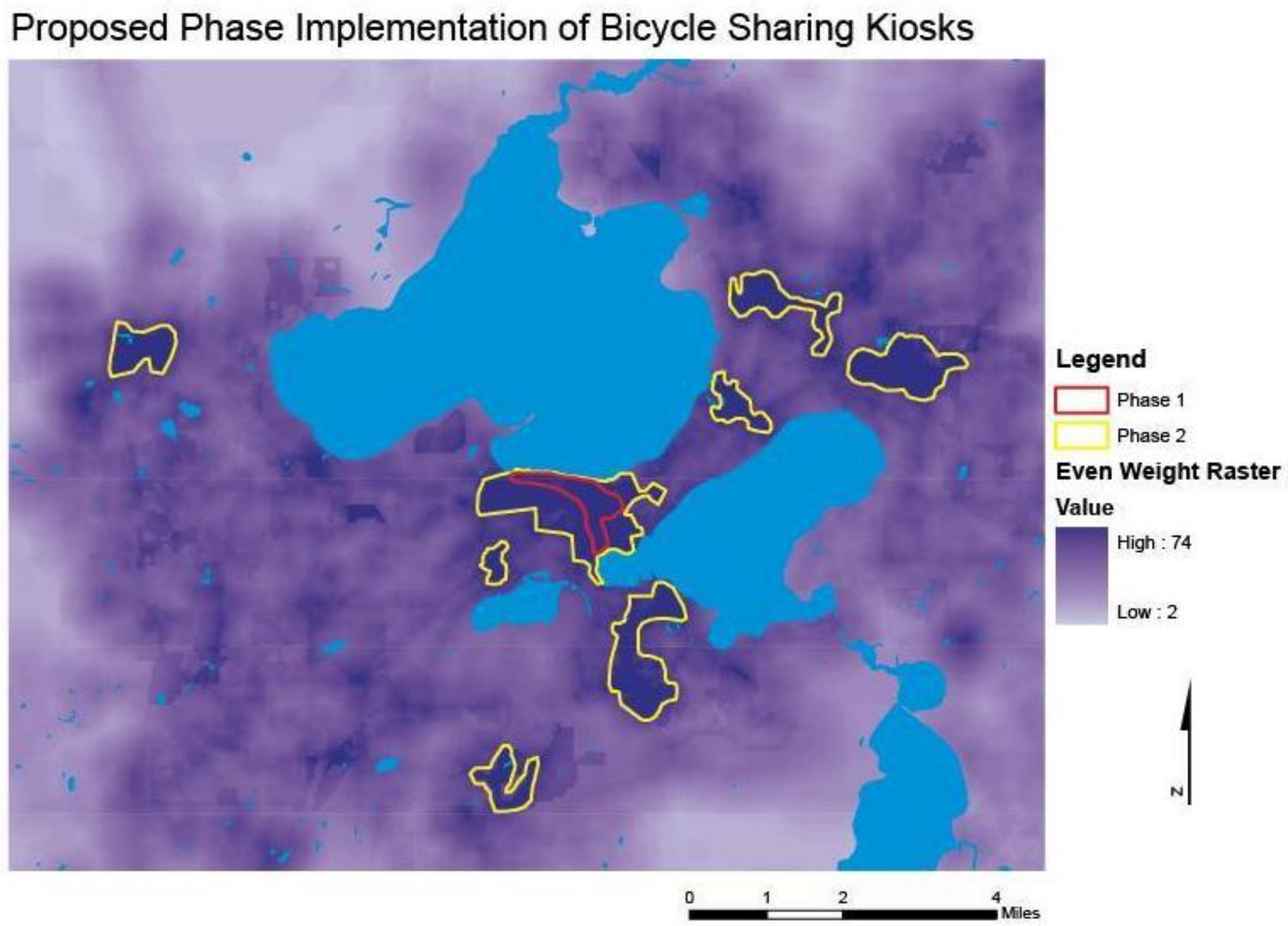


Figure 6. This map show our phase implementation overlaid on the evenly weighted summed raster layer to display regions of high suitability.

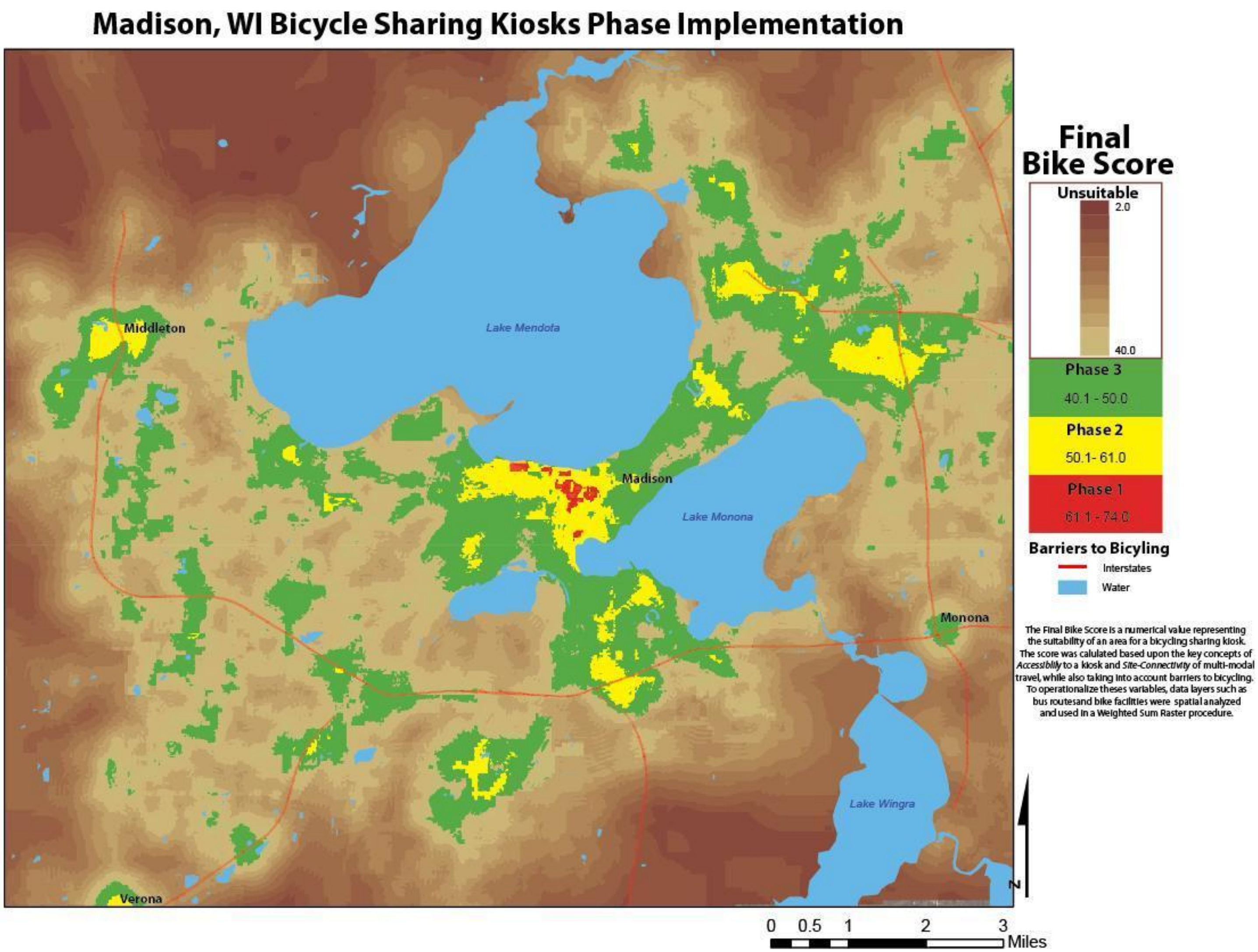


Figure 7. This map depicts our final classified phases for implementation on bicycle-sharing kiosk locations.

| Step: | Description: |
|---|---|
| **What does this data set describe?** | *Title:* University of Wisconsin Housing<br><br>*Abstract:*<br><br>A set of points marking the locations of University of Wisconsin dorms. Attribute information includes number of residents in each dorm while at capacity. |
| **How should this data set be cited?** | Bicycle-sharing Kiosk Project, 5/15/2011, University of Wisconsin Housing.<br><br>Online Links: \\discovery\classes\g578\DBs\BK\Final Layers\FINAL VECTOR\University_Housing_Project.shp |
| **What geographic area does the data set cover?** | *West_Bounding_Coordinate:* -89.417941<br><br>*East_Bounding_Coordinate:* -89.396782<br><br>*North_Bounding_Coordinate:* 43.078527<br><br>*South_Bounding_Coordinate:* 43.069021 |
| **Does the data set describe conditions during a particular time period?** | Calendar_Date: February 2011<br><br>*Currentness_Reference:* 2011 |
| **What is the general form of this data set?** | *Geospatial_Data_Presentation_Form:* vector digital data |
| **How are geographic fetures stored in the data set?** | This is a Vector data set. It contains the following vector data types (SDTS terminology):<br><br>▪ Entity point (17) |
| **What coordinate system is used to represent geographic features?** | The map projection used is Lambert Conformal Conic.<br><br>Projection parameters:<br><br>*Standard_Parallel:* 43.069516<br><br>*Longitude_of_Central_Meridian:* -89.422222<br><br>*Latitude_of_Projection_Origin:* 43.069516<br><br>*False_Easting:* 811000.000000 |

| | |
|---|---|
| | *False_Northing:* 480943.886000<br><br>Planar coordinates are encoded using coordinate pair<br>Abscissae (x-coordinates) are specified to the nearest 0.000000<br>Ordinates (y-coordinates) are specified to the nearest 0.000000<br>Planar coordinates are specified in survey feet<br><br>The horizontal datum used is D_North_American_1983_HARN.<br>The ellipsoid used is Geodetic Reference System 80.<br>The semi-major axis of the ellipsoid used is 6378137.000000.<br>The flattening of the ellipsoid used is 1/298.257222. |
| **How does the data set describe geographic features?** | `University_Housing_Project`<br><br>`FID`<br><br>Internal feature number. (Source: ESRI)<br><br>*Sequential unique whole numbers that are automatically generated.*<br><br>`Shape`<br><br>Feature geometry. (Source: ESRI)<br><br>*Coordinates defining the features.*<br><br>`Id`<br><br>`NAME`<br><br>`Residents`<br><br>`Distance` |
| **Who produced the data set?** | Bicycle-sharing Kiosk Project |
| **To whom should users address questions about the data?** | Andrew Wilson<br>UW-Madison<br>144 Langdon Street<br>Madison, Wisconsin 53703<br>United States<br><br>(860) 575-3888 (voice) |
| **Why was the data set created?** | Used to supplement population data with information about where incoming Wisconsin students live. |

| | |
|---|---|
| **Are there legal restrictions on access or use of the data?** | *Access_Constraints:* Open access<br><br>*Use_Constraints:* Open access |
| **Who distributes the data set? (Distributor 1 of 1)** | Bike Sharing Kiosk Group<br><br>(860) 575-3888 (voice) |
| **What's the catalog number I need to order this data set?** | `Downloadable Data` |
| **Who wrote the metadata?** | Dates:<br><br>Last modified: 12-May-2011<br><br>Metadata author:<br><br>UW-Madison Bike Sharing Kiosk Project<br>c/o Andrew WilsonREQUIRED: The city of the address., REQUIRED: The state or province of the address. REQUIRED: The ZIP or other postal code of the address.<br><br>(860) 575-3888 (voice)<br><br>Metadata standard:<br><br>FGDC Content Standards for Digital Geospatial Metadata (FGDC-STD-001-1998)<br><br>Metadata extensions used:<br><br>• <http://www.esri.com/metadata/esriprof80.html> |

Table 3. This table shows the FGDC Standards for Metadata of our original data layer (University Housing)

Works Cited

"Download Census 2000 TIGER/Line® Data." January 30, 2011. http://arcdata.esri.com/data/tiger2000/tiger_download.cfm (accessed January 30, 2011).

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Seattle Bike-Share Studio, *Seattle Bike Share Full Report, (*University of Washington College of Built Environments, Department of Urban Design & Planning, 2010). http://seattlebikeshare.org/ (Accessed February 3, 2011).

"Wisconsin Department of Natural Resources WisconsinView 2008 NAIP." February 3, 2011. http://www.wisconsinview.org/ (Accessed February 3, 2011).

Mednick, Adam of the Wisconsin Department of Natural Resources, Sciences Services consultation interview

Stoltenberg, Jaime of UW-Madison GIS Map Librarian majority data layer provider

Veroff, Dan of UW-Madison Applied Population Laboratory, consultation interview

Appendix

| Data Layer: | Weight: |
|---|---|
| **1. Bicycle facilities** | 1.5 |
| **2. Bicycle routes/paths** | 1.5 |
| **3. Bus Frequency** | 1.0 |
| **4. Transfer points** | 1.0 |
| **5. Bus stops (Frequency)** | 1.0 |
| **6. Park and rides** | 1.0 |
| **7. Parks** | 1.0 |
| **8. Job density** | 1.5 |
| **9. Population density** | 1.5 |
| **10. UW Housing** | 1.5 |

Table 4: Accessibility

| Data Layer: | Weight: |
|---|---|
| **1. Bicycle facilities** | 1.0 |
| **2. Bicycle routes/paths** | 1.0 |
| **3. Bus Frequency** | 1.5 |
| **4. Transfer points** | 1.5 |
| **5. Bus stops** | 1.5 |
| **6. Park and rides** | 1.5 |
| **7. Parks** | 1.0 |
| **8. Job density** | 1.0 |
| **9. Population density** | 1.0 |
| **10. UW Housing** | 1.0 |

Table 5: Site Connectivity