

GISC 6389: GIS Masters Research

Development of AHP add-in using ArcGIS Pro SDK for .Net for performing Spatial Multi Criteria Decision Analysis of housing development sites - An accessibility level perspective for Richardson, TX

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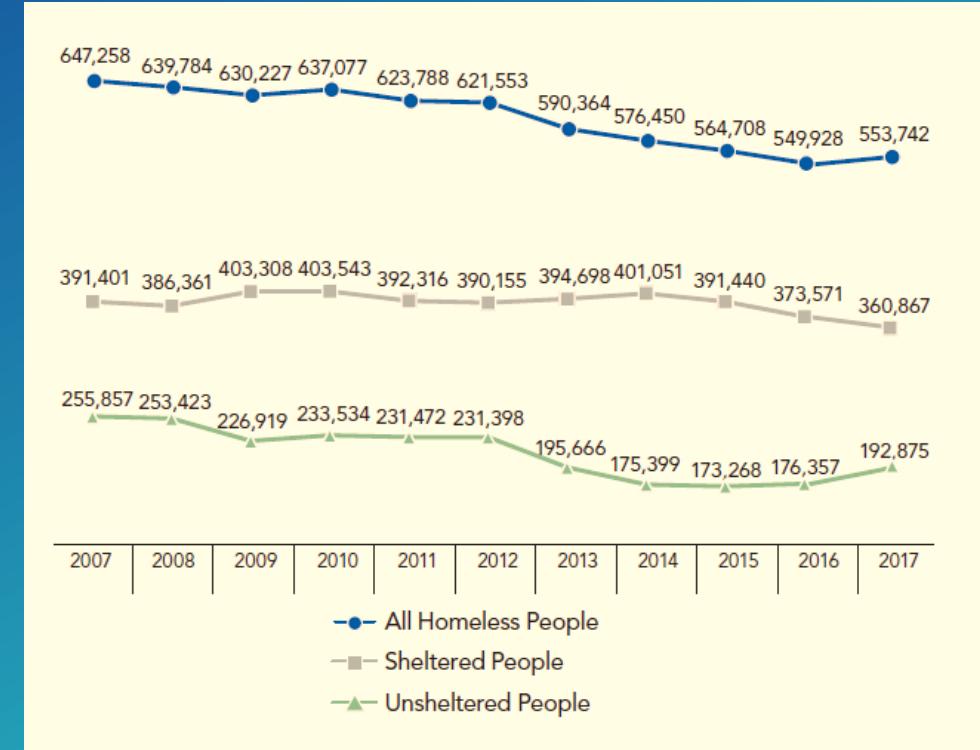
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Background, Idea and Motivation

What drove me towards this research?

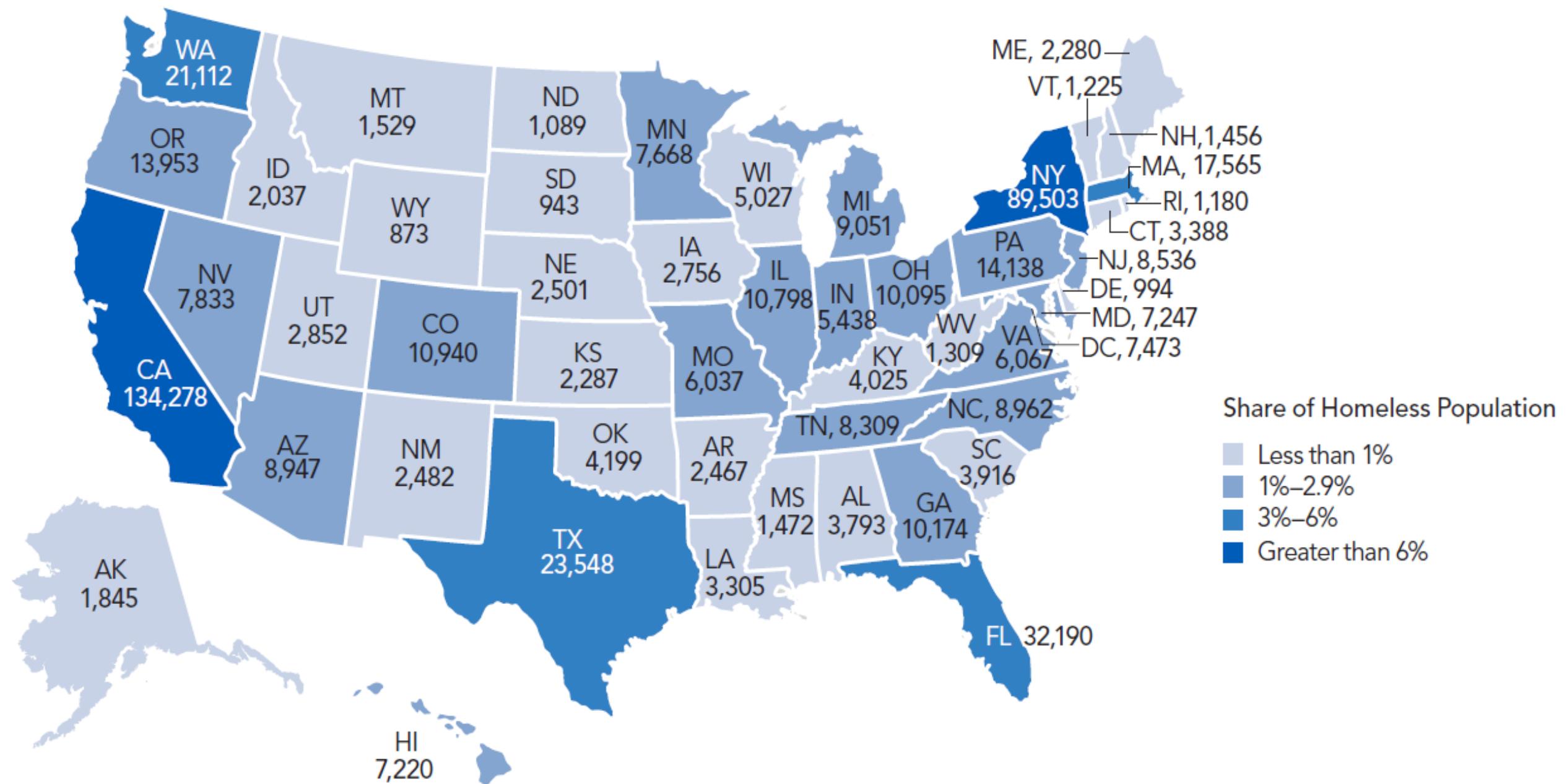
How's the current homelessness situation in the US?

- HUD 2017 Annual Review
 - On a single night 553,742 people are homeless in the US.
- According to HUD, families with only **one full-time worker** making minimum wage couldn't afford rent for a two-bedroom market-priced apartment anywhere in the country.
- Next to food, **Shelter** is the most important basic necessity for a human survival.
- Hence, the study of housing development needs a greater emphasis and update.



**Estimates by Sheltered Status
2010 - 2017**

By State, 2017



Source : HUD Annual Report 2017 to Congress

Major Reasons for Homelessness

- Poverty
- Unemployment
- **Lack of Affordable Housing**
- Serious Health Issues
- Family Relationships
- Domestic Violence
- Physical and Sexual Abuse



Section 8 housing for solving affordability?

- Targeted towards very low-income families, elderly and disabled.
- Authorizes rental assistance to private landlords on behalf of 11.9 M as of 2017 low income households
- For affording a decent, safe and sanitary housing in private market.
- Administered by Public Housing Agencies (PHA's)
- Eligibility – Family's income < 50% Median HHI of respective county or MSA.
- Mandatory for PHA's to provide 75% of vouchers to families whose income is less than 30% Median HHI.



Research Questions?

What I would like to address?

Section 8 housing help the poor –***But only if housing is available***

- Not all families can be covered in Section 8 housing.
- Hence, is there a need for affordable housing?
- How can planners select sites for affordable housing?
- What major factors any planner can think of?
 - Geological conditions.
 - **Accessibility** to basic facilities (transit, emergency, grocery, education)
- Are there any **decision making tools** which may aid planners in taking important decisions for housing or other themes?
- How can these tools help planners in evaluating multiple conflicting criteria?



Literature Review

What research I have done?

Topic	Methodology Used	Result / Conclusion
A GIS – Based Multi Criteria Approach to Accessibility Analysis for housing development in Singapore	<ul style="list-style-type: none"> <input type="checkbox"/> Multi-criteria framework for accessibility analysis from a resident's perspective in Singapore. <input type="checkbox"/> Integrated multi criteria decision analysis with GIS based accessibility models. <input type="checkbox"/> Transit, Shopping Centers, Health care, Banks, Schools, Post offices, Parks were taken as accessibility criteria. <input type="checkbox"/> Weights derived from survey data. <input type="checkbox"/> Used Arc View extension, Accessibility Analyst developed by Liu <i>et al</i> (2004) <input type="checkbox"/> An MCDA model was built using JAVA AHP (Zhu <i>et al</i>, 2001) process based on SMART (Simple Multi Attribute Rating Technique) method 	<ul style="list-style-type: none"> <input type="checkbox"/> The output maps were generated as a hexagonal tessellation for observing the varying patterns in accessibility criteria. <input type="checkbox"/> Visualized the overall attractiveness of an area from a demand-side perspective. <input type="checkbox"/> Depicted that 10 zones out of 256 zones in the chosen study area have the highest overall accessibility to chosen criteria
Authors:		
<input type="checkbox"/> X. Zhu, <input type="checkbox"/> Liu S. <input type="checkbox"/> Yeow M.C		
Proceeding of SSC 2005		
Spatial Intelligence		
Year : Sep, 2005		
Spatial Sciences		
Institute		
ISBN 0-9581366-2-9		
		Limitations
		<ul style="list-style-type: none"> <input type="checkbox"/> Limited Spatial Aspects. <input type="checkbox"/> Automation deficiency for making real time simulations and SA.

Topic	Methodology Used	Results / Conclusion
Spatial Sensitivity Analysis of multi-criteria weights in GIS-based land suitability evaluation	<ul style="list-style-type: none"> <input type="checkbox"/> Analyzed how GIS- based MCDM with sensitivity analysis procedure are crucial to understand any decision making model behavior and its limitations. <input type="checkbox"/> Developed a simulation based model for observing the suitability changes in a spatial dimension. 	<ul style="list-style-type: none"> <input type="checkbox"/> Relative changes in the suitable areas were observed using raster based analysis. <input type="checkbox"/> Visualized spatial change dynamics relative to decision making problems.
Authors: <ul style="list-style-type: none"> <input type="checkbox"/> Y.Chen <input type="checkbox"/> J.Yu <input type="checkbox"/> S.Khan 	<ul style="list-style-type: none"> <input type="checkbox"/> High consideration and importance provided to spatial visualization and cartographic capabilities. <input type="checkbox"/> ArcGIS Engine 9.2 (ESRI 2008) platform was used to visualize result. MATLAB COM – compliant DLL was used for AHP process. 	<ul style="list-style-type: none"> <input type="checkbox"/> Showcased which parts of the catchment area have poor soil texture, low hydraulic conductivity, undulating surfaces.
Environmental Modelling & Software 25:1582 – 1591 Year: 2010	<ul style="list-style-type: none"> <input type="checkbox"/> One-at-a-time (OAT) method was used for varying criteria weights for Sensitivity Analysis. <input type="checkbox"/> Visualized a case study of irrigated crop land and performed suitability assessment using the SA framework. 	<p style="text-align: center;">Limitations</p> <ul style="list-style-type: none"> <input type="checkbox"/> Limited insights into spatial patterns of weight sensitivity in evaluating multiple criteria. <input type="checkbox"/> Dated technology in application.

Topic	Methodology Used	Result / Conclusion
<p>A GIS-Based Multicriteria Decision Analysis Approach for Mapping Accessibility Patterns of Housing Development: A Case Study in Canmore, Alberta</p>	<ul style="list-style-type: none"> <input type="checkbox"/> Utilized two major spatial decision making methods for selecting housing sites. <input type="checkbox"/> Integrated AHP and OWA methods in a raster based GIS environment. <input type="checkbox"/> Incorporated linguistic quantifiers as a method for obtaining the weights. <input type="checkbox"/> An expert in the Planning Department of Canmore was consulted to provide judgements regarding the relative importance of objectives and attributes. <input type="checkbox"/> Fuzzy linguistic quantifiers (At least one, Few, Some, Half, Many, Most and All) were utilized for series of accessibility evaluation outcomes. 	<ul style="list-style-type: none"> <input type="checkbox"/> Helped housing authorities in addressing the uncertainty involved in decision making process. <input type="checkbox"/> Assisted housing authorities in understanding the accessibility patterns to a greater extent. <input type="checkbox"/> Assisted authorities in evaluating, planning and prioritizing the potential housing development from the accessibility perspective.
<p>Authors:</p> <ul style="list-style-type: none"> <input type="checkbox"/> Yuliang Meng <input type="checkbox"/> Jacek Malczewski <input type="checkbox"/> Soheil Boroushaki 		Limitations
<p>Journal of Geographic Information System, 2011,3, (50-61)</p> <p>Year: 2011</p>		<ul style="list-style-type: none"> <input type="checkbox"/> Limited Selection Criteria <input type="checkbox"/> Lack of automation to integrate into GIS software packages directly

Topic	Methodology Used	Result / Conclusion
<p>A GIS-based multi criteria decision making approach for evaluating accessibility to public parks in Calgary, Alberta</p>	<ul style="list-style-type: none"> ❑ A weighted linear combination with entropy weighting method was used obtaining the criterion weights. ❑ 9 criterion were considered for evaluating the accessibility majority of them being distance based, population based and number/ count based. 	<ul style="list-style-type: none"> ❑ Showcased a core-periphery pattern of accessibility to public parks in Calgary. ❑ Depicted that residents of central and eastern parts of Calgary tend to have higher level of accessibility to public parks than those living in the peripheral neighborhoods.
<p>Authors:</p> <ul style="list-style-type: none"> ▪ Yunliang Meng ▪ Jacek Malczewski 	<ul style="list-style-type: none"> ❑ A comparison of accessibility patterns in 2006 and 2011 was performed. ❑ 3 park category classification <ul style="list-style-type: none"> • Mini • Neighborhood • Community. 	<ul style="list-style-type: none"> ❑ Showed how GIS-MCDM procedures are very much useful for planning experts to analyze various scenarios.
<p>Human Geographies – Journal of Studies and Research in Human Geography Vol 9, No.1, ISSN: 2067-2284 Dated: May 2015</p>	<ul style="list-style-type: none"> ❑ 3 distance based model were applied <ul style="list-style-type: none"> • Covering Model, • Travel cost model • Minimum distance model. 	<h3 style="background-color: #2e6b2e; color: white; padding: 5px; text-align: center;">Limitations</h3> <ul style="list-style-type: none"> ❑ Concerned only about population and levels of physical access to public parks. ❑ Model calculations could have been automated saving time.

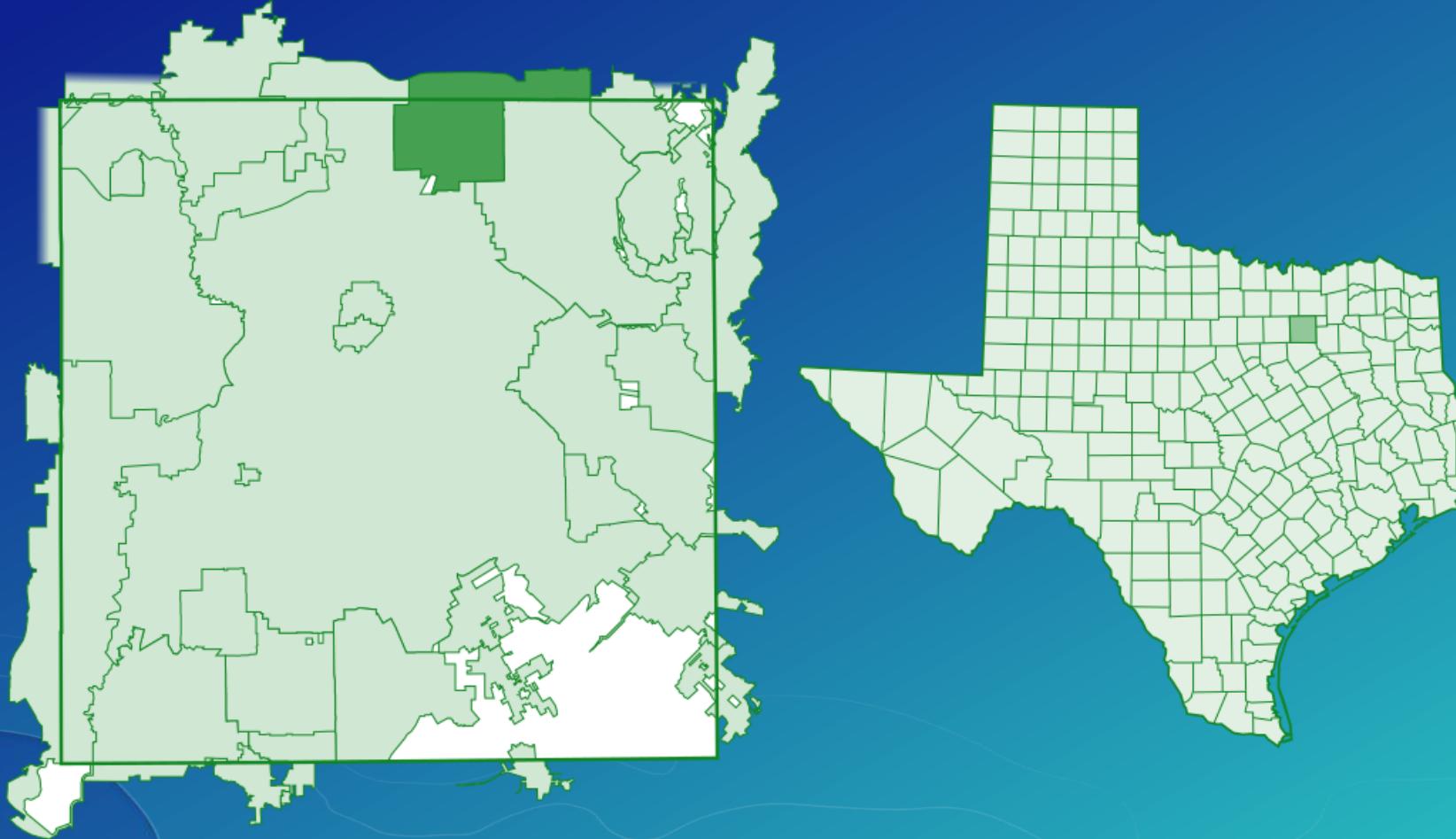
Objectives

What I tried to accomplish?

1. To prepare a generalized decision model which can be applied not only to housing but also for any other chosen theme.
2. To develop a modern desktop GIS- based interface for automated Spatial MCDA with AHP.
3. To perform sensitivity analysis and find out how suitability varies based on altering weights by a certain percentage.
4. To understand where potential housing sites could be developed based on the user assigned weights for criteria.

Study Area & Data Acquisition

Applicability of research idea



- Located in Collin and Dallas counties.
- Population of 113,347 as per 2016 census.
- But only 4 low income housing apartment complexes.
- 50 project based Section 8 subsidized apartments.
- Less units of affordable housing available

Data Sources and Tools:

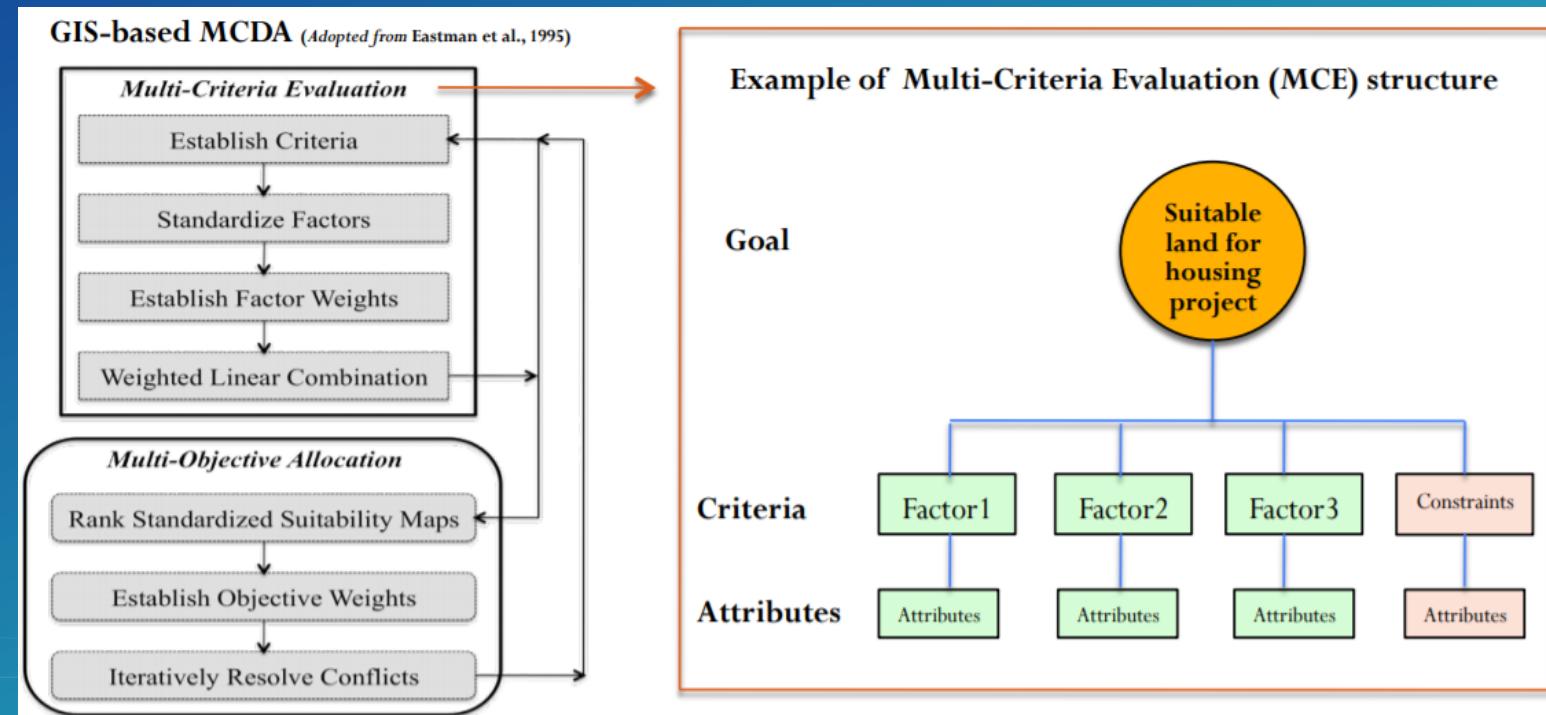


Methodology

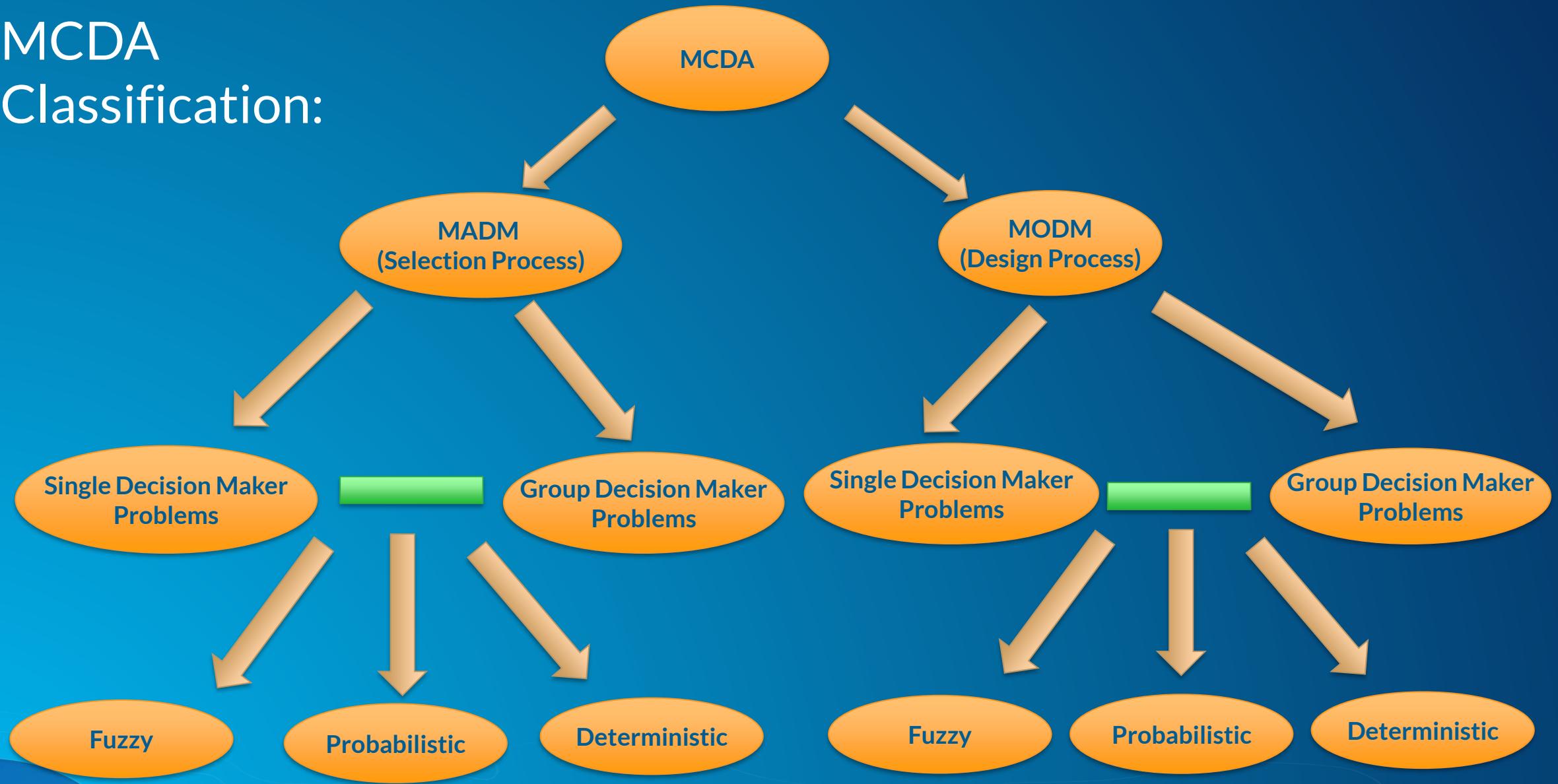
What procedure I followed?

What is MCDA?

- Most valuable tool for evaluating multiple conflicting criteria and reaching a decision.
- Widely applied in solving problems where choice is an alternative.
- Has gained huge popularity in Spatial Decision Support System.



MCDA Classification:



Some MCDA Methods:

- Analytical Hierarchy Process (AHP)
- Ordered Weighted Averaging (OWA)
- Weighted Sum Model
- TOPSIS Model (Technique for order of preference by similarity to Ideal Solution)
- ELECTRE (Elimination and choice expressing reality)
- Goal Programming
- Weighted Product Model

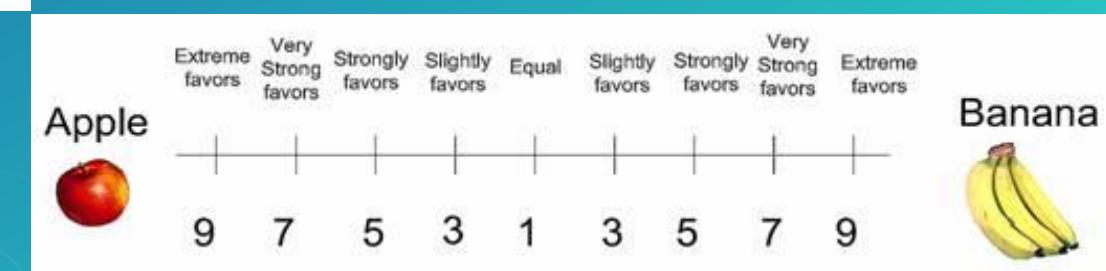
AHP and how it works?

- Developed by Saaty (1980) which is wide spread in many decision making fields.
- Based on 3 major principles :
 - Decomposition : Break up the complex problem , capture essential elements.
 - Comparative Judgement : Assessment at various hierarchy levels.
 - Synthesis of Priorities : Constructing global set of priorities at lowest hierarchy level.
- Major steps involved:
 - Developing Hierarchy
 - Pairwise comparison of decision elements
 - Overall priority rating

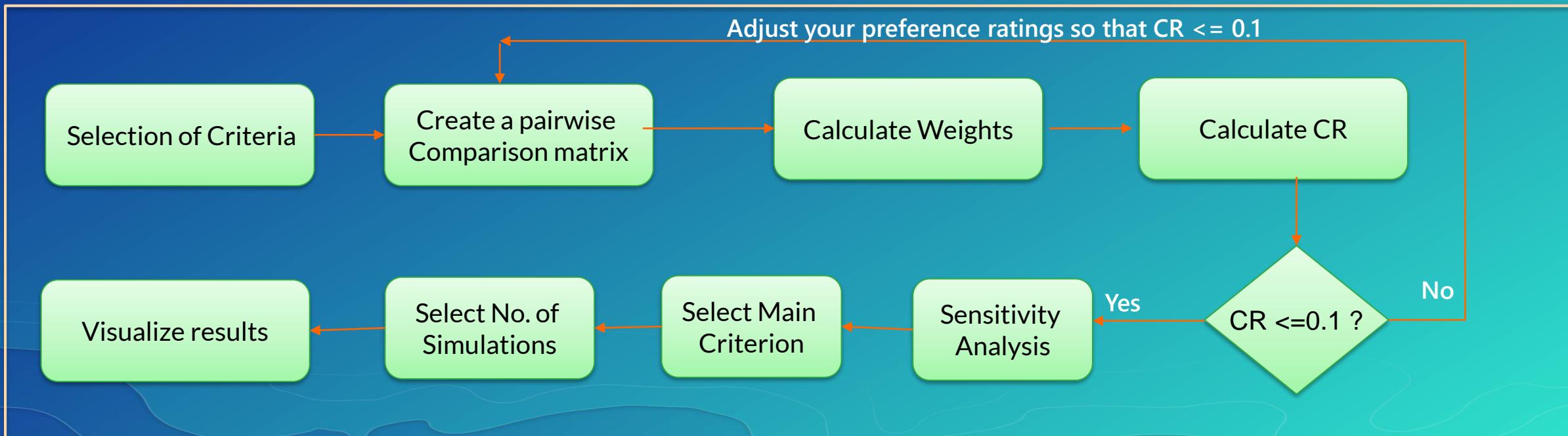
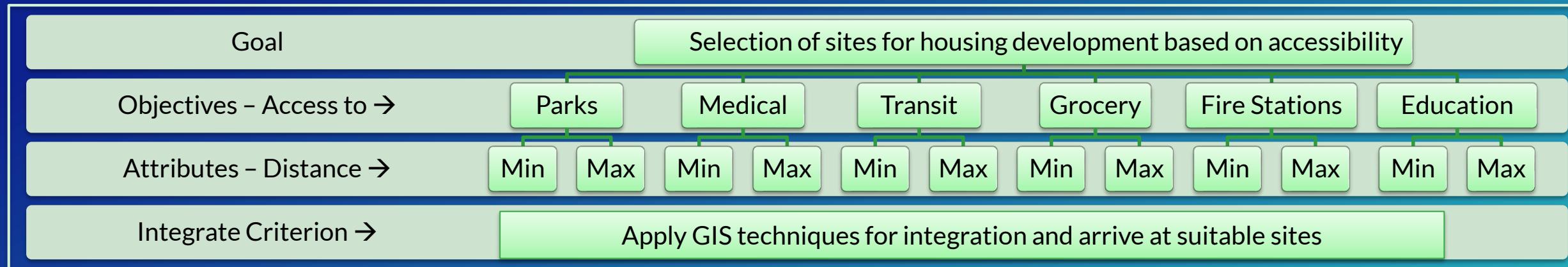
AHP pairwise ratings (Saaty Scale)

Scale	Numerical rating	Reciprocal
Extremely importance	9	1/9
Very to extremely strongly importance	8	1/8
Very strongly importance	7	1/7
Strongly to very strongly importance	6	1/6
Strongly importance	5	1/5
Moderately to strongly importance	4	1/4
Moderately importance	3	1/3
Equally to moderately importance	2	1/2
Equally importance	1	1

AHP: Analytic hierarchy process

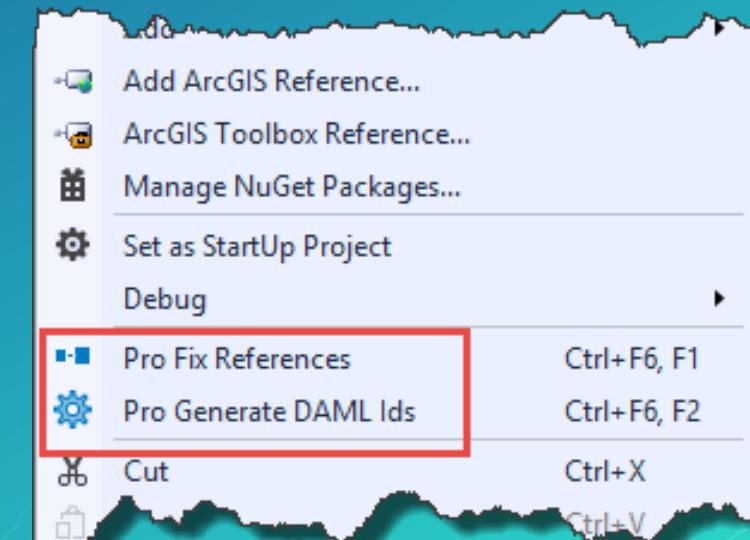
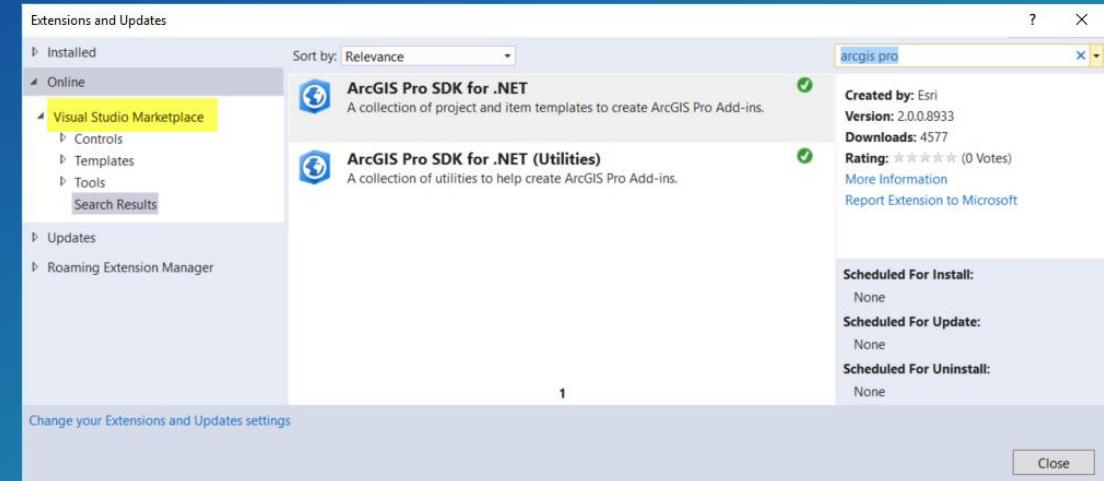


Flow Diagram

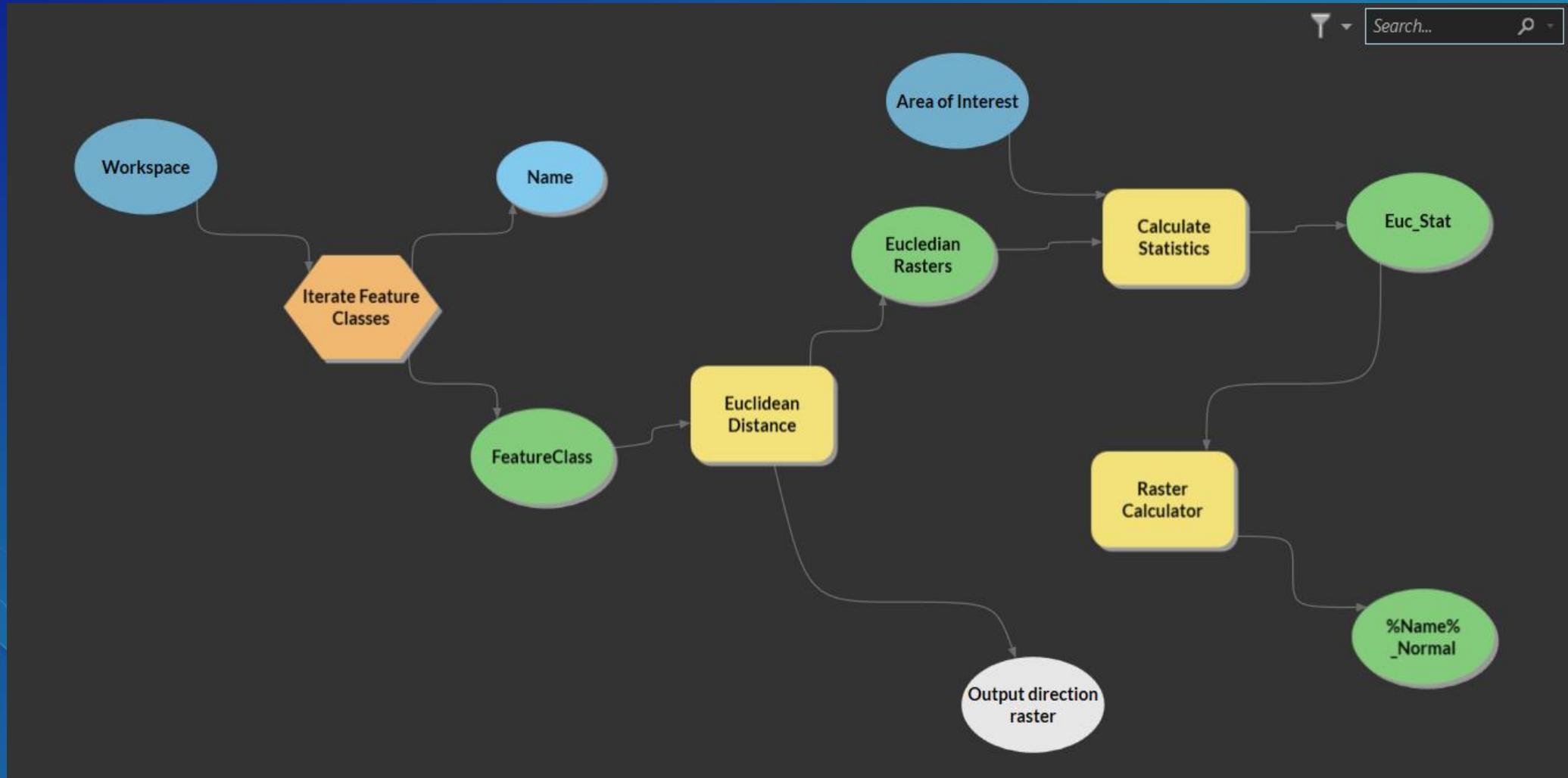


ArcGIS Pro SDK for building custom add-ins

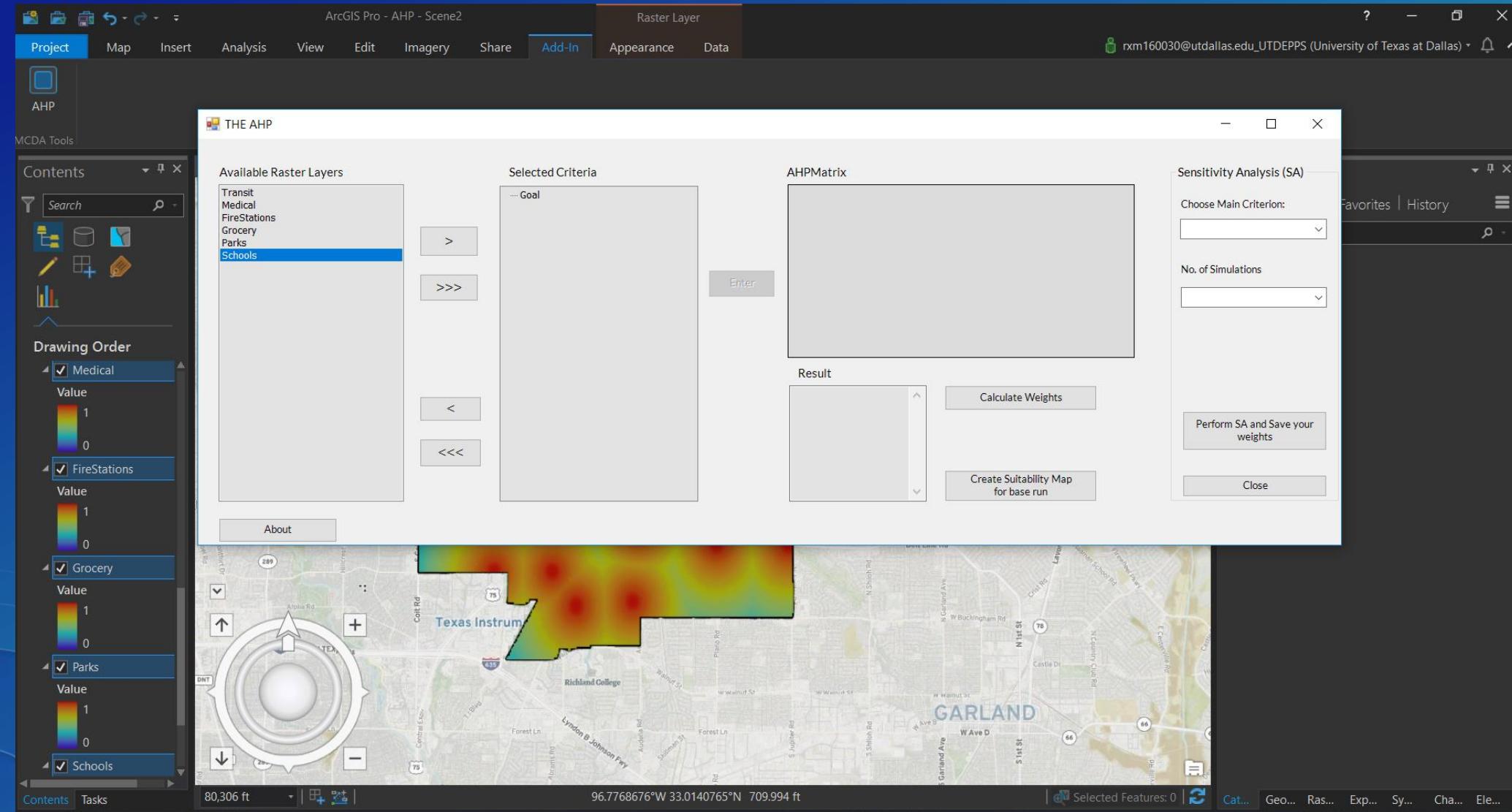
- How Pro is better over ArcView/Map?
 - Next gen desktop GIS – 64 bit multi threaded.
 - Background GP installation not required
 - High level mapping capabilities
 - Integrated with ArcGIS Online & Portal
- Major SDK features:
 - Task Asynchronous Programming (TAP)
 - Parallel Programming, task runs separately from main thread
 - LINQ
 - Language Integrated Query
 - MVVM (Model – View – ViewModel)
 - Separates GUI development from business logic development.



Initial Data Preparation for AHP in ArcGIS Pro

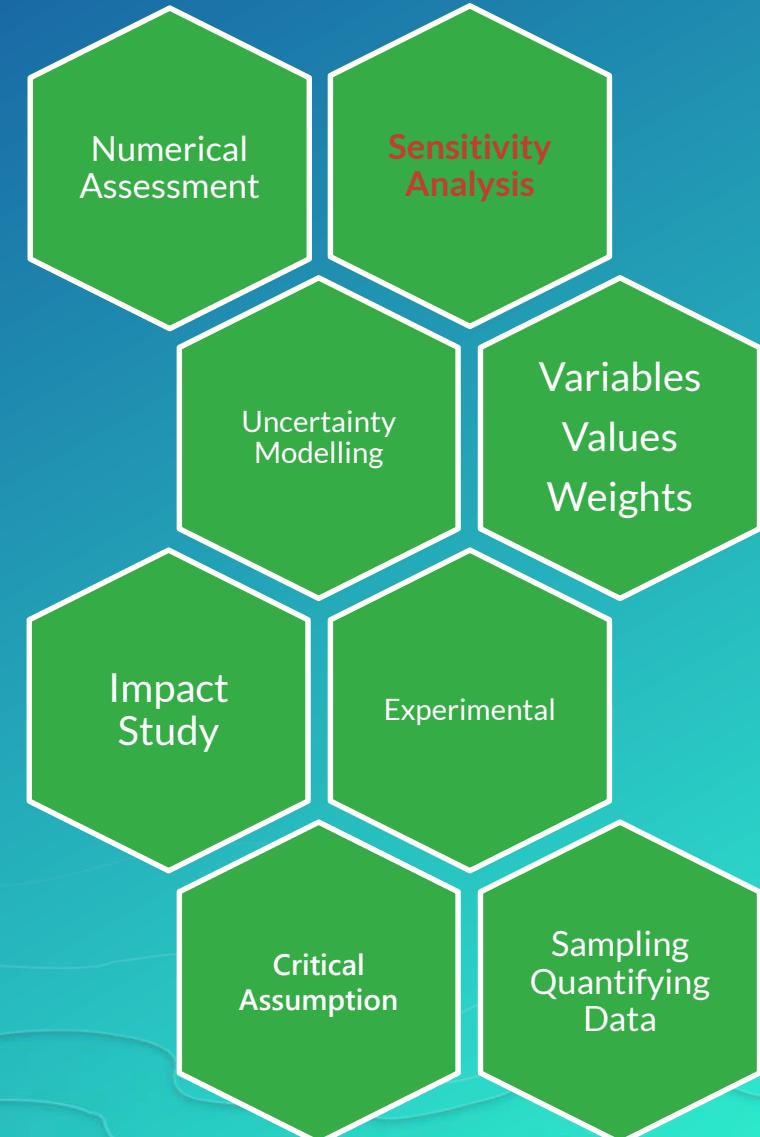


AHP Add-in interface in ArcGIS Pro

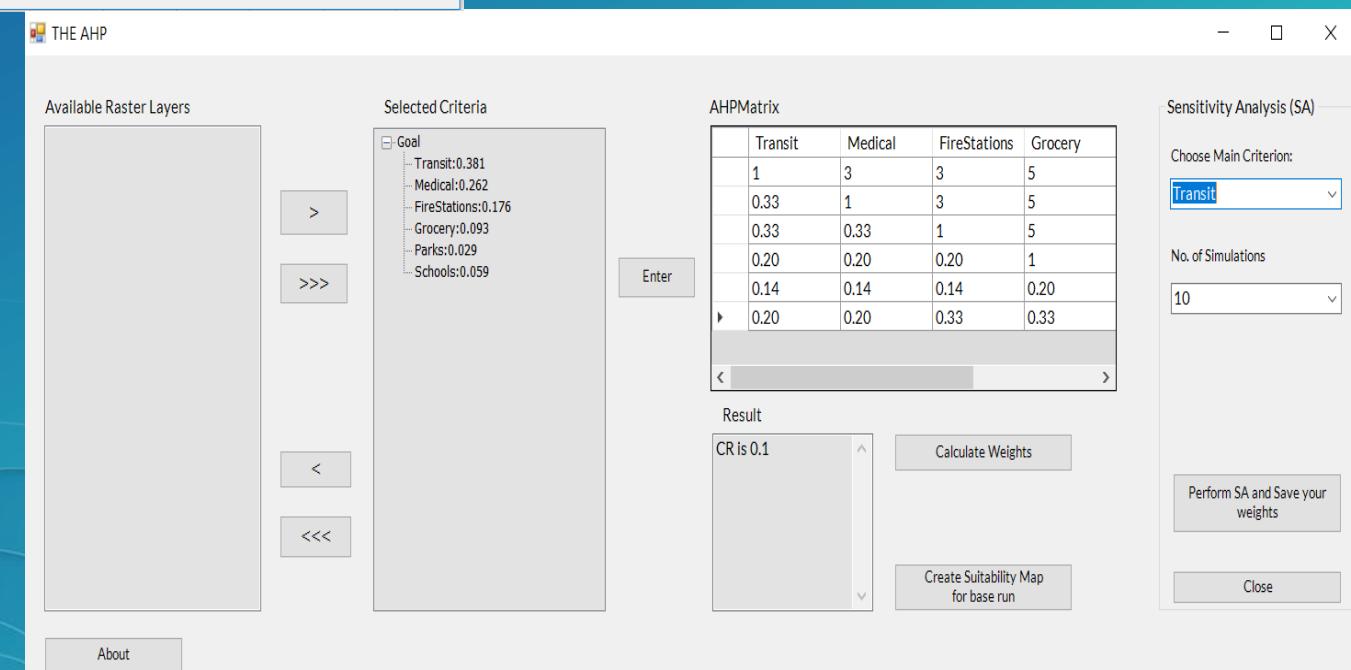
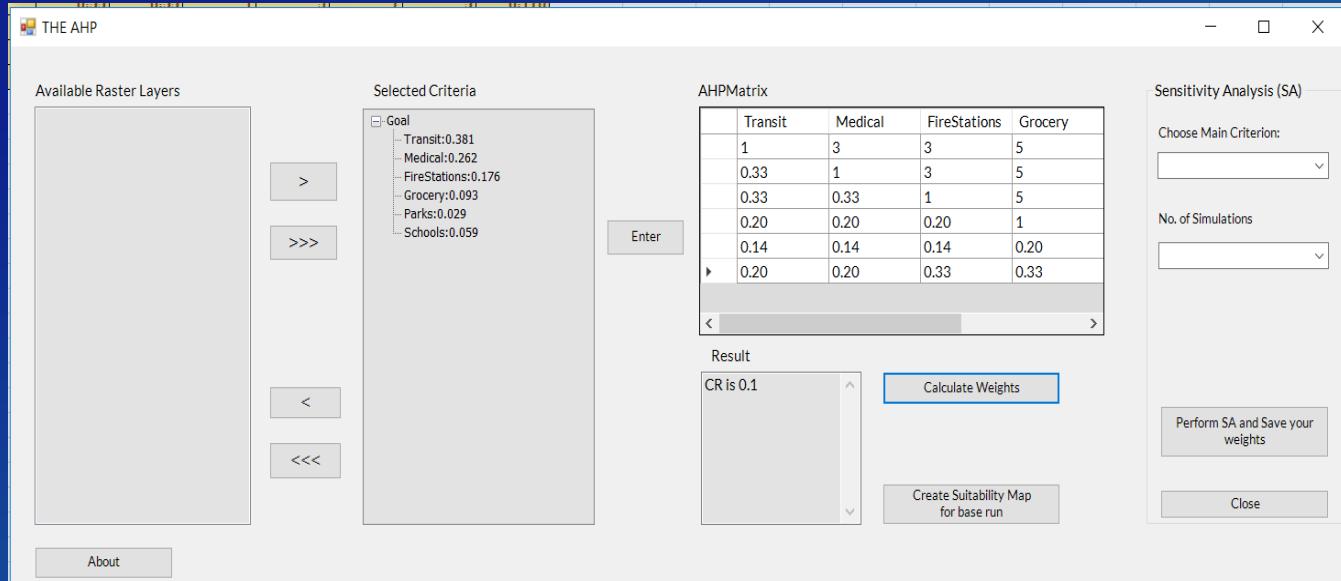


Sensitivity Analysis – Change and Observe Behavior

- Powerful alternative for the method of indirect incorporation of uncertainties into decision making process.
- Mainly concerned with the way in which errors in a set of input data affect the error in the final output .
- Explores dependency of model output on varying input criteria weights facilitating to identify criteria that are sensitive to weight changes.
- Showcases the impact of changing criteria weights on the resultant output from model in a spatial dimension.



AHP and sensitivity analysis interface



AHP Add-in Demo

using ArcGIS Pro SDK

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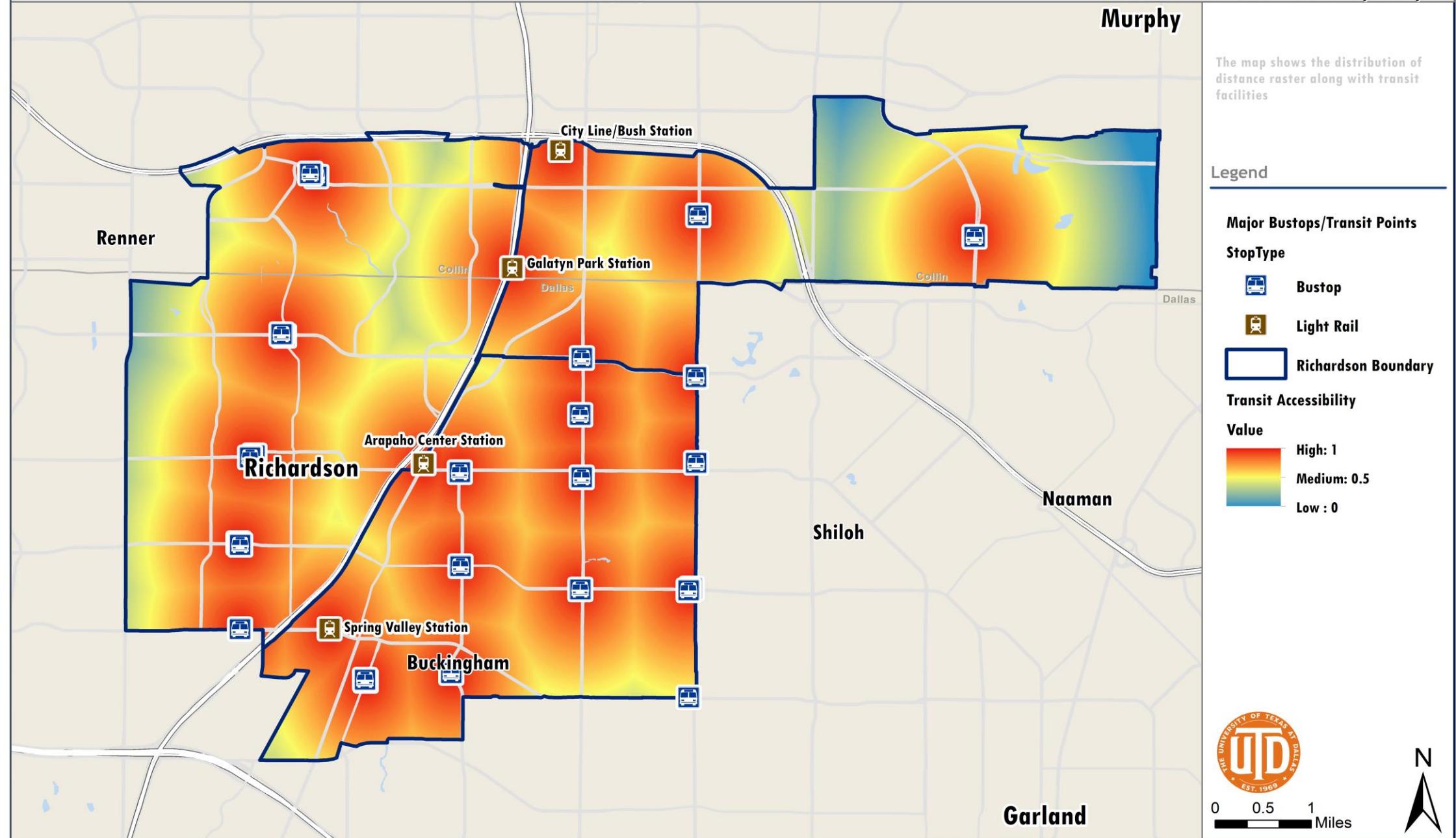
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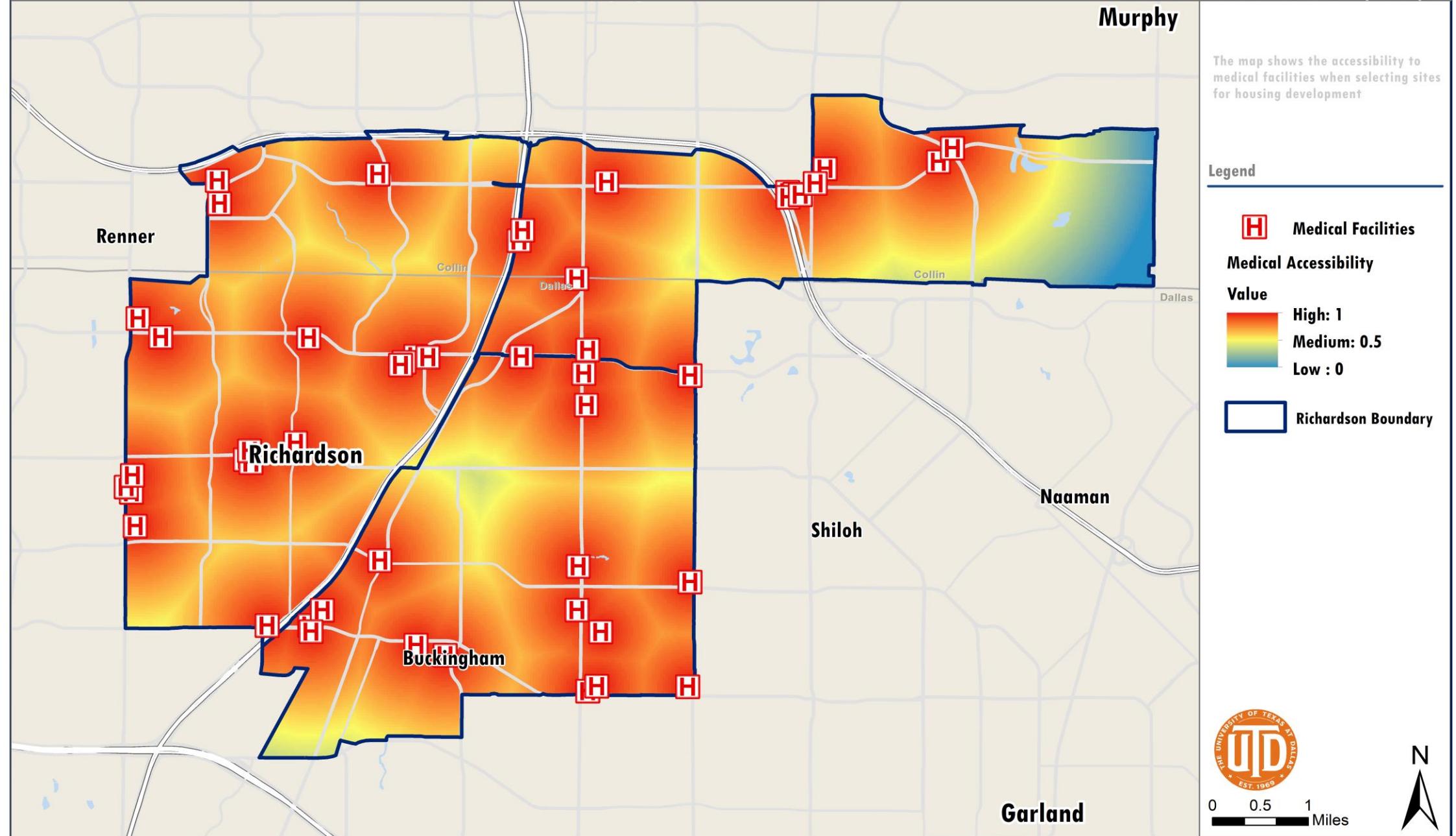
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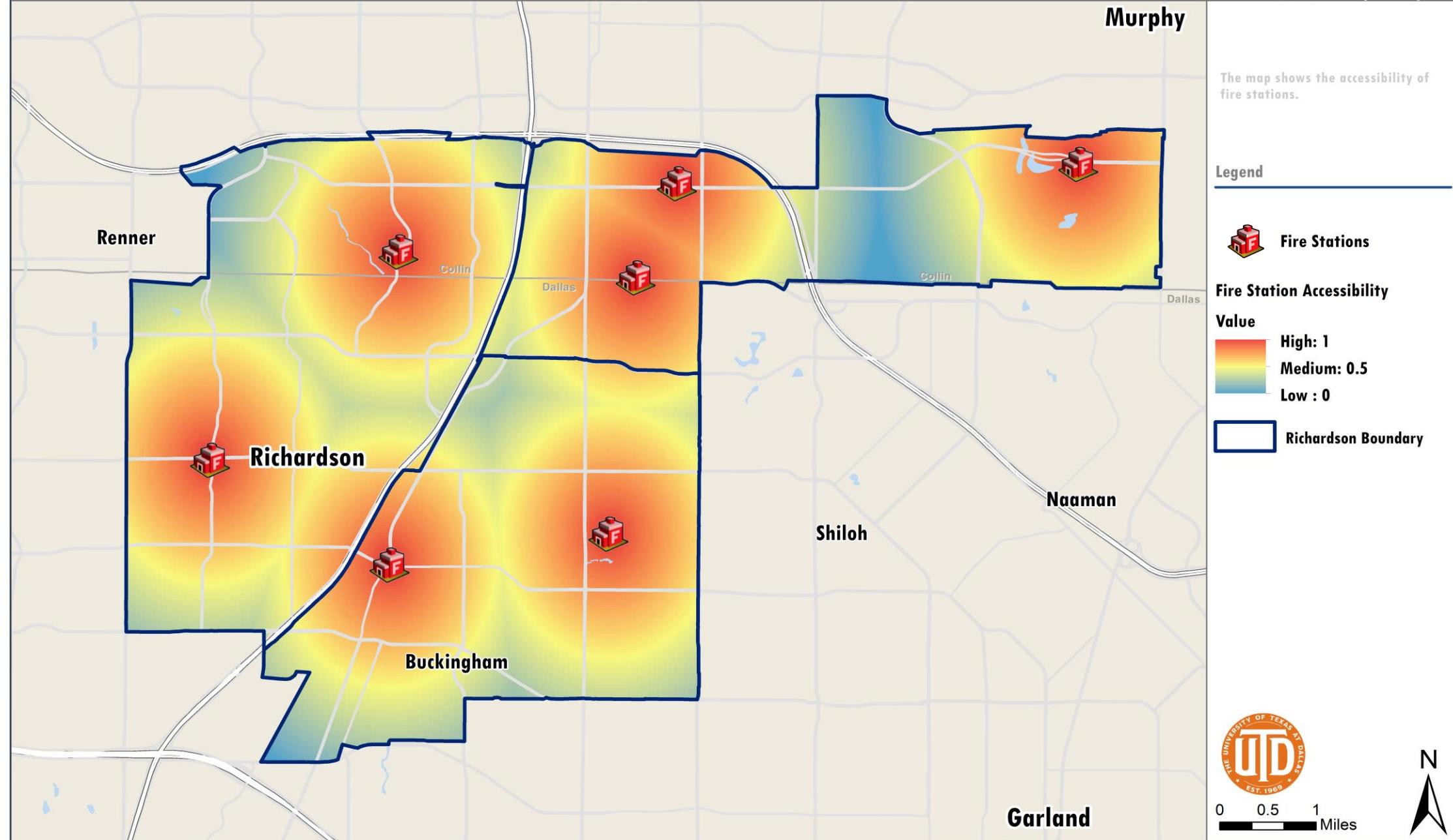


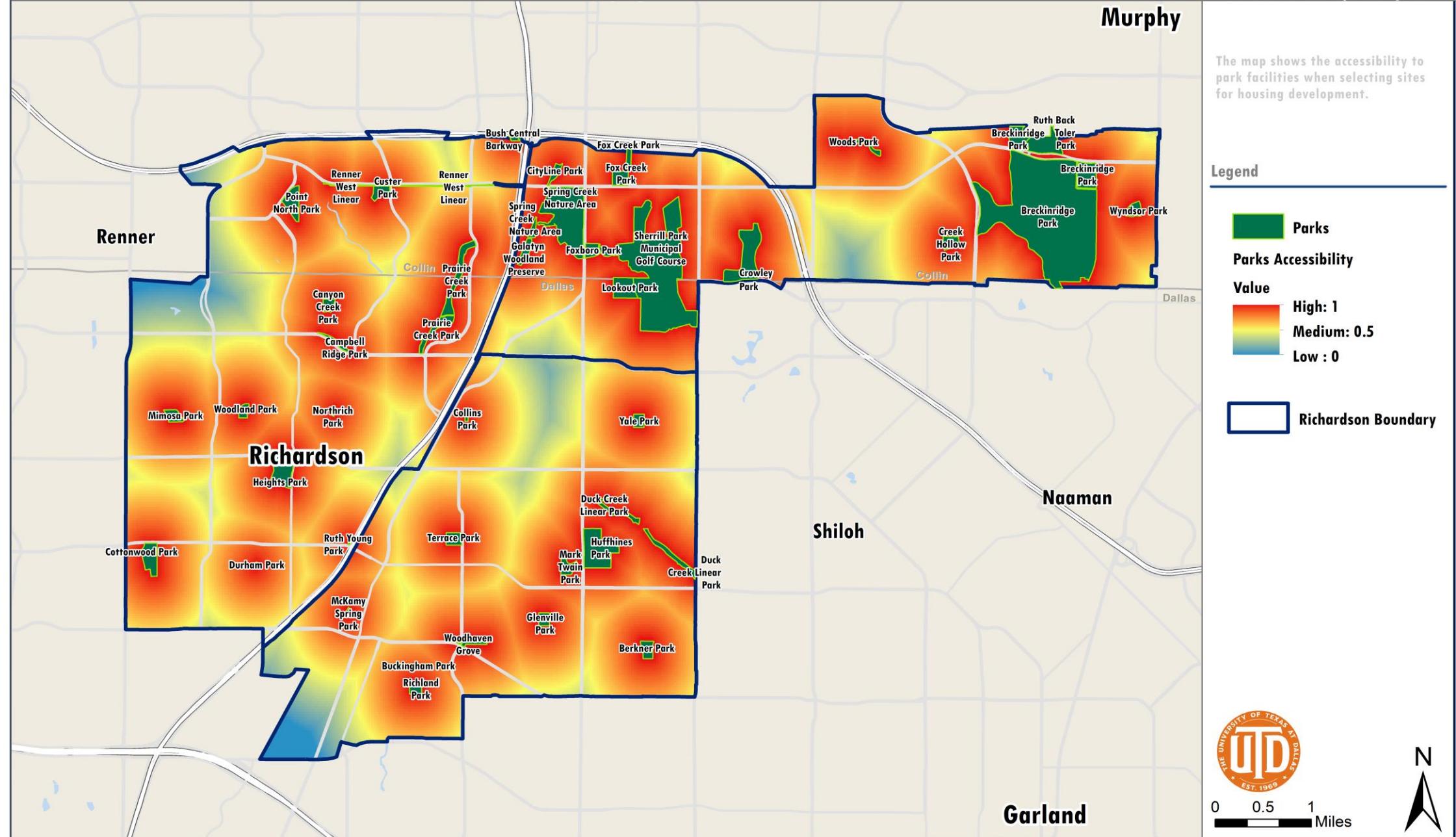
Results & Discussions

What I have obtained?

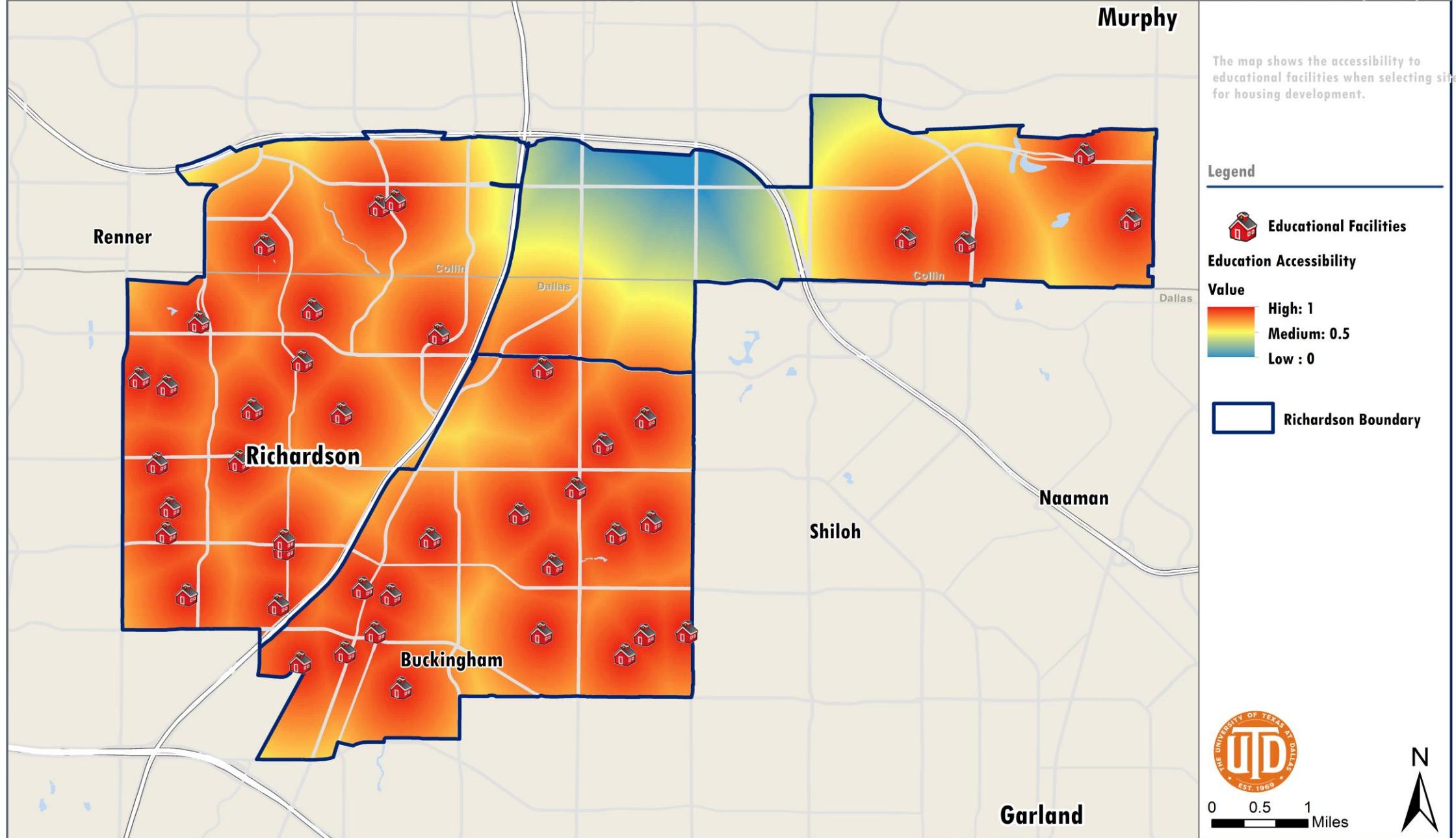








Murphy



Grocery Stores Accessibility Analysis

Murphy

The map shows the accessibility to grocery facilities when selecting sites for housing development.

Legend



Major Grocery Stores

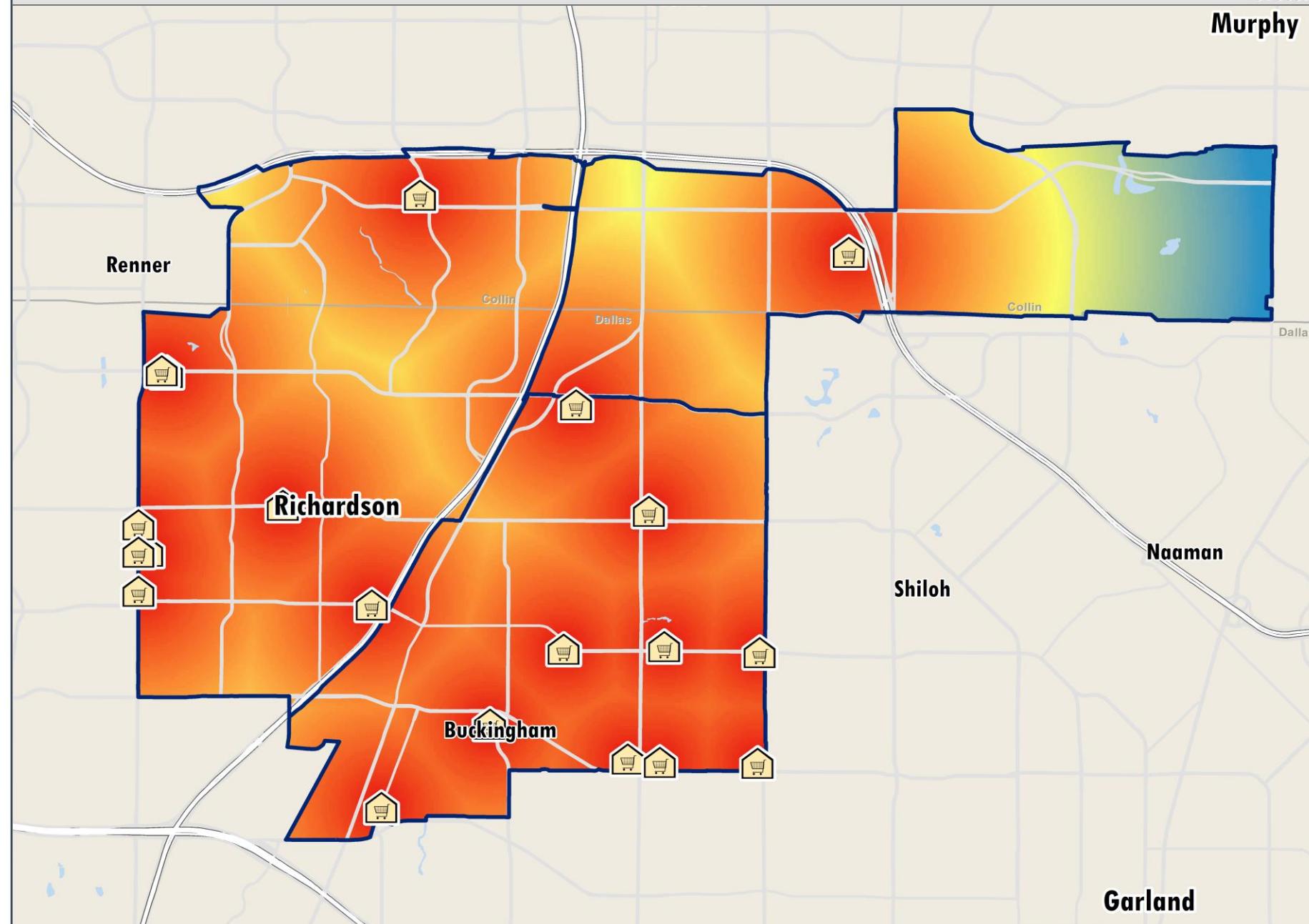
Grocery Stores Accessibility

Value

High: 1
Medium: 0.5
Low : 0



Richardson Boundary



0 0.5 1 Miles

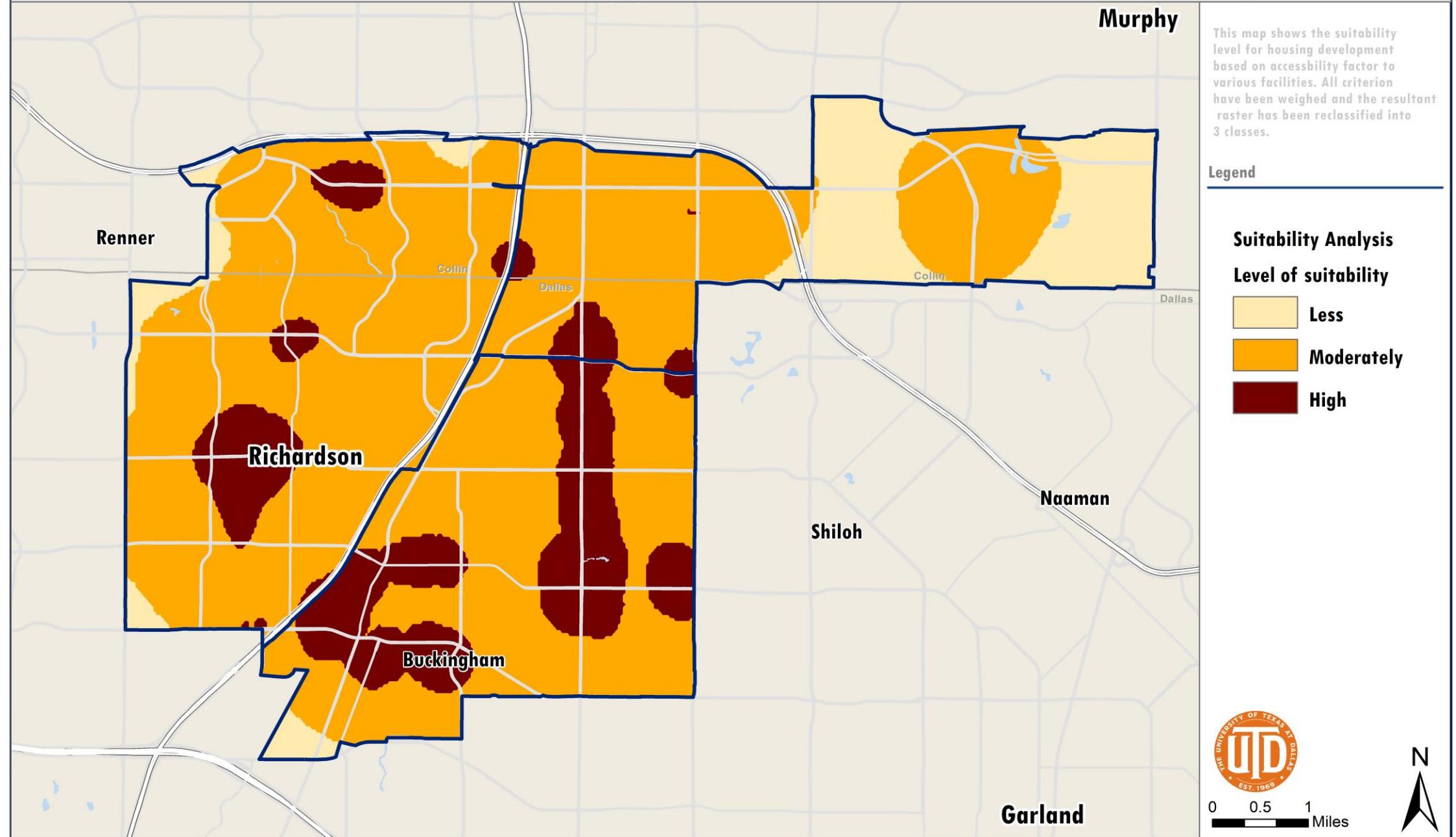
WGS 1984 Web Mercator



Sample Weighing Criterion and CR

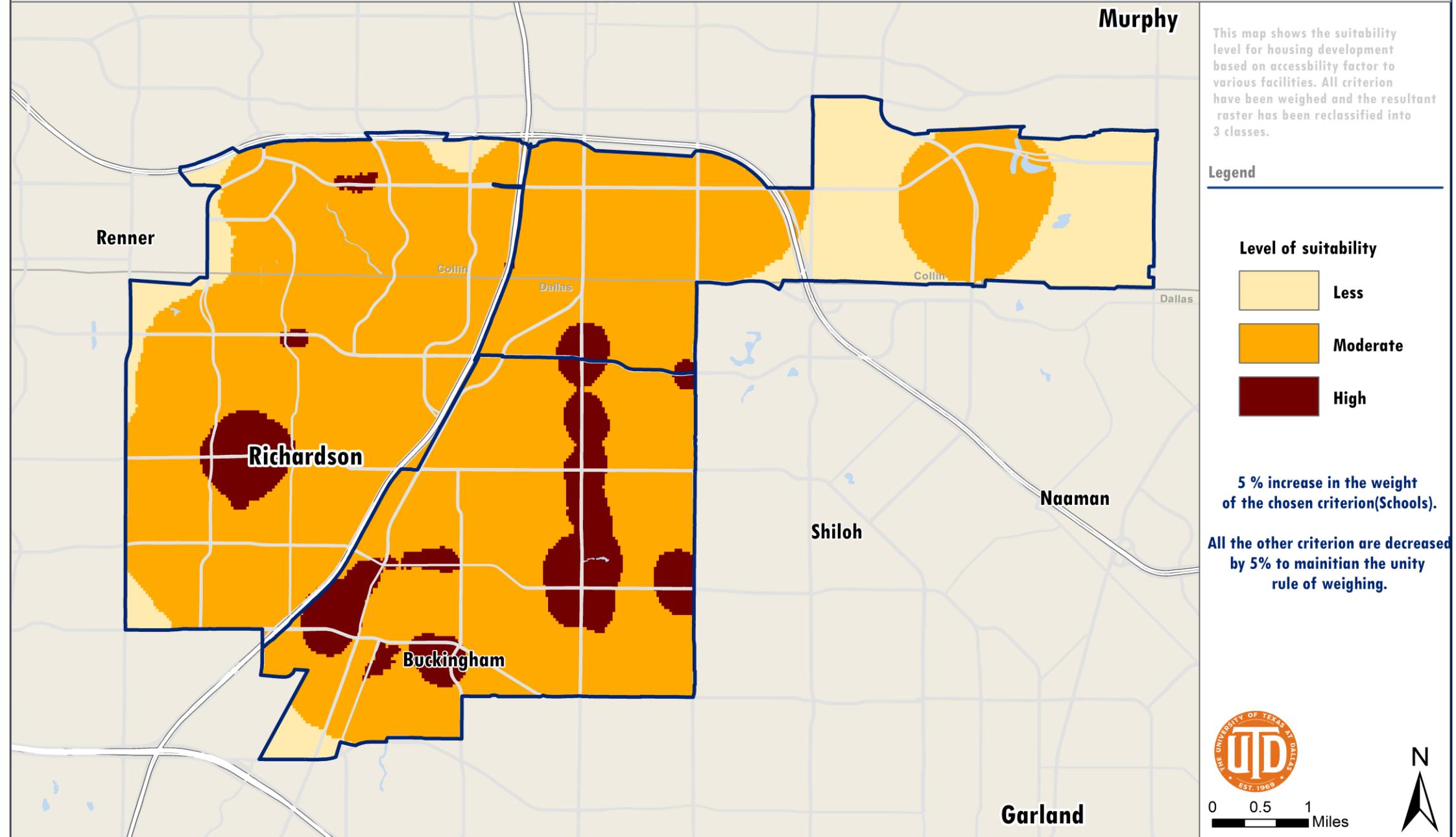
Criterion	Transit	Medical	Fire	Grocery	Parks	School	Weights
Transit	1	3	3	5	7	5	0.381
Medical	0.33	1	3	5	7	5	0.262
Fire	0.33	0.33	1	5	7	3	0.176
Grocery	0.2	0.2	0.2	1	5	3	0.093
Parks	0.14	0.14	0.14	0.2	1	0.33	0.029
Schools	0.2	0.2	0.33	0.33	3	1	0.059

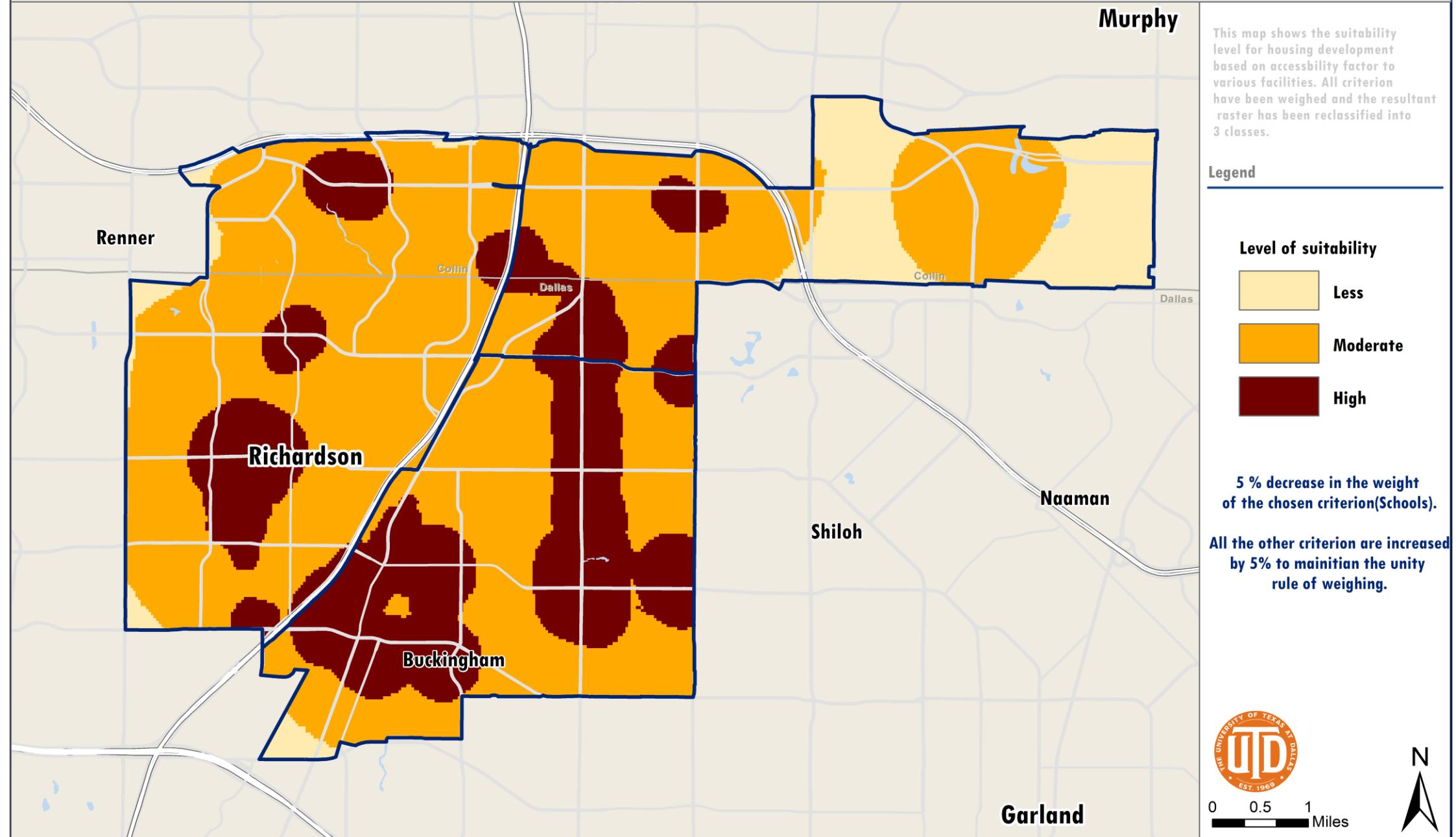
- CR = 0.1 (consistent enough, need not adjust weights again)



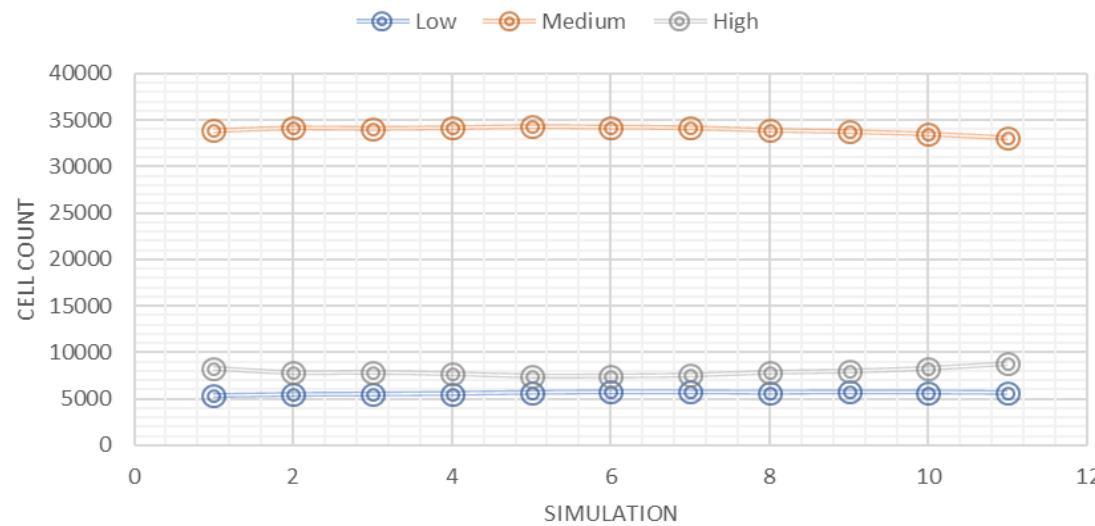
Sample Sensitivity Analysis Result stored as csv

% Change	Transit	Medical	Fire Stations	Grocery	Parks	Schools	Low	Medium	High	Simulation	Total Cells	Low to Medium	Medium to Low	Medium to High	High to Medium	Low to High	High to Low
-5	0.4	0.275	0.185	0.098	0.031	0.043	4915	30494	12049	1	47458	793	0	4563	0	0	0
-4	0.396	0.272	0.183	0.097	0.03	0.046	5088	31483	10887	2	47458	620	0	3401	0	0	0
-3	0.392	0.27	0.181	0.096	0.03	0.049	5220	32208	10030	3	47458	488	0	2544	0	0	0
-2	0.389	0.267	0.18	0.095	0.03	0.052	5339	32802	9317	4	47458	369	0	1831	0	0	0
-1	0.385	0.264	0.178	0.094	0.029	0.055	5544	33692	8222	5	47458	167	3	736	0	0	0
0	0.381	0.262	0.176	0.093	0.029	0.059	5708	34264	7486	6	47458	0	0	0	0	0	0
1	0.377	0.259	0.174	0.092	0.029	0.062	5829	34848	6781	7	47458	0	121	0	705	0	0
2	0.373	0.257	0.173	0.091	0.029	0.066	5915	35233	6310	8	47458	0	207	0	1176	0	0
3	0.37	0.254	0.171	0.09	0.028	0.07	6068	35785	5605	9	47458	0	360	0	1881	0	0
4	0.366	0.251	0.169	0.089	0.028	0.074	6218	36375	4865	10	47458	0	510	0	2621	0	0
5	0.362	0.249	0.167	0.088	0.028	0.079	6300	36746	4412	11	47458	0	592	0	3074	0	0

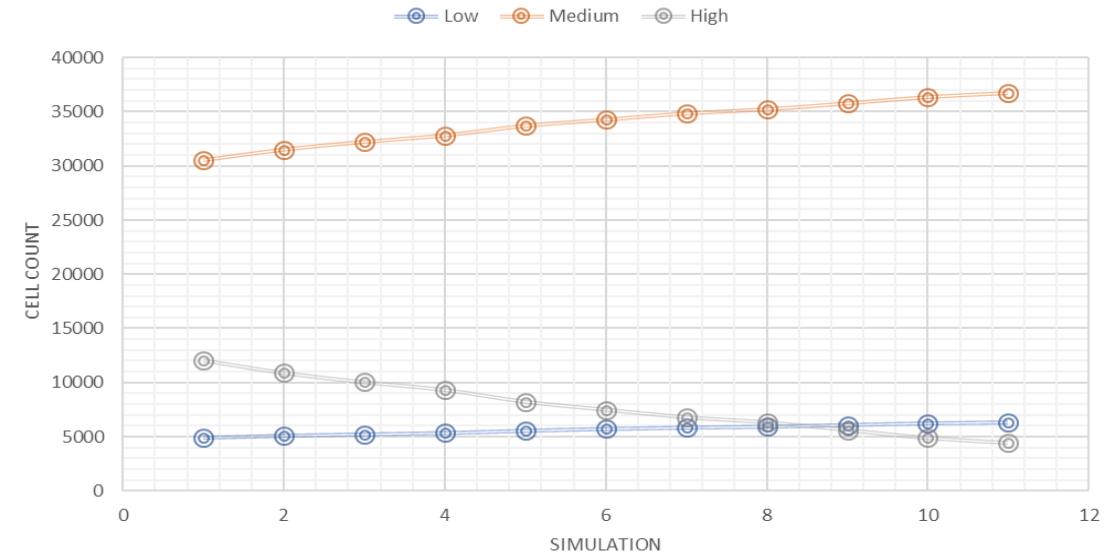




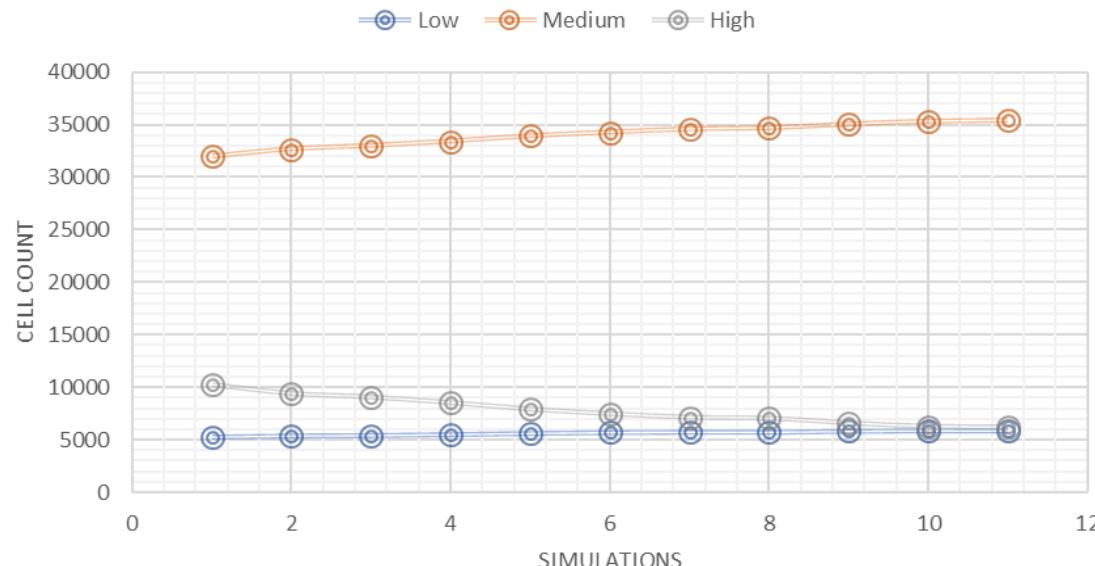
Accessibility Trend for Fire Stations



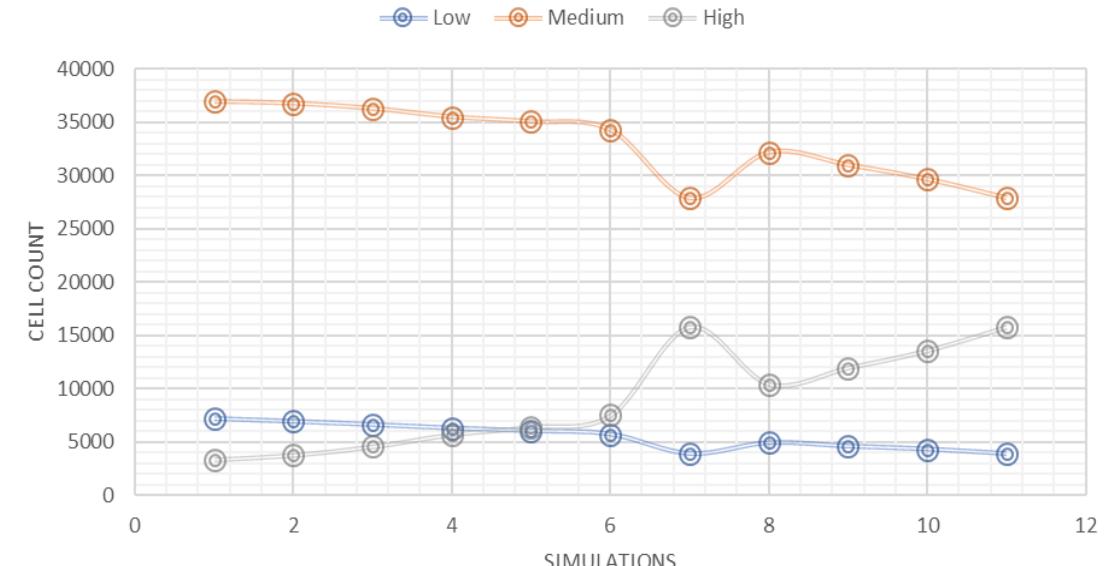
Accessibility Trend for Schools



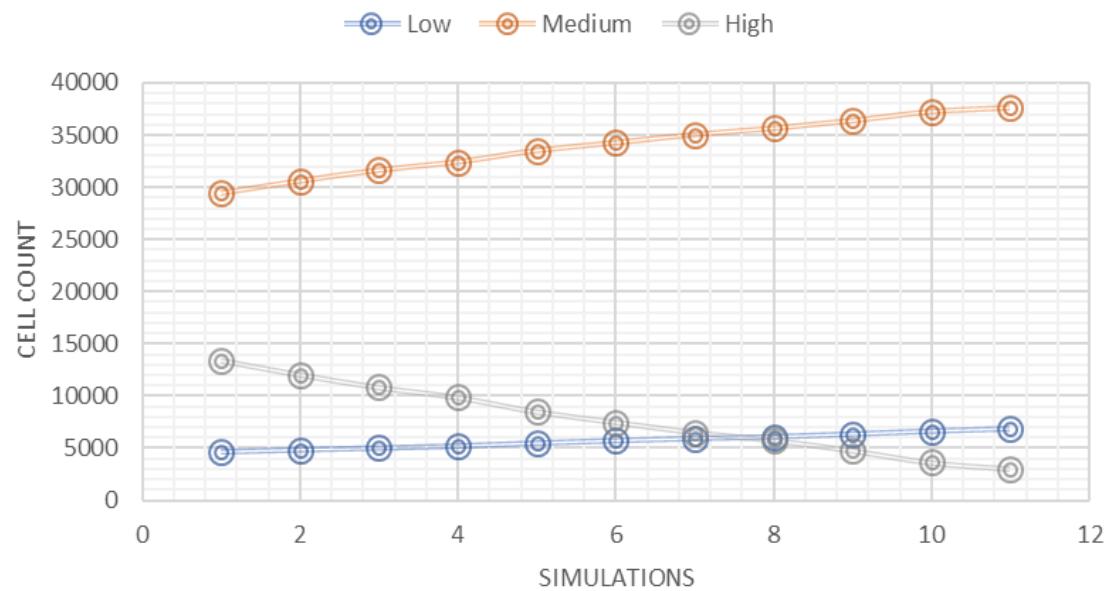
Accessibility Trend for Grocery Stores



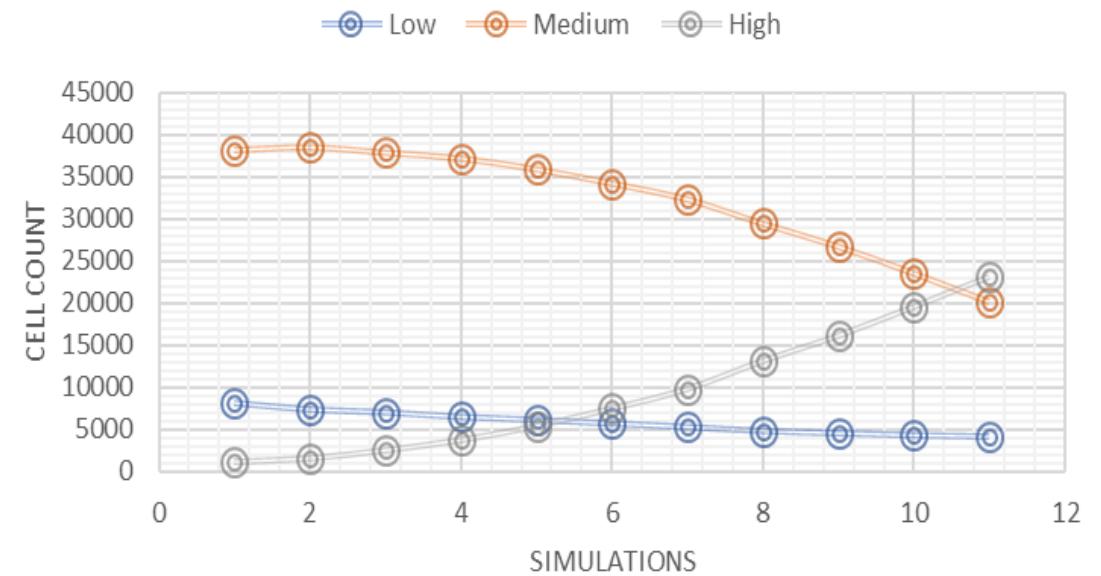
Accessibility Trend for Medical Facilities



Accessibility Trend for Parks



Accessibility Trend for Transit Facilities



- Total Simulations : 60
- Simulation for each criterion : 10
- 6th Simulation : Base run (0% weight change)
- 1st Simulation : -5% weight change
- 11th Simulation : +5% weight change

Note: Medium refers to moderate in the maps

Some key observations:

- Cells increased/decreased more than one suitability level : 0
- Highest Sensitivity : Transit and Medical
- Lowest Sensitivity : Parks and Schools
- Highest variation occurred in “Medium” and “High” class suitability.
- Dramatic increase in their cell count within +/- 5% change.
- Medium and High : Most sensitive to criteria weight changes. Cell exchange observed.
- Base run reclass result :
 - 16% - Highly Suitable
 - 72% - Moderately Suitable
 - 12% - Less Suitable

Conclusions and Future Findings

What I have done so far and what will be done in future?

Conclusions and Limitations

- A generalized decision model was created which can be applied to any theme.
- An automated Spatial MCDA with AHP interface was developed which was embedded into latest desktop GIS unlike the outdated applications.
- Packaged all customization into a single compressed file (.esriAddInx).
- Can share easily without the need of any side installations .
- What-if analysis was performed and results were analyzed when there is an increase or decrease in the weights of the criteria considered.
- To refine the areas which have higher suitability, we have to compare with land-use and land cover

Future Works

- Plug and Play interactive reclassification extension – Real Time Suitability
- Make the add in to be integrated into open source GIS packages like QGIS, GRASSGIS.
- Automatic graph generator using MS Graph API – Detect % suitability change with single click.
- Multi -core processing speed improvisation - High Quality Rasters.
- Find out how suitability varies by using other distance types like network, cost in the automation for AHP process.
- Utilize other MCDA methods for performing this analysis and compare them.
- Receive critical inputs from SME and Urban Planners about Housing site selection based on accessibility.

References

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- <https://docs.microsoft.com/en-us/dotnet/csharp/>

Thank you all!!!

Queries??