HIGH SPEED / COMMUTER RAIL SUITABILITY ANALYSIS
FOR
CENTRAL AND SOUTHERN ARIZONA

By
MATTHEW R. DEVENEY

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ABSTRACT

Current transportation methods within the Central Arizona region revolve primarily around automobiles. In order for the region to become more economically resilient and environmentally sustainable, alternative transportation methods must be considered. One such alternative that has shown great promise in other regions of the United States is rail transport. Rail transport, including commuter rail or high speed rail, has proven to not only be an effective alternative to automobile transport, but also as a more environmentally sustainable transportation option. The I-11 Super Corridor study, a part of the University of Arizona’s Sustainable City Project 2014, applied next generation urban planning design ideas to the planned Interstate 11 corridor, a major transportation artery that will connect Mexico and Canada. This study inspired this project’s focus on the concept of identifying suitable routes for new transportation infrastructure within the central and southern Arizona regions. Through the incorporation of commuter or high speed rail within central and southern Arizona, a more resilient regional economy and environment can be created. The previous I-11 Super Corridor study presented the incorporation of different regional factors, including population density and economic statistics, to determine suitable routes for future transportation corridors. This project integrates the utilization of specific local and regional data and advanced GIS analysis to determine suitable routes for new rail transport corridors within Maricopa, Pinal and Pima Counties.
INTRODUCTION

Background

Current transportation methods within the Central Arizona region revolve primarily around automobiles. In order for the region to become more economically resilient and environmentally sustainable, alternative transportation methods must be considered. One such alternative that has shown great promise in other regions of the United States is rail transport. Rail transport, including commuter rail or high speed rail, has proven to not only be an effective alternative to automobile transport, but also as a more environmentally sustainable transportation option.

The I-11 Super Corridor study, a part of the Sustainable City Project 2014, conducted by the University of Arizona was consulted for this project. The study focused on taking infrastructure to the next level, and applying next generation ideas to a real world test case, the planned Interstate 11 corridor, a major transportation artery that will connect Mexico and Canada. This study inspired this projects focus on the concept of identifying suitable routes for new transportation infrastructure within the central and southern Arizona regions.

By incorporating commuter or high speed rail within central and southern Arizona, a more resilient regional economy and environment can be created. The I-11 Super Corridor study presented the incorporation of different regional factors, including population density and economic statistics, to determine suitable routes for future transportation corridors. Through the use of GIS, this project focuses on the utilization of specific local and regional data to determine suitable routes for new rail transport corridors within Maricopa, Pinal and Pima Counties.
METHODS

To identify suitable areas for future transportation infrastructure, key factors were identified that would define what the term “suitable” would refer to. Within this project, suitability was determined for not only future rights-of-way, but also for effective station area locations. Suitability for possible rights-of-way was determined using the following factors:

**Noise pollution** – Noise pollution near residential areas was a primary concern within this project and was minimized by identifying a minimum Euclidean distance surrounding residential uses as unsuitable.

**Soils** – Suitable soils were identified as those with; a moderate or low corrosiveness to concrete, low or moderate corrosiveness to steel and drainage defined as somewhat excessively drained, somewhat well drained or well drained defined by the Natural Resources Conservation Service.

**Land uses** – All land uses that did not include Industrial were defined as being unsuitable.

**Conservation land** – All conservation land was isolated and defined as unsuitable for right-of-way development.

**Elevation and grades** – Elevation data was collected for the study area and grades of 5% or less would be considered suitable.

**Existing interstate rights-of-way** – Given the possibility for right-of-way improvement, existing Interstate rights-of-way are defined as suitable.
**Existing railroad rights-of-way** – In a similar way, given the possibility for right-of-way improvement, existing railroad rights-of-way are defined as suitable.

Similar to suitable areas for future rights-of-way, future station areas were defined by the following factors:

- **Land uses** – All land uses that did not include Industrial were defined as being unsuitable.
- **Population Density** – Areas with a high population density were favored over those with less.
- **Existing interstate rights-of-way** – Given the possibility for right-of-way improvement, existing Interstate rights-of-way are defined as suitable.
- **Existing railroad rights-of-way** – In a similar way, given the possibility for right-of-way improvement, existing railroad rights-of-way are defined as suitable.
- **Transportation Connectivity** – Areas which include the possibility of connection to as many other forms of transportation as possible were defined as more suitable than those with less.

Based on the factors listed above and the requirements of each, areas within the study area are determined as either suitable or non-suitable on a scale from 1 to 9. By isolating these specific criteria, one can begin to uncover suitable and unsuitable areas for infrastructure development. By isolating each defined factor and then overlaying each on top of each other, and by applying a weight to each, one can further define areas that meet all criteria for each infrastructure item, rights-of-way and station areas.
The extraction of only the highest values from these overlays was then used to identify suitable route and station location options.

The data that make up the layers that are used in this analysis include; residential parcels, soil survey data, existing land use, areas of land conservation, elevation data, locations of interstates and locations of railroads. All of this data was collected for all of the three counties in the study area, Maricopa, Pinal and Pima. Given the extent of the study area, all data was converted to UTM Zone 12N.
ANALYSIS

Analysis of data was done on an individual basis for each factor used to determine suitability for future rights of way and station areas. The results of these individual analyses are then combined utilizing a weighted analysis. Upon the completion of these overlays, the highest values were extracted and utilized to determine options for future routes.

Right-Of-Way Identification

Noise pollution

In order to ensure that residential areas would not be affected by the possible noise created by a high speed rail or commuter rail right-of-way, residential parcels within the study area needed to be identified. To do this, parcel data was collected from the Maricopa Association of Governments, Pinal County and Pima County.

Residential parcels for Maricopa and Pima Counties were separated using the Select by Attribute tool that identified all residential land use codes within each data set. Given the data available, specific parcel-level land use code identification was not available for Pinal County; however, the Select by Location tool was used with the existing generalized land use data to identify all residential parcels in Pinal County. Residential parcels for all three counties were then merged together using the Merge Tool into a single dataset that could be used in the regional analysis. The Euclidean Distance tool was used to create a raster defining distances from all residential parcels in the study area. The resulting distances were reclassified to define suitable and unsuitable distances from existing residential areas for future rights-of-way on a scale from 1-9, 9 representing the most suitable distance.
Soils

In order to identify suitable soils for a future right-of-way, soils data (soil surveys) for the study area was collected from the USGS Natural Resources Conservation Service (NRCS). Twenty-four (24) individual shapefiles make up the soils for the study area. In order to utilize these files to identify corrosiveness and drainage, the “component” table containing several different attributes, provided by NRCS, was joined to these files. The files were then exported as new feature classes containing the joined data into a geodatabase. These files were then merged together using the Merge tool.

As stated earlier, suitable soils were identified as those with a moderate or low corrosiveness to concrete, low or moderate corrosiveness to steel and drainage defined as somewhat excessively drained, somewhat well drained or well drained defined by NRCS. A new attribute field was added to identify a suitability score. Using the select by attributes tool, only soils meeting all of the above conditions were selected and exported into a new feature class. All of these records were given a suitability score of 9, while all of the others received a 1. The Feature to Raster tool was then used to create a raster identifying suitable soils. The suitability score attribute was used as the Value field for this process.

Land uses

For the purposes of this project, industrial land uses were defined as being suitable for future rights-of-way. Existing land use data for the study area was collected from the Maricopa Association of Governments, Pinal County and Pima County.

Utilizing select by attributes for each, industrial features were exported into individual shapefiles and combined using the Merge tool into a new feature class.
order to identify areas outside of these industrial uses within the study area, this feature class was then combined with the study area using the Union tool. The feature to raster tool was then used to create a raster that identified industrial uses within the study area. The reclassify tool was then used to apply a value of 9 to industrial areas and a value of 1 to non industrial areas.

**Tribal Land**

In order to ensure that a future right-of-way does not encroach on tribal lands, these lands were identified. The boundaries of all tribal lands within the study area were collected from AZGEO, the Arizona State GIS Clearinghouse created by the Arizona State Cartographer’s Office. The boundaries of all tribes within Arizona were included in the provided layer package.

These were then clipped, using the Clip tool, to the study area, preserving only those tribal lands within the study area. The Union tool was then used to combine tribal lands and the study area in order to identify those lands that were not tribal. The Feature to Raster tool was then used to transform the new combined features into a raster that would identify tribal and non tribal lands. The Reclassify tool was then used to assign tribal lands a value of 1 and non tribal lands a value of 9.

**Conservation land**

To ensure the preservation of lands that has been set aside for conservation, these lands needed to be identified. These boundaries were gathered in a layer package format from AZGEO for the entire state of Arizona.

The boundaries included in this layer package were then clipped to the study area using the Clip tool and combined with the study area using the Union tool so that
both conservation and non conservation land could be identified. The Feature to Raster tool was then used to transform the data into a raster that could then be classified. The Reclassify tool was then used to apply a value of 1 to conservation lands and a value of 9 to non conservation lands.

**Elevation and grades**

Any type of rail transportation is limited in the grade that can be traversed. For the purposes of this project, a grade of 7% is considered the absolute maximum that would be considered suitable. A digital elevation model (DEM) for the State of Arizona was collected from the University of Arizona and utilized for this process.

Utilizing the extract by mask tool, the DEM was clipped to include only those elevations within the study area. The slope tool was then used to calculate the slope for all elevations using “percent rise” as the output measurement. This result was then reclassified using the reclassify tool in order to identify suitable and non suitable grades. Nine (9) classes were then created manually by inputting a grade of 1% for a value of 9, 2% for a value of 8, etc. The least suitable value of 1 contains grades of 8% and above.

**Existing interstate rights-of-way**

The purchase of lands for new rights-of-way can be highly expensive and therefore, the inclusion of existing rights-of-way within this analysis was highly important. Existing interstates for the State of Arizona were gathered from AZGEO in a layer package format.

This layer was then clipped the study area, using the Clip tool. The Euclidean Distance tool was then used to define all areas within the study area a distance value from the existing right-of-way. Suitable values were then defined using the Reclassify
tool, creating 9 classes. Each class was defined in intervals of 50 feet, value 9 defined as 50ft, value 8 as 100ft, etc. Value 1 was defined as 450ft and above.

**Existing railroad rights-of-way**

Similarly, utilizing existing railroad rights-of-way can also be highly cost effective and therefore, have also been included in this analysis. Existing railroads were gathered from AZGEO as a layer package.

These existing railroads were then clipped to the study area using the Clip tool. The Euclidean Distance tool was then used to define all areas within the study area a distance value from the existing right-of-way. Suitable values were then defined using the Reclassify tool, creating 9 classes. As with existing interstates, each class was defined in intervals of 50 feet, value 9 defined as 50ft, value 8 as 100ft, etc. Value 1 was defined as 450ft and above.

**Weighted Overlay**

The Weighted Overlay tool was then used, including all of the outputs above. The applied weights for each output were as follows: Residential: 15%, Soils: 15%, Elevation: 15%, Land Use: 5%, Tribal Land: 10%, Preserve Land: 10%, Existing Rail: 15%, Existing Interstate: 15%. The output was then symbolized to represent suitability based on the 1-9 value.

**Station Areas Identification**

All of the factors included within the right-of-way analysis were utilized to identify station areas. However, two additional factors were added to the analysis process to identify suitable areas for station areas. These factors include population density and transportation connectivity.

**Residential Density**
In order to calculate residential density, residential parcels, previously created for the “Noise Pollution” sub objective, were utilized for this analysis. Utilizing the residential parcels feature class, the Feature to Point tool was utilized to transform each parcel into a single point. The Density tool was then used to calculate the residential parcels per square mile for the entire study area. The output raster was then reclassified using the Reclassify tool, dividing the density values into nine (9) classes.

Transportation Connectivity

Effective station areas are in close proximity to a diverse transportation network that offers as many options as possible. For this analysis, proximity to ground transport (roads, interstates, etc.) and airports were considered. Arizona roads and airport locations were gathered from AZGEO in a layer package format.

Arizona roads included interstates, US highways, highways, highway loops, access ramps, arterials, streets, primitive roads and trails / alleys. For this analysis, primitive roads and trails / alleys were left out. The layer package was then clipped, using the Clip tool, to the study area. The result was then exported as a feature class to the working geodatabase. The Create Geometric Network tool was then used to create points for every intersection within the study area. An attribute field was added to this new point feature class called “Rating”. Within this field, each type of road was rated based on capacity, with the highest capacity receiving a value of 9 and the lowest a value of 1. The spatial join tool was then used to apply these ratings to the previously derived points. The Hot Spot Analysis tool was then used to identify hot and cold spots within these points, utilizing the Rating attribute as the input field. Within the result, all intersections identified as being within a hot spot and containing a value of 99%
confidence or higher were then exported. Utilizing the Density tool, a raster was then created for the study area representing hot spot intersections per square mile.

Proximity to airports, another important transportation option, is also important for an effecting station location. For this analysis, only public airports were considered. Utilizing the select by attributes tool, public airports were selected and exported out of the layer package and stored in the working geodatabase as a new feature class. The Euclidean Distance tool was then used to define a distance around all public airports within the study area. The reclassify tool was then used to define suitable distances from airports. These were divided into values of 1, 2, 3, 4, 5, 6, 7, 14 and 28 miles. A value of 9 was defined as a distance of 1 mile and a value of 1 was defined as a value of 28 miles.

**Weighted Overlay**

The Weighted Overlay tool was then used, including all of the outputs from the right-of-way identification section as well as the residential density and transportation connectivity results identified above. The applied weights for each output were as follows: Residential: 10%, Soils: 10%, Elevation: 10%, Land Use: 5%, Tribal Land: 5%, Preserve Land: 10%, Existing Rail: 10%, Existing Interstate: 10%, Residential Density: 10%, Road Proximity: 10%, Airport Proximity: 10%. The output was then symbolized to represent suitability based on the 1-9 scale.

**Route Identification**

The weighted overlay result from the right-of-way identification section was utilized for the final identification of suitable routes. From the overlay result, the Raster to point tool was used to transform every pixel within the study area into a point. From
this point feature class, the highest values were selected and exported using the select by attribute tool within the Value field. The highest values were identified as 5, 6 and 7. The combination of Existing Interstates and Existing Railroads outlined all of these highest values and were each combined, using the Merge tool, into a new feature class. Utilizing the Spatial Join tool, the individual values from each point were then joined to every overlapping line segment. These segments were then symbolized to emphasize suitability based on these values.
RESULTS

Right-of-Way Identification

Legend
Proximity to Residential
9 - 1700-1800ft
8 - 1500-1700ft
7 - 1500-1600ft
6 - 1300-1400ft
5 - 1200-1300ft
4 - 1100-1200ft
3 - 1000-1100ft
2 - 900-1000ft
1 - 0-900ft

Figure 1
Figure 3
Right-of-Way Identification

Legend
1 - Preserve Lands
9 - Non Preserve Lands

Figure 5
Figure 6
Figure 7
Figure 8
Figure 9

Right-of-Way Identification

Suitability

Legend
Suitability for Future Right-of-Way

0 5 10 20 30 40 Miles

N

Figure 9
Within the result, Figure 9 above, there are a few things that clearly stand out. First, highways and railroad rights-of-way are being described as the most suitable areas for new rights-of-way. The majority of the study area has been defined as being on the lower end, 5 and below, of the suitability scale. Mountainous areas, preserves and tribal lands clearly stand out as unsuitable with values ranging from 2 to 4.
The population and transportation connectivity factors that were included in this overlay, noticeably made a large difference within our study area. Suitable areas are now clustered around populated areas with airports. The expected result was to see two clusters, one for the City of Phoenix and City of Tucson. In figure 12 above, that this is clearly not the case. There are several clusters of suitable locations spread throughout the study area.
Route 1 had the largest collection of high suitability values, primarily 6 and 7. It clearly stands out as the most suitable location for right of way improvement and is located on Interstate 10 connecting Phoenix and Tucson. This route also connects the centralized City of Casa Grande with these two major Arizona cities.
Route 2 contained the second largest number of high suitability values, primarily 5 and 6. It avoids the Gila River Indian Community and connects Phoenix and Tucson through the City of Coolidge by an existing railroad right of way.
CONCLUSIONS

Current transportation methods within the Central Arizona region revolve primarily around automobiles. In order for the region to become more economically resilient and environmentally sustainable, alternative transportation methods must be considered. The application of high speed or commuter rail to central and southern Arizona appears to have great promise in achieving both of these goals. Through this analysis, it has been determined that not only is there suitable land for such a project, but there are also multiple options and alternatives available.

Suitability analysis can be used for an entire range of subjects from problem solving to market research. When applied to any type of industry, it has the potential to improve business practices by identifying and weighting each and every factor that makes up individual problems to be solved or markets to be researched. The adoption of new practices like these...

If the project could be done over again, more transportation rights-of-way, such as state highways, would be included. Also, within the nature of this project, there was a large emphasis on cost; in a second attempt, a model in which cost was not as important would have been included in order to show the distinction between low cost and high cost options.

The hope is that this project has the potential to show that suitability analysis, in concert with other methods, can be used for a wide range of subjects. At the beginning of this project, suitability analysis was not even a consideration as a solution to this application. It was successfully applied as the central component of the project and can be successfully applied to many other unrelated projects.
LIST OF REFERENCES


