Madison Metro Rapid Transit Park & Ride Study

Exercising the potential of GIS to explore potential solutions to a temporal socio-environmental issue

Geography 578
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Capstone Statement

Identify and map suitable locations for Park & Ride lots along the periphery of the city of Madison to serve as starting points for optimal express bus routes to-and-from event locations in downtown district. The conclusions can be used to help alleviate city traffic congestion and determine future public transportation.

Introduction

The scope of the project arose from the initiative for reducing traffic congestion resulting from major events within the city of Madison (i.e. UW sporting events and performing arts). From conceptualization to system design and onto the final deliverables, the project went through constant review to maintain a high degree of accuracy. To satisfy the goal of the project it was vital to clearly develop the key concepts used for identifying the project parameters and provide a high level of transparency throughout the implementation. Each of the three major operations produced separate final outputs, which in combination serve as a resource for future public transportation and traffic planning proposals.

Downtown Madison's geographic constraint and growing population size continues to put stress on the existing transportation infrastructure. Madison has seen an average 12 percent population growth rate over the last decade (Dane County Board of Supervisors, 1998). The continued growth in Madison and the surrounding communities will only add to the number of commuters to-and-from downtown Madison. An evaluation of the current traffic conditions and existing public transportation options will provide the opportunity to investigate the possibility of expansion for the public bus system to service more of the general population and reduce traffic volume in downtown Madison.

The project proposal was designed to reduce the incentives for individuals who choose to drive into the downtown area by offering low-cost public transportation from the periphery of Madison with direct service to the city's key event locations. The study investigates the potential of constructing a series of park & ride locations around the perimeter of the city of Madison, WI and offering express bus routes to-and-from event sites and each park & ride. Essentially the project was divided into three major operations defined as (1) a site suitability analysis, (2) event location selection, and (3) network analysis for routing. Each of the three aforementioned operations will be describe in detail and their system parameters will be discussed in the conceptualization and implementation sections. The following sections address the key decisions and processes that were used to arrive at the final outputs.

The conceptualization model for the project (Figure01) includes specific bench markers used to determine the key concept and secondly define the key variables of the concept. Once fully defined, the key variables were operationalized to provide detailed metrics for each variable and finalize the terms of the analysis. The final sections review the findings, assess the overall execution and examine future applications of the project.

Conceptualization

To best understand the selection process for each variable, it is advantageous to consider the key concepts as standalone models that were tested repeatedly to determine each potential route. From the assessment only the routes able to fulfill all the criteria listed below were considered in the final report and deliverables. For clarification the starting site for a route refers to the location of the park & ride. Considerations for the starting location variable included defining the extent of the study area, known as the city roadway perimeter. Figure 02 shows the extent of the study area as bound by the primary roadways around the perimeter of the city. The Beltline (State Highways 12, 14, and 18) delineates the western and southern boundary and Interstate (90/39) forms the eastern edge of the study area (Table01). The U-shaped boundary created by the aforementioned roadways, serves as the primary access point for those coming from the periphery to the downtown area. Intersections of the boundary that include both on and off ramps access to city streets served as the starting location for each optimal route. Understanding the location of major primary and secondary roads servicing downtown Madison was crucial in defining the extent of the study. Influences on the variable include traffic volume levels at the intersections along the perimeter roadways and spatially where these intersections occur.

The second variable for the optimal route concept was determining the route endpoint. The end point for the purpose of clarification is at an event sites, but in reality the optimal route runs as a loop between start (park & ride) and end (event/capitol square) locations. For the endpoint variable, a venues' event seating capacity served as a threshold for an event location to qualify. The last variable for the optimal route was determining the factors of influence on the actual bus route. After the selection of both the start and endpoint for the route the actual optimal route analysis served as the final variable. Setting cost parameters and selecting attributes such as road type were used to determine the lowest cost pathway from park & ride location to the event location define the final variable. Each the variable's details are explained in the following section from start to finish of the operationalization phase.

Each of the selected starting point intersections were assigned a buffer with a one-mile radius used to represent the appropriate zone for locating the actual park & ride lot. Potential park & ride lots were then selected within the buffer zone based on several land-cover and land-use data layers to determine suitability. After the start location for each of the optimized route had been set, the end points for route locations were selected. In order to address the goals and reduce increases in traffic during events, attendance potentials that would cause higher traffic volume were identified. After assessing event locations in Madison based on revenue and capacity numbers for locations around the downtown area, the minimum criteria for an event location to be considered required an event venue to have a capacity of 10,000 or more attendees.

Therefore the attendee constraint only considered event locations that have the capacity to significantly contribute to the amount and flow of traffic in the downtown area. Developing the optimal route between the start and endpoints is based on a network analysis of the roadways within the study area. To obtain the project goal, the network parameters coincided with the available roadway and traffic data for Madison. The optimal route is defined as the pathway with the lowest overall impedance, while also fulfilling the parameterized restriction attributes (Cairns, 1997). Travel time cost attribute served as the measure of impedance for the study. Restriction attributes applied included accounting for one-way street travel (illegal to drive the wrong way), U-turn at dead ends only, and right side curb approach for busses. These variables are based on current Madison Metro route parameters. The model evaluates all possible paths on the network from the starting point to the destination to determine which has the lowest impedance.

Data Collection

Prior to building the models and implementing the specific design parameters a number of data layers need to be collected. Each of the data layers involved needed to facilitate accuracy in locating potential park & ride sites, end points, and optimal route characteristics. As with any GIS intensive project the search and acquisition of acceptable data can be a taxing process. This project was no exception and required several emails to different city and state officials along with data manipulation. The following paragraphs detail the source of each layer and specifically where it was used in the GIS operationalization along with mentioning what alterations (beyond reprojecting the data to the project's environmental parameters) were performed.

The Madison bus route layer was obtained from the Robinson Map Library. The metadata shows that the data was originally constructed by Madison Metro Transit and shared with the library for academic purposes gives us the locations of existing bus stops and transfer points, current as of August 2010. To address traffic density a traffic analysis roads layer from the City of Madison Engineering Department was obtained via the Robinson Map Library. The metadata for the city's roads layer was current as of 2010, though the collected averages are from no later than 2001. This layer provided data and attributes for the full extent of road centerlines and ramps, along with details such as speed limits, bus lane locations, number of lanes and one-way roads. The traffic data was used during the network analysis.

The Engineering office used engineering software, thus the data had to be converted from KML format to a DBF format and imported as a shapefile into the ArcGIS environment. The intersections of the arterial roads provided the points for generating the extent of the study area. Several constraints that come into play here are protected areas, developed land, and hydrology. The protected areas come from the US Geologic Survey's Protected Areas Database, which has been updated annually since 2005, through 2011. The Land Use data came from the Capital Area Regional Planning Commission, with the last renditions of the polygons completed in 2005. The data was already ArcGIS compatible as an older ArcInfo layer and was imported into the study environment. Land use information showed the areas within the intersection radii that remain undeveloped.

The building footprint polygons collected from a 2005 survey study were used in determining exact event location sites and also used in the park & ride site suitability analysis were derived from data provided by the Dane County Land Information office. An original data layer was created by one of the group members and was designed to show event site locations and hold attribute data about attendee capacities for known Madison area venues.

Implementation

Within ArcGIS 9.3 the operationalization of the project goals were completed in what could be considered three separate models or functions; that ultimately complimented each other by arriving at the final deliverable. The entire project was built within a file geodatabase to ensure smooth data acquisition, while simultaneously allowing multiple users to work on the same data layers without conflict. It was also vital to build and maintain all the necessary layers within a geodatabase (Figure01b) for constructing a road network for evaluation using network analysis. Prior to conducting the three major models the study area extent was created to define the environment and scope of the project. Sequentially one process' output served as a parameter for the next and the diagrams included in the appendix help conceptualize the GIS operations conducted.

The first step in accomplishing our conceptualization in a GIS setting was to produce a layer for our study area which all of our subsequent layers could be clipped to. The resulting polygon consists of a portion of our study area (Figure02).

To be added to that study area polygon was the intersection points that we determined by finding the major roadways that intersected with the study area boundary we created. As you can see in Table01 eight intersection points were found. In order to actually determine a park &

ride site associated with each intersection, a one-mile buffer radius was added at each point. It is in these radii that all of the subsequent GIS operations will be performed to find a suitable park & ride location. These two layers (initial study area and intersection radii) were then added together to produce a final study area map, as shown in Figure02b.

The next step was to clip all of our layers to two different study areas: one being the overall study area that includes both the radii and the boundary, and the second study area consisting of only the radii. For the overall study area, the following layers were clipped: Roads, Intersection Controls, Bus Stops, and Building Footprints. For each individual radius, the following layers were clipped: Roads, Building Footprints, Land Use, and Protected Areas. The process of clipping data layers focused the scope of the project to within the defined study areas.

Park & Ride Locations

With all of the layers formatted to the radii, the appropriate manipulations of the data could occur. The first layer that had to be dealt with was land use. We had to make some subjective decisions about what types of land use would be acceptable to build on, and which were off limits. Our final decisions can be found in the acceptable land use table (table02). We eliminated non-suitable land types including wetlands, resident, commercial, government institutions, and outdoor recreation areas. The process provided a layer of acceptable land use polygons. From this layer, we had to erase parts of these polygons that were not acceptable to build on. First, building outlines were erased. Because our land use layer was from 2005 and our building outlines were from 2005, there were some areas where buildings were present, but were not classified as developed. We felt this was a way to "update" our land use by using another factor. Next, we took our protected areas layer, which wasn't a class in our land use layer, and erased it from the new acceptable areas with buildings erased. Lastly we created a 150-foot buffer around any water land use and erased that from the newly created layer. Once these erasures were complete, we were left with all acceptable areas. This brought about a new issue, as there was a wide range of polygon sizes, as well as polygons that were adjacent to each other, but seemingly too small to be considered.

We decided that it would be best to aggregate those polygons that were adjacent to each other to maximize the areas that we can utilize. Our park & ride acceptable size was determined by looking at the capacity for the largest existing park & ride lot in Madison, Dutch Mill. We found the capacity to be 250 cars, which translates to a minimum lot size of around 40,000 square feet. We added 10,000 square feet for driveways and other areas, and used 50,000 square feet as our acceptable lot cut-off. After applying this constraint, we were left with every acceptable polygon for a park & ride lot. Next we determined the lot by simple proximity to our intersection point. Thus, we were left with our eight potential park & ride lot sites that would serve as starting and ending points for our optimal routes (Figure03). To avoid encountering acceptable polygons that had adequate total area but were too narrow (i.e. long and skinny polygons) the query was also specified a minimum edge length greater than 100 feet.

For certain intersections multiple polygons met the criteria so a final query and near function combination selected the closest acceptable polygon to the centroid of study area intersection. Each of the eight intersections now had a selected park & ride site based on a rudimentary suitability analysis.

Optimal Route

In order to properly run the optimal route analysis, selected starting and ending points for the routes were required. Using the previously created full study area extent as a clipping mask the following layers were clipped to remove extra data; bust stop points, building footprints (identified event venues already joined to this layer), and the Madison road network. Following the clipping procedure a query was run to select only potential event venues with capacity to hold 10,000 or more people. This reduced the number of venues from 20 plus to less than ten. A capacity minimum of 10,000 was derived from traffic density studies that suggested smaller events do not have a quantifiable impact on traffic congestion in the downtown area. The selected event locations are listed in (Table03). From here the proximity function (using the bus stop point layer) was use to find the nearest bus stop to service each venue and act as the start/end point for the ensuing network analysis.

ArcGIS's network analysis extension is a powerful and vastly capable tool with nearly endless ways of fine-tuning. For example different a user can set different determining factors for an "optimal route," whether that means distance, time or another factor. For this application time was used as the determining factor and several costs were built into the system to influence the selected optimal routes between each park & ride and event location. An optimal route was constructed for to-and-from thus creating eight routes per park & ride location. At the time of the study accurate traffic light signal (wait) times were not readily available and an intricate formula based on a statistical equation (figure04) and group member collected observations were used to assign global values for wait times at stoplights (table04).

The other cost variables used in building the network included travel time which was stemmed from a start to end point of a road segment. To best describe a road segment imagine that at each road intersect a segment ends/begins and the travel time is based on the speed limit and actual length. One-way streets (limit travel along edges) served as a restriction (similar to a cost attribute) and ensured optimal routes would also follow legal traffic patterns. Our final costs and restrictions can be seen in Table05.

Once the network was built, our process involved creating 64 individual routes. A list of routes and travel times can be seen in Table06. These routes include trips to-and-from each of eight park & ride locations to our four event sites. Finally, to produce our final outputs all route maps were exported to Adobe Illustrator to make them easier to interpret.

Results

There are many interesting results that were noted after finishing our project. One of the results we found was that after running our network analysis from each park & ride location to our downtown event locations, the majority of our routes began at the starting points for our park & ride locations and for reach route they took the same roads when traveling to the downtown Madison area, because these were obviously found to be the quickest routes. (Figure05, 06)But, as the routes actually came into the downtown area then came a large differentiation between each route. As shown in Figure07 you can clearly see that the routes split off onto separate roads to reach their respective event destination.

The routes in our network analysis were based on the time, not distance. Time was assigned based on the time it took it travel a certain road combined with stop sign, yield sign, and stop light times. So it is interesting to note that although a certain route may appear to have taken a longer route than necessary to reach a certain event location, it is because the network analysis parameters used arrived at the quickest way to-and-from an event location based on time. Even if the route is actually longer distance wise, that doesn't mean it takes longer to get their because of things like stop lights and stop signs that must be taken into consideration. From a visual standpoint there is a clear distinction between optimal routes based on time and distance. For the sake of a “rapid transit” system, optimality must be based on time, rather than distance.

Another interesting find came after we performed ground-truthing to our project results. The method of ground truth assessment applies an orthophoto cross-validation overlay with our vector layers. After determining our initial park & ride locations determined by the aforementioned criteria, we had to ground-truth them to make sure that the locations were actually possible to build on. There was an instance as shown in Figure09 that clearly shows an area where we were initially told was suitable for a park & ride, but recently a new building was put up in that area that our data wasn't able to account for. This is due to the fact that data, especially of urban areas like Madison, can become outdated almost immediately because things are constantly being built.

Discussion

To further this study more depth could be applied to all three of the major GIS model operations to include greater detail. For example the site suitability analysis for potential park & ride locations could delve deeper into the demographical data and use more census block driven approach to select sites. This could include looking at population growth factors and model which potential sites could see future growth and thus become more relevant.

In advancing the site suitability analysis an inclusion of soil layer data and elevation modeling would help in selecting potential sites. Certain potential sites were located in areas that after ground-truthing were found to have high slope and thus impractical for constructing a park & ride lot.

Ground-truth data and the use of satellite imagery to adjust site selection in the post-GIS application help retain a higher level of validity for the study. In future application these originally unforeseen challenges could have been easily mitigated within the GIS operationalization.

Another critique and area for improvement is within the network analysis section of the study. When building a network within a geodatabase, selecting costs and determining restrictions could be more detailed. The statistical equation used is too general to be an effective cost path variable for the city of Madison, because of timed lights and other variables. With more resources and time a newly derived layer that had actual wait times for each individual stoplight for the entire city would be the most accurate representation. By knowing individual stoplight cycles a route could be more accurately timed based on the actual wait times for each individual site. Realistically the creation of that layer alone could take over six months to create and integrate. As the network analysis section could be amended with route barriers to reflect current construction and continually updated allowing routes to be adjusted according to real-time ground truth.

A final critique that can be almost be said for any study is the level of accuracy of the data layers used in the analysis. Certainly true time data is rarely available and researchers must work with the most recent data available. Particularly in the urban setting data that is not to the current year can lead to discrepancies. These slight inaccuracies due to the rapid change of road conditions, new building construction, and other factors can limit the overall accuracy of a study. Looking back on this particular project the data used was the most current and freely available data, yet throughout the process it was clear that exceptions (especially in the site suitability analysis) and compromises had to be made because of data becoming outdated.

Conclusion

Overall the study was able to deliver solid recommendations, with relevant outputs in the form of cartographic maps, site suitability analyses, and optimal routes. The project is best viewed within the GIS system because of the complexity of working with the network analysis extension and the ability to continually refresh outdated data. Although the outputs are accurate to the level of available data, more importantly the project provides a basic framework for future investigations into park & ride planning. The project involved several different tools found within ArcGIS and provided the project team with valuable insight into the future of GIS in city planning through a collaborative leadership model. Hopefully this project will serve as a guideline and stepping stone for future studies for public transportation.

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Appendix.

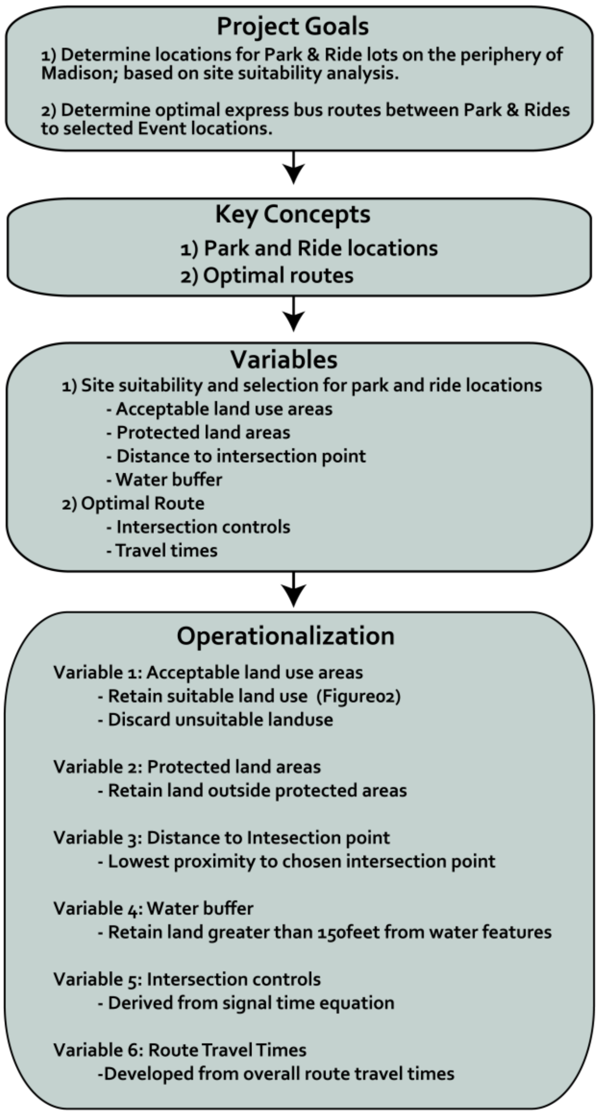

Figure01. Full conceptualization diagram for the project showing the connection between the main key concepts, their variable, and how each variable will operate within our data structure.

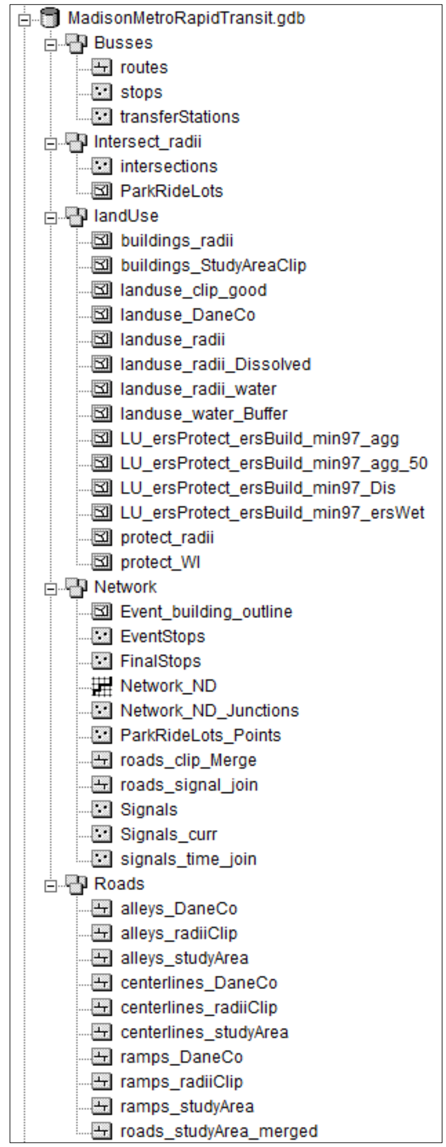

Figure1b. Shown here is a glimpse at the structure of the file geodatabase used throughout processing within ArcGISv9.3.1

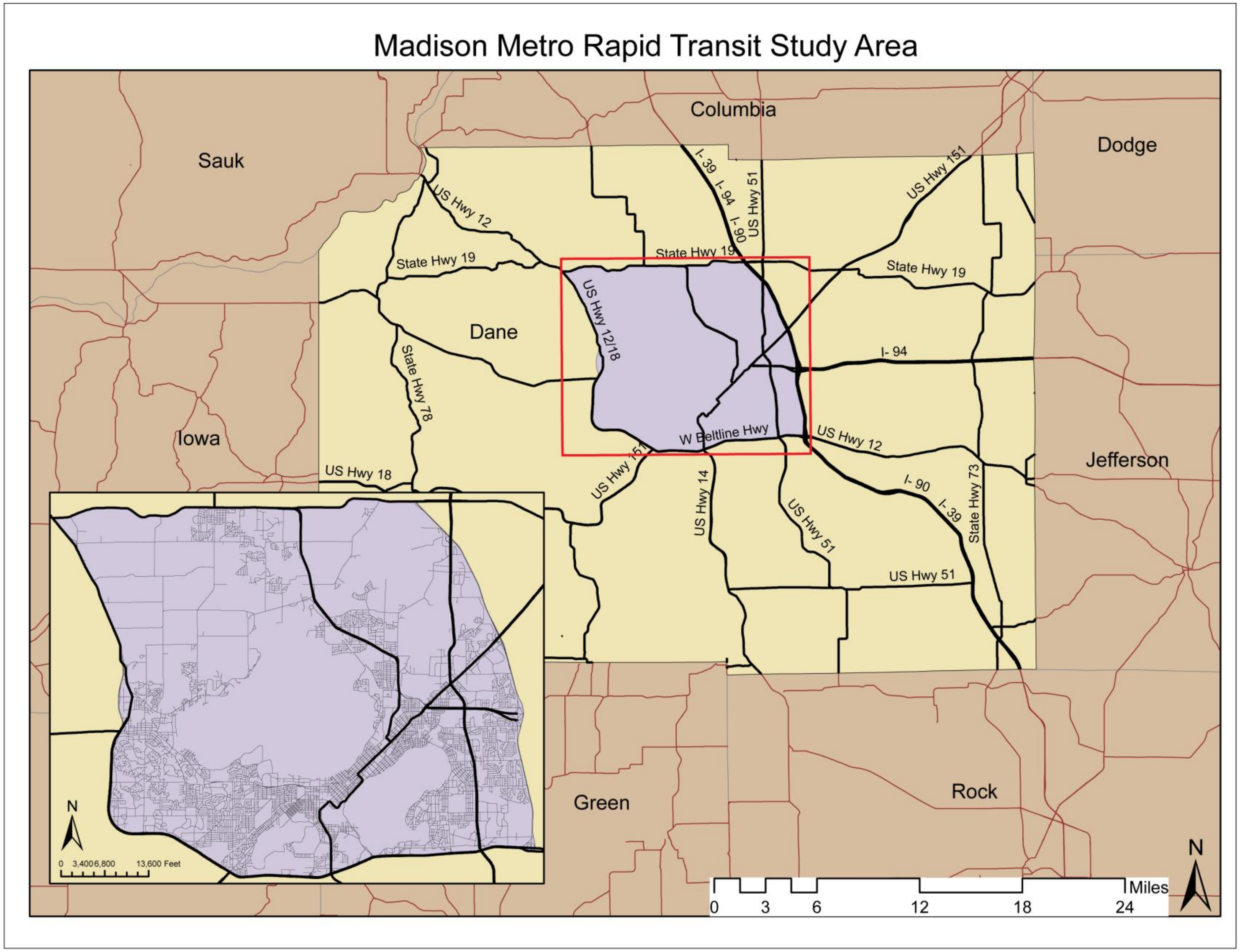

Figure02. Shown here is the project study area in Dane Co., Wisconsin. The focus of the study is on Madison, WI, so the highway restrictions were based on major roads surrounding the greater Madison area. The border was made up by US highways 12, 18, 14, and 151 on the West and South, Interstates 39, 90, and 94 on the East, and State Highway 19 to the North.

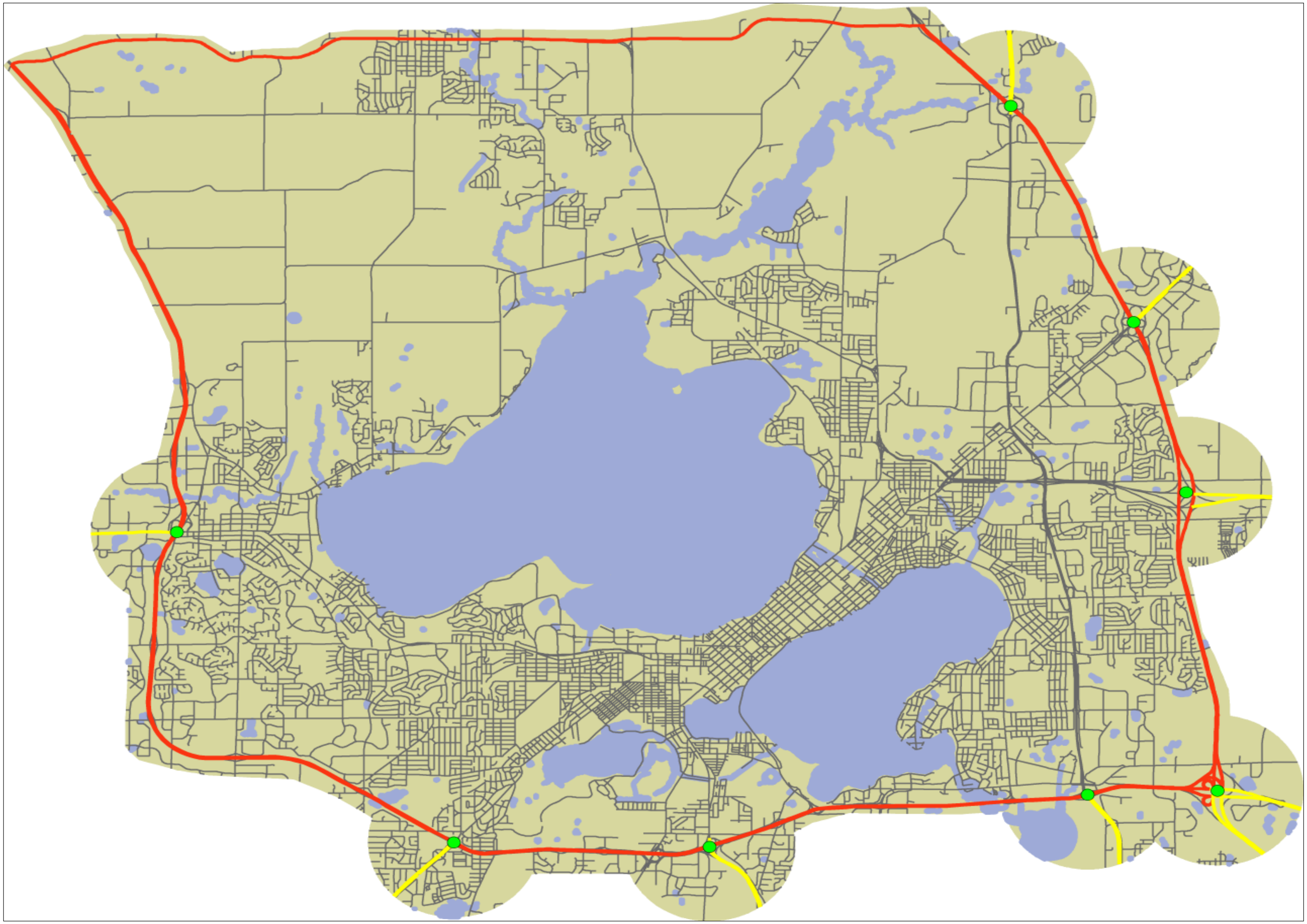

Figure2b. Shown here is the full extent of the study area after combination with the intersection buffers. Green points indicate the intersection points selected at points where the incoming major roads (yellow), crossed the initial study area boundary (red).

Road Intersection Parameters

Boundary Roads	Incoming Roads
I39/90/94	US51
I90/94	US151
I90/39	US30
US18/12 & I90/39	US18/12 & I90/39
US18/12	US51
US12/18	US14
US12/14	US18
US12	US14

Table01. Shown here are the roads that defined the borders of the initial study area (left), and the intersecting highways (right). The points comprising the intersections layer are defined by the centroids of the aforementioned intersecting road segment centerlines.

Acceptable Land Use Selection

Land Use Code	Main Type	Sub-Type
46	Transportation	Automobile Parking (non-commercial)
91	Agriculture	Cropland / Pasture
94	Agriculture	Commercial Forest
96	N.E.C.	Other Agriculture
98	Other	Vacant, Unused Land (zoned, not open)
99	Other	Woodlands (non-commercial forest)

Table02. Land use types remaining after eliminating types that were deemed unacceptable for development of single high traffic parking lots. Individual "acceptable" areas, defined by adjacent type similarity, were defined in discrete units, independently of surrounding land use.

Acceptable Event Sites

Event Venue	Potential Capacity
Alliant Energy Center	10,231
Kohl Center	17,230
Camp Randall Stadium	80,321
Capitol Building	10,000+

Table03. Acceptable event sites, listed here, were narrowed down from a general list of event locations in the madison area based on venues with the potential for holding greater than 10,000 attendees for any given event. Potential capacity values were based on actual capacity limitations and reported event totals.

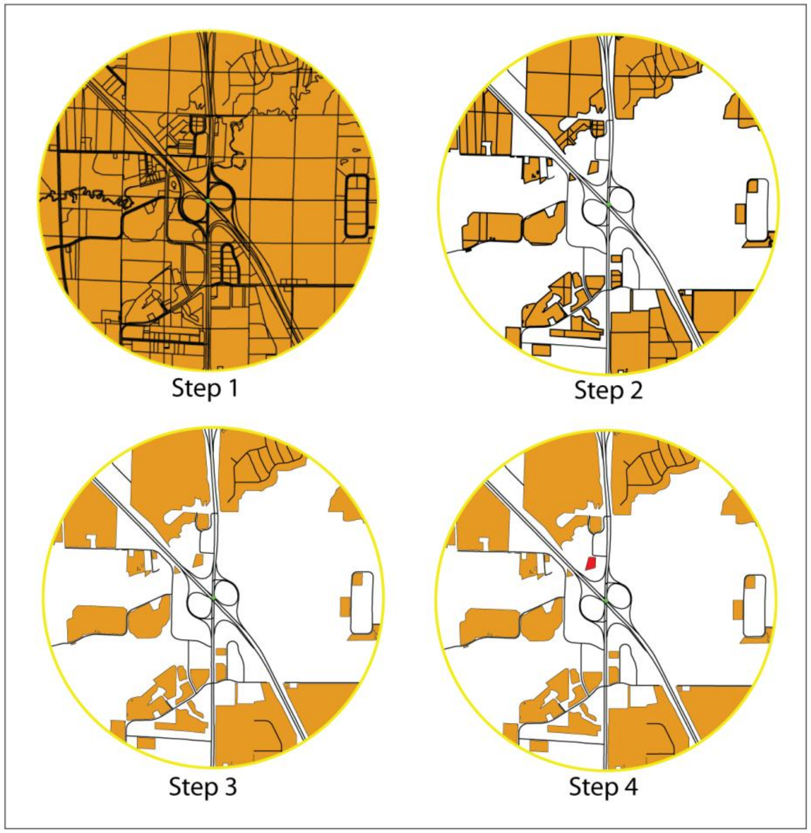

Figure03. Acceptable land use regions within the intersection buffer (step1) radii were derived through elimination of buildings, protected areas, unacceptable landuse types (see table02), and a water feature buffer (step2). Resultant areas were then aggregated based on adjacent type similarity, and reduced based on size (step3). Finally, based on proximity, a park&ride site was chosen for the current intersection region (step4).

Signal Waiting Time Calculation

$$W(avg) = \{[c(t)-d(t)]*[c(t)-d(t)+1]\}/2c(t)$$

Figure04. Shown here is the formula used to approximate the average time (in seconds) spent waiting at a signal controlled intersection. Where, c(t) is the total time it takes to cycle through all four directions of the signal, and d(t) is the time the signal is green in any given direction. (The PUMAS Collection, 2000 http://pumas.jpl.nasa.gov)

Intersection Time Cost

Intersection Control	Time Cost (seconds)
Traffic Signal	7.56
Stop Sign	3
Yield Sign	~1

Table04. The time cost determined for each type of intersection control. Yield times are minimal, and given a value of 1 to factor in a cost. First-hand observations contributed to average stop sign wait time, and values for the traffic signal formula, denoted in figure04.

Network Analysis Parameters

Name	Usage	Layer Used	Column
Oneway	Restriction	Road Network	one_way
Travel Time	Time Cost	Road Network	travel_time
Intersection Time	Time Cost	IntersectionControls	Intersection_Time

Table05. Final costs and restrictions applied to the route calculation. Restrictions acted as physical directional barriers within the road network itself, while time cost were delays imposed by intersection controls and overall length of calculated routes.

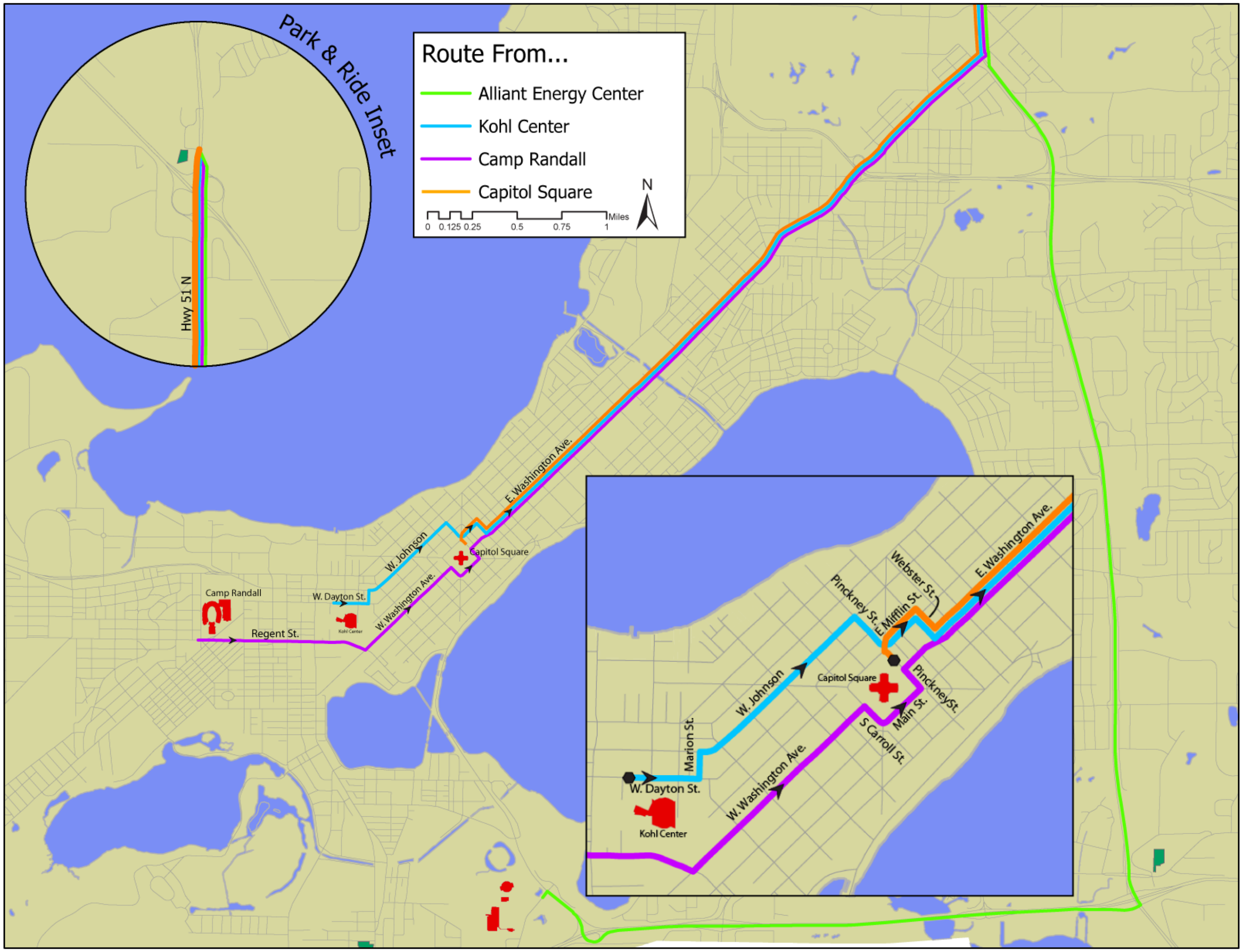

Figure05. Shown here are the optimal routes from all event sites to the Highway 51N park & ride. Stopping locations were determined based on closest available bus stop. Some additional restrictions, such as road closures, required bus stop selections to be adjusted to the locations seen here.

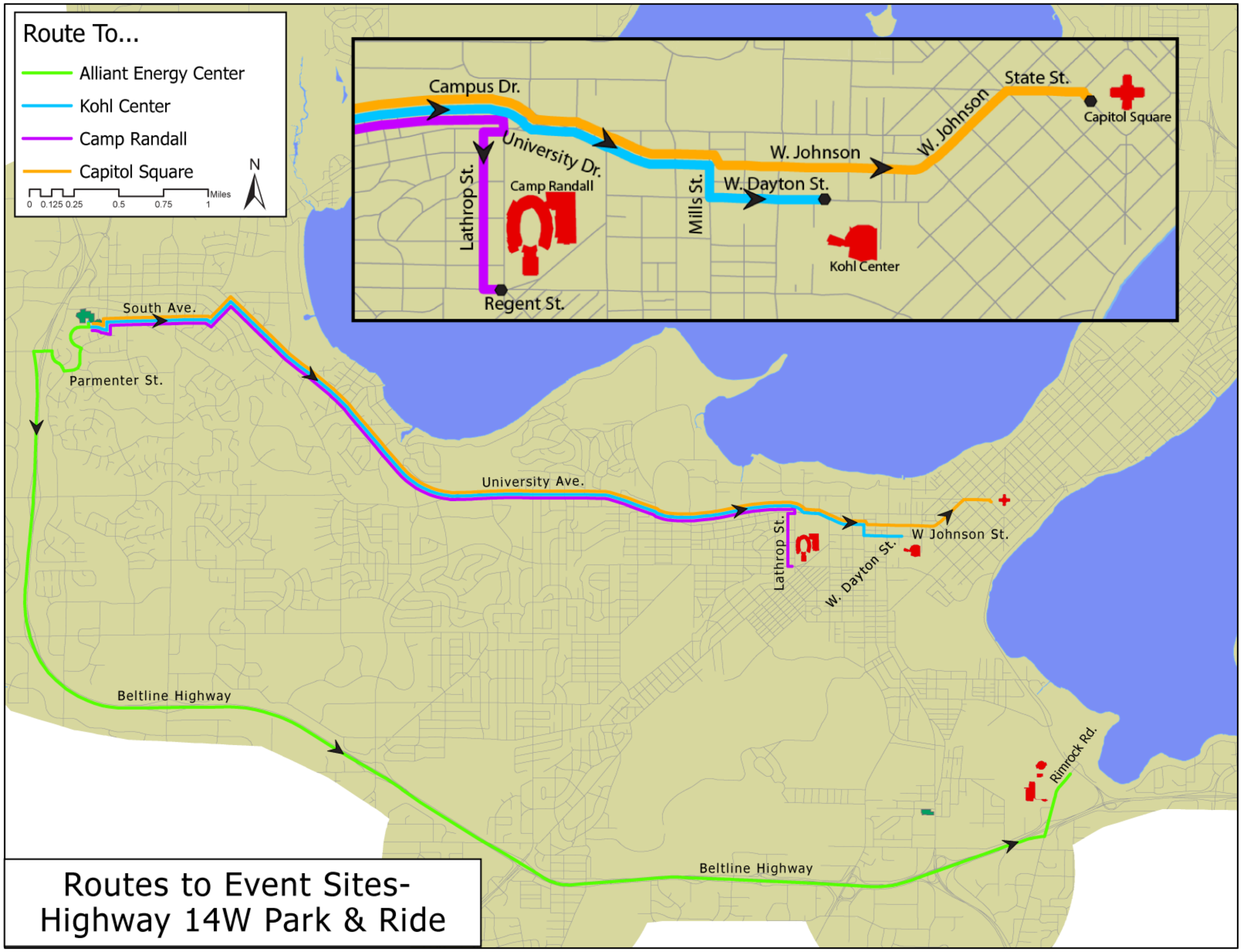

Figure06. Shown here are the optimal routes from the Highway 14 park and ride to all event sites. Stopping locations were determined based on closest available bus stop. Some additional restrictions, such as road closures, required bus stop selections to be adjusted to the locations seen

Total Route Travel Times

Route Index	Park&Ride Site	(direction) Event Site	Minutes
1 a i	Hwy51N	(To) Capitol Building	12.79
1 a ii	Hwy51N	(To) Alliant Energy Center	15.61
1 a iii	Hwy51N	(To) Kohl Center	15.38
1 a iv	Hwy51N	(To) Camp Randall	17.45
1 b i	Hwy51N	(From) Capitol Building	13.60
1 b ii	Hwy51N	(From) Alliant Energy Center	16.61
1 b iii	Hwy51N	(From) Kohl Center	15.86
1 b iv	Hwy51N	(From) Camp Randall	18.03
2 a i	Hwy151	(To) Capitol Building	10.39
2 a ii	Hwy151	(To) Alliant Energy Center	12.36
2 a iii	Hwy151	(To) Kohl Center	12.97
2 a iv	Hwy151	(To) Camp Randall	15.07
2 b i	Hwy151	(From) Capitol Building	10.22
2 b ii	Hwy151	(From) Alliant Energy Center	13.20
2 b iii	Hwy151	(From) Kohl Center	12.46
2 b iv	Hwy151	(From) Camp Randall	14.62
3 a i	Hwy30	(To) Capitol Building	9.46
3 a ii	Hwy30	(To) Alliant Energy Center	11.17
3 a iii	Hwy30	(To) Kohl Center	12.04
3 a iv	Hwy30	(To) Camp Randall	14.11
3 b i	Hwy30	(From) Capitol Building	9.35
3 b ii	Hwy30	(From) Alliant Energy Center	11.36
3 b iii	Hwy30	(From) Kohl Center	11.58
3 b iv	Hwy30	(From) Camp Randall	13.72
4 a i	Hwy12/18	(To) Capitol Building	8.83
4 a ii	Hwy12/18	(To) Alliant Energy Center	5.30
4 a iii	Hwy12/18	(To) Kohl Center	10.37
4 a iv	Hwy12/18	(To) Camp Randall	12.59
4 b i	Hwy12/18	(From) Capitol Building	11.27
4 b ii	Hwy12/18	(From) Alliant Energy Center	11.71
4 b iii	Hwy12/18	(From) Kohl Center	11.71
4 b iv	Hwy12/18	(From) Camp Randall	13.32

Total Route Travel Times, pt.2

Route Index	Park&Ride Site	(direction) Event Site	Minutes
5 a i	Hwy51S	(To) Capitol Building	8.39
5 a ii	Hwy51S	(To) Alliant Energy Center	4.81
5 a iii	Hwy51S	(To) Kohl Center	9.18
5 a iv	Hwy51S	(To) Camp Randall	10.81
5 b i	Hwy51S	(From) Capitol Building	9.13
5 b ii	Hwy51S	(From) Alliant Energy Center	5.94
5 b iii	Hwy51S	(From) Kohl Center	9.55
5 b iv	Hwy51S	(From) Camp Randall	11.19
6 a i	Hwy14S	(To) Capitol Building	5.68
6 a ii	Hwy14S	(To) Alliant Energy Center	4.11
6 a iii	Hwy14S	(To) Kohl Center	4.57
6 a iv	Hwy14S	(To) Camp Randall	5.38
6 b i	Hwy14S	(From) Capitol Building	5.90
6 b ii	Hwy14S	(From) Alliant Energy Center	3.17
6 b iii	Hwy14S	(From) Kohl Center	4.58
6 b iv	Hwy14S	(From) Camp Randall	5.31
7 a i	Hwy18/151	(To) Capitol Building	11.26
7 a ii	Hwy18/151	(To) Alliant Energy Center	7.71
7 a iii	Hwy18/151	(To) Kohl Center	10.14
7 a iv	Hwy18/151	(To) Camp Randall	8.12
7 b i	Hwy18/151	(From) Capitol Building	10.82
7 b ii	Hwy18/151	(From) Alliant Energy Center	7.12
7 b iii	Hwy18/151	(From) Kohl Center	10.12
7 b iv	Hwy18/151	(From) Camp Randall	8.11
8 a i	Hwy14W	(To) Capitol Building	14.57
8 a ii	Hwy14W	(To) Alliant Energy Center	14.22
8 a iii	Hwy14W	(To) Kohl Center	12.71
8 a iv	Hwy14W	(To) Camp Randall	12.00
8 b i	Hwy14W	(From) Capitol Building	14.70
8 b ii	Hwy14W	(From) Alliant Energy Center	13.91
8 b iii	Hwy14W	(From) Kohl Center	12.86
8 b iv	Hwy14W	(From) Camp Randall	12.14

Table06. Shown here is the final compiled list of travel times for all routes, coming and going from park & ride or event sites. Route index values are comprised of: intersections numbering, "clockwise" on the map; direction, to or from event site; and an arbitrary ordering of event sites.

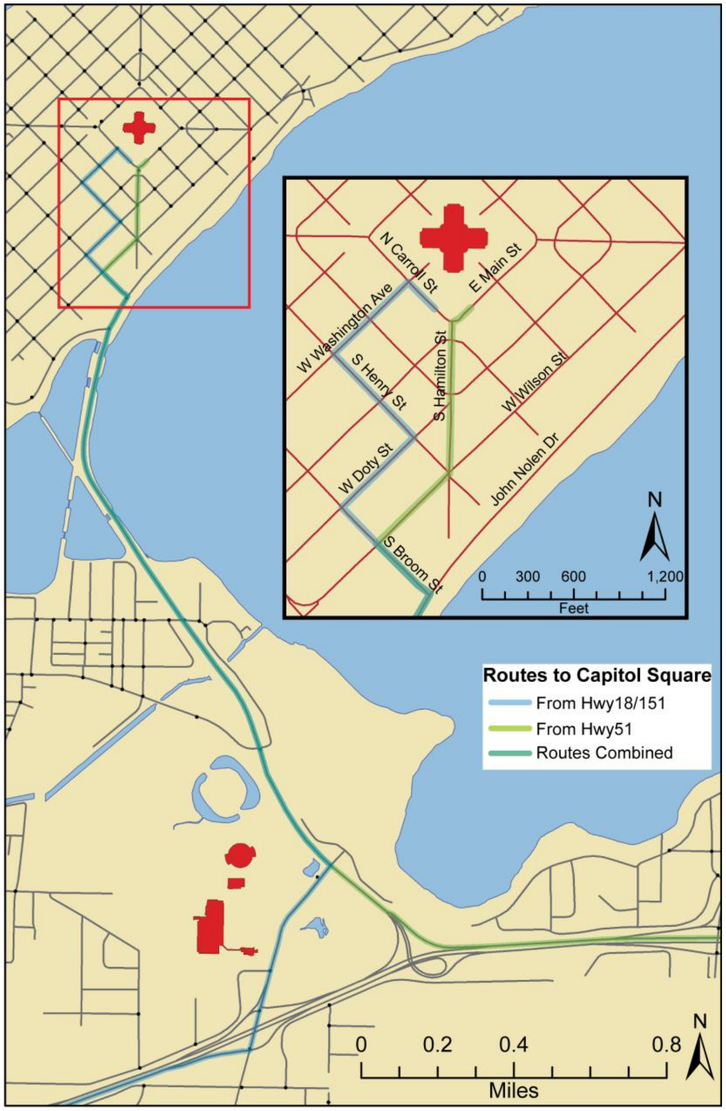

Figure07. Shown here is the comparison of routes that are both similar and divergent. At the initial approach, both routes take the same major roads towards the downtown, where they branch off to find their own quicker routes. Madison's unique combination of intersections and one-ways has an interesting effect on route optimization.

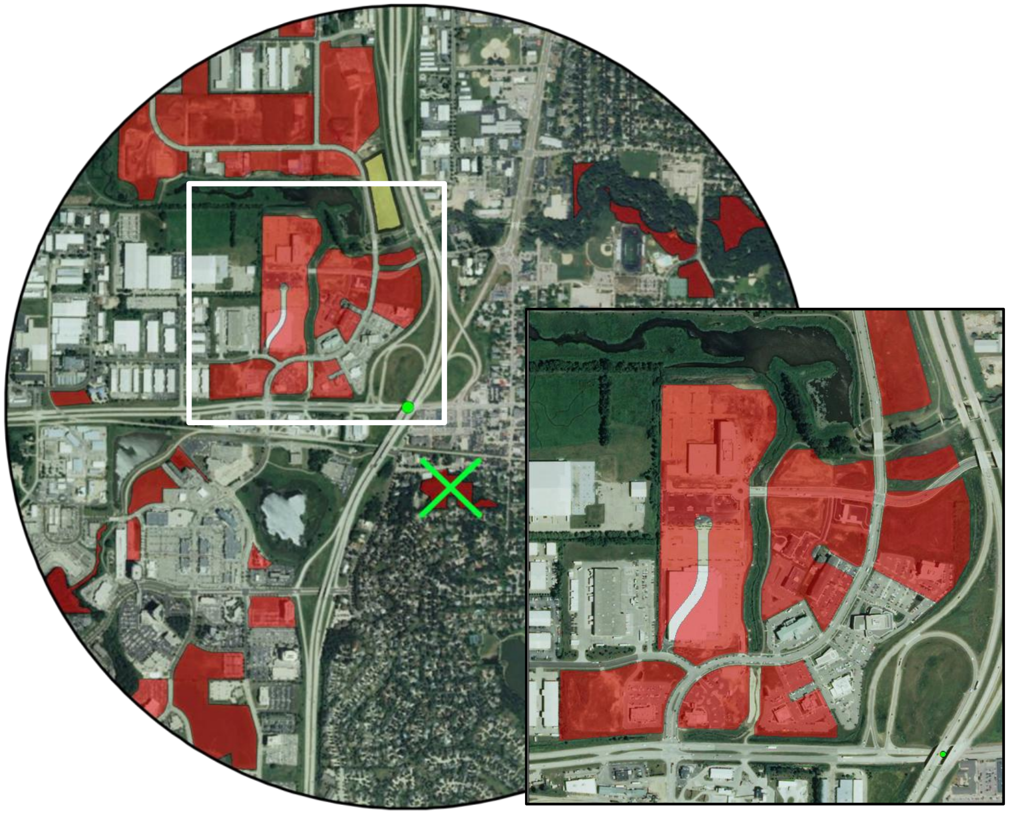

Figure09. Looking at the Hwy14W intersection radii, we can see the confliction between the 2005 land use polygons and current satellite imagery. Buildings and land use change quickly in an urban setting, so a ground truth assessment gives up-to-date insight. A more acceptable location (yellow) is selected based again on size and distance to intersection, but also on how that plot would look today.