

Filling the Gaps in the Mile High City

Analyzing infill development suitability in Denver, Colorado

Urban infill, a key tenant of green urban design, intends to promote development of vacant or underused lots in urban cores to increase urban density and reduce environmental externalities associated with sprawl. The City of Denver stands to benefit greatly from urban infill development because of its extremely low metropolitan density and resultantly high negative environmental impact due to persistent car-dependency. Forever a city conscious of the natural world around it, urban infill development is vital to a sustainable future for the mile high city.

Background: defining infill suitability

The concept of directing new development to already dense, built up areas is relatively new in the American history of urban expansion, and is just exiting its phase as a radical idea. What research as been done thus far on infill as a specific development technique, however, has done well to indicate a few key requirements for success building to densify urban areas:

- I. Pre-existing levels of density: infill development is most effective in reducing negative environmental externalities when it is located in areas with existing high levels of local amenities.
- II. High diversity of local land uses: infill intends to reduce the need to travel long distances from home to accomplish daily wants and needs.
- III. Flexibility in zoning codes: infill sites are more likely to be developed for mixed-use purposes that will continue to support land use diversity if zoning codes are already flexible when development is intended.
- IV. Access to alternative, sustainable methods of transit: infill intends to reduce reliance on automotive transit by locating within range of reliable alternatives.
- V. Proximity to nature and biophilia: infill developments have been seen to be more effective if they provide residents access to the natural resources they would expect out of a suburban setting.
- VI. Geographic sustainability: like all developments, infill has a greater potential for success if build out of floodplains and other geographically unsuitable areas.

Infill development is frequently used as well to as a means of cleaning up past brownfield sites and redeveloping current “greyfield” sites - underutilized, impervious spaces in urban cores. As the City of Denver suffers from a dearth of surface parking and abandoned lots in its urban core, this analysis has specifically focused on grading vacant, underutilized and brownfield sites in its analysis.

Methodology: grading with LEED-ND

To create a model for analyzing the suitability of brownfield and greyfield sites for infill development, a representative relationship between the variables had to first be formed. LEED for Neighborhood Development, an accreditation program through the U.S. Green Building Council that deals with such variables, was a good source for baseline classifications attributing relative importance to each variable. The relevant LEED-ND credits chosen and their respective point values (adding up to 23) are represented below, alongside the adaptive grading classifications used in the spatial analysis given available data.

LEED-ND credits	Infill analysis variables
7 Access to quality public transit	7 Access to quality public transit
3 Housing and jobs proximity	3 Land use diversity
6 Compact development	3 Compact development: structural
1 Access to Civic and Public Space	3 Compact development: housing
2 Tree-Lined and shaded streetscapes	1 Access to open space
	2 Tree-Lined and shaded streetscapes
21 Total credits possible	21 Total points possible

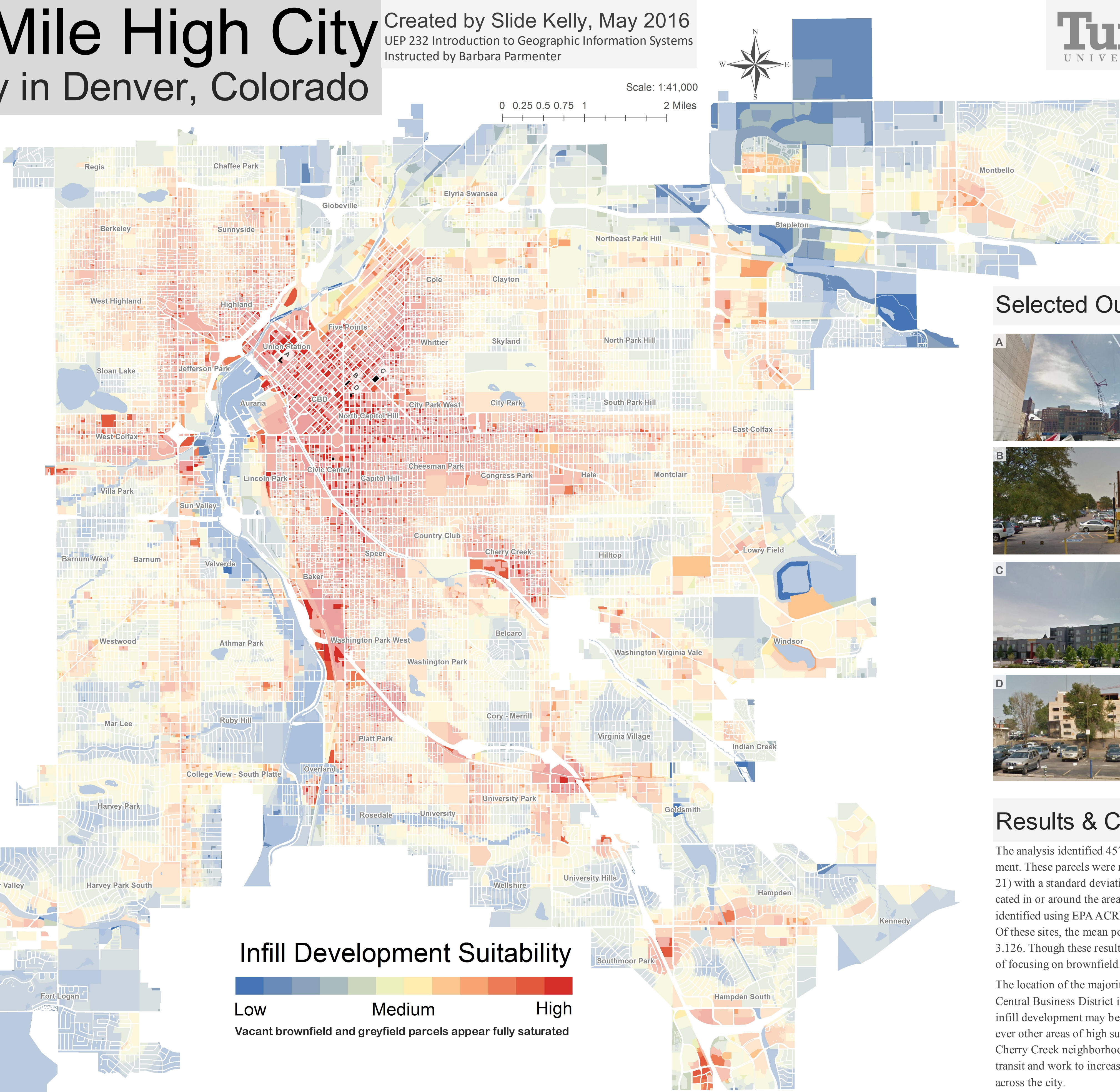
Location in a floodplain generates a null result in both cases



1600 Glenarm Place: A successful infill brownfield redevelopment on 16th street mall: a high density area of the Central Business District.



Rendering for SugarSquare: an infill development planned in LODO (Lower Denver) to fill a narrow slot next to the historic Sugar Building (left). Courtesy of blog.denverinfill.com.



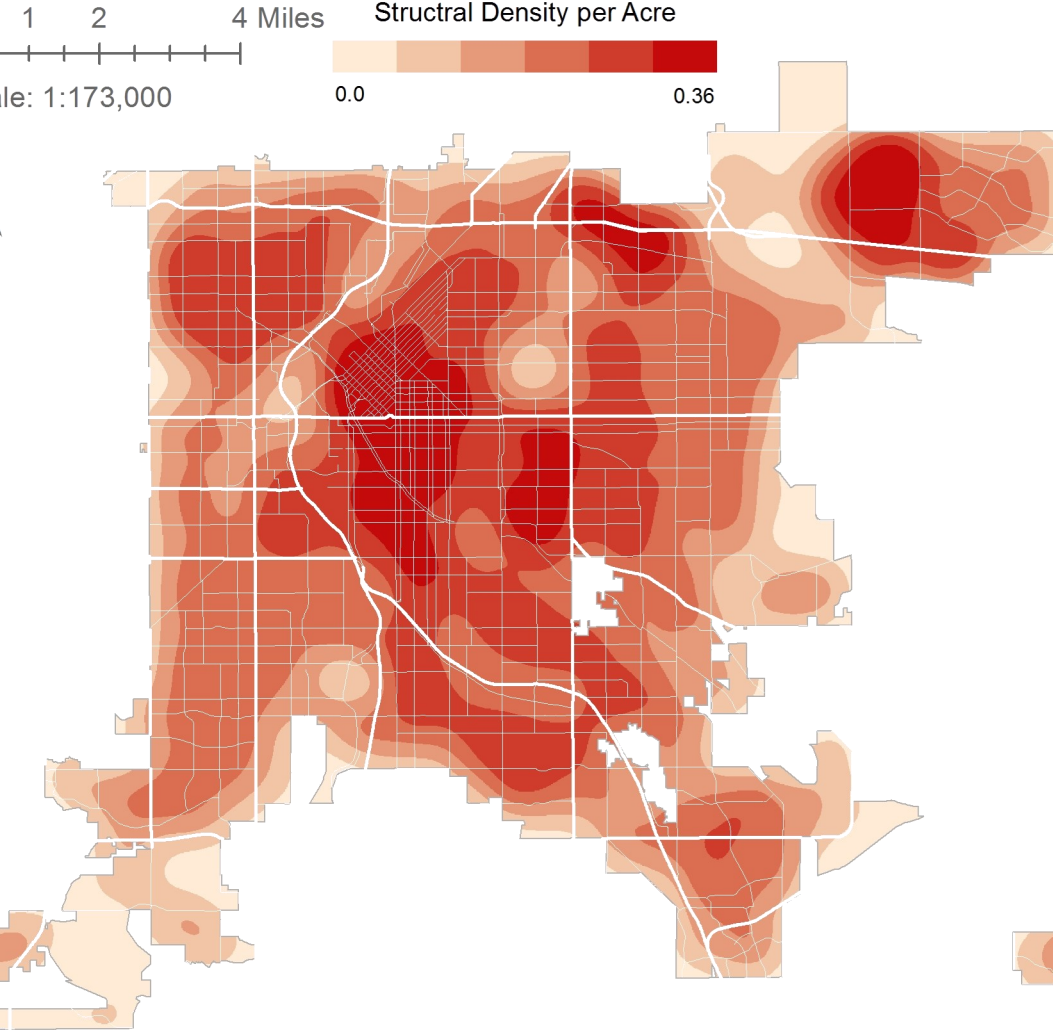
Infill Development Suitability

Low Medium High
Vacant brownfield and greyfield parcels appear fully saturated

Analysis: geo-spatial suitability models

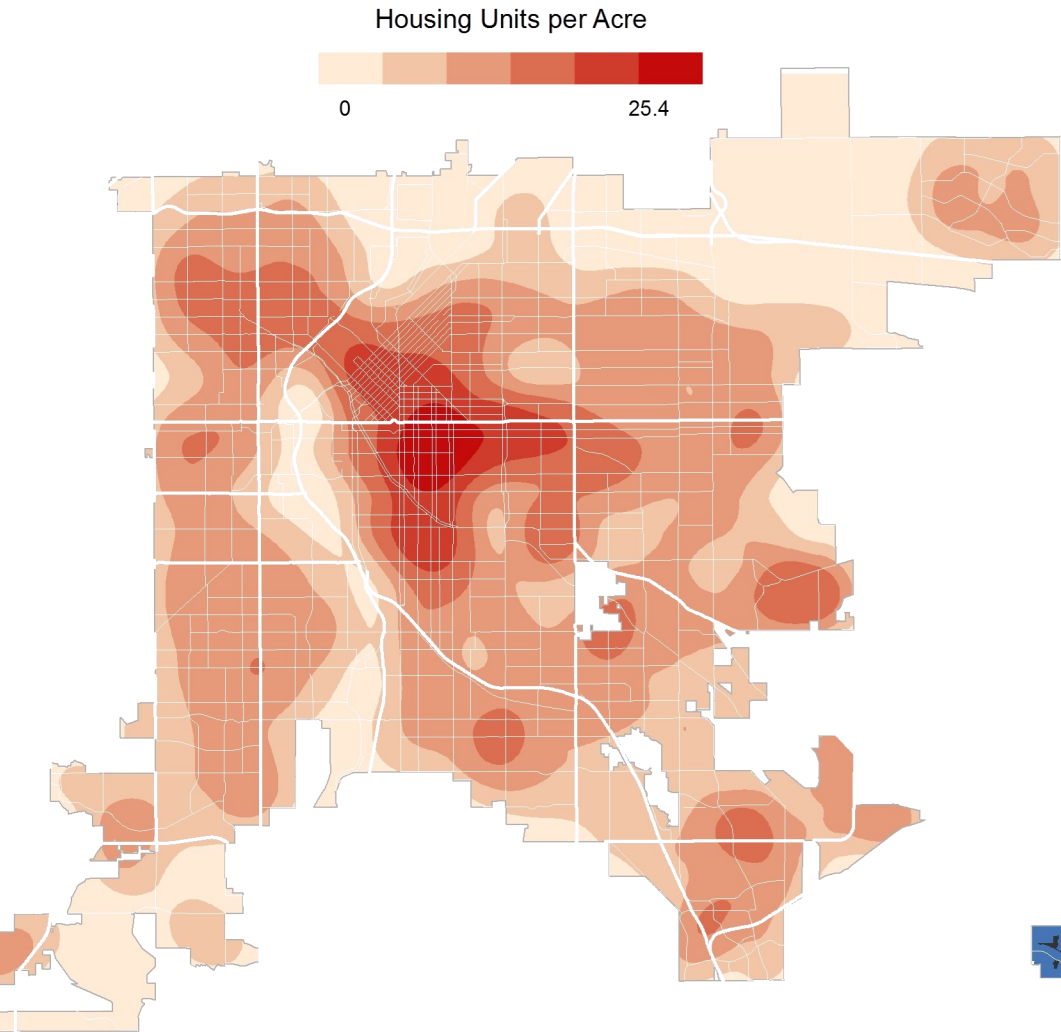
Compact Development: Structural Density

LEED-ND requires certain floor-area ratios (FAR) for non-residential and mixed-use structures to receive points in the compact development credit. Though comprehensive data on multi-story floor-areas could not be retrieved for the City of Denver, a kernel density analysis was done of building footprint data to provide a rudimentary analysis of structural density.



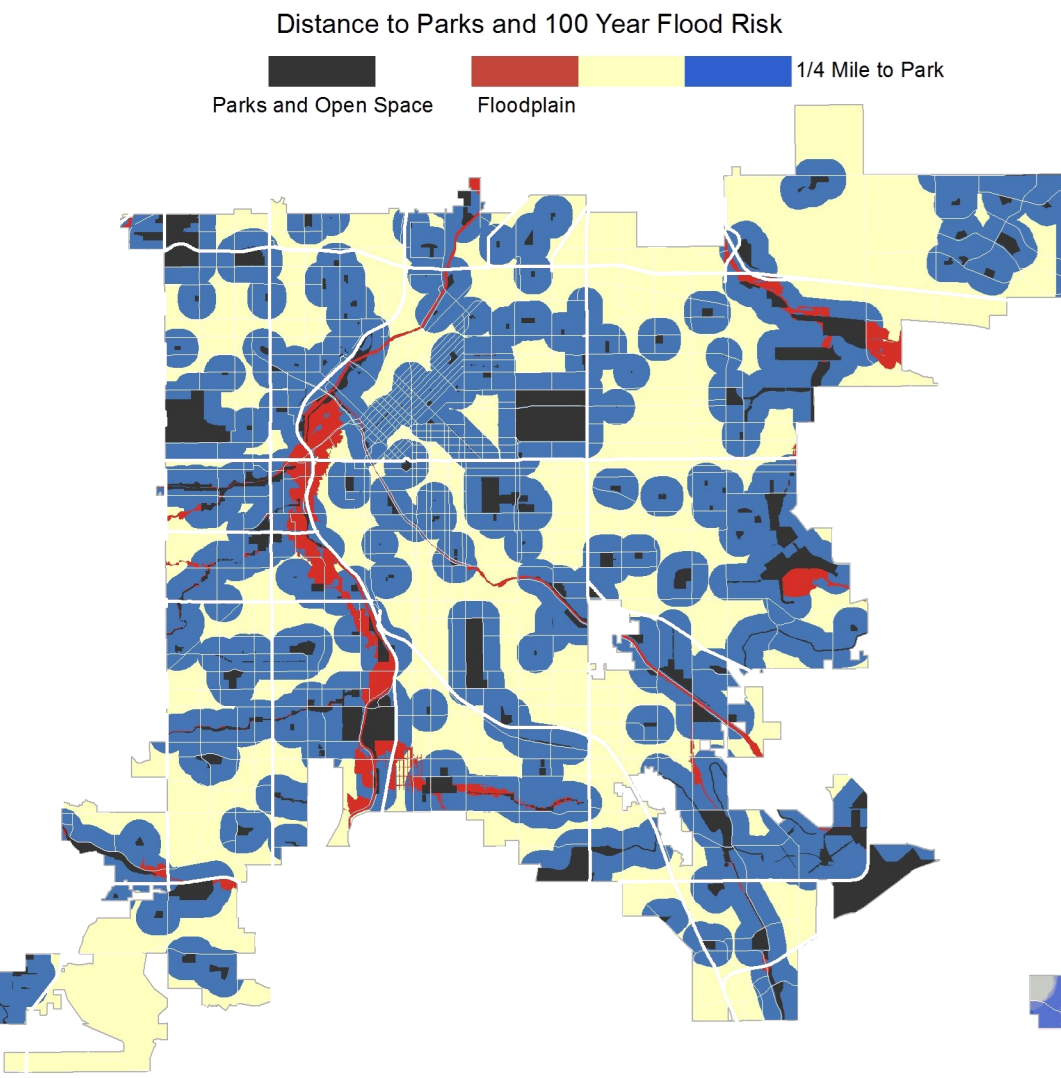
Compact Development: Residential Density

For residential buildings, LEED-ND requires a baseline density of 12 housing units per acre to achieve the required level of accreditation in compact development, with additional credits awarded to greater densities. 2010 US Census block-level data on dwelling units in the City of Denver was used to analyze housing unit densities across the city.



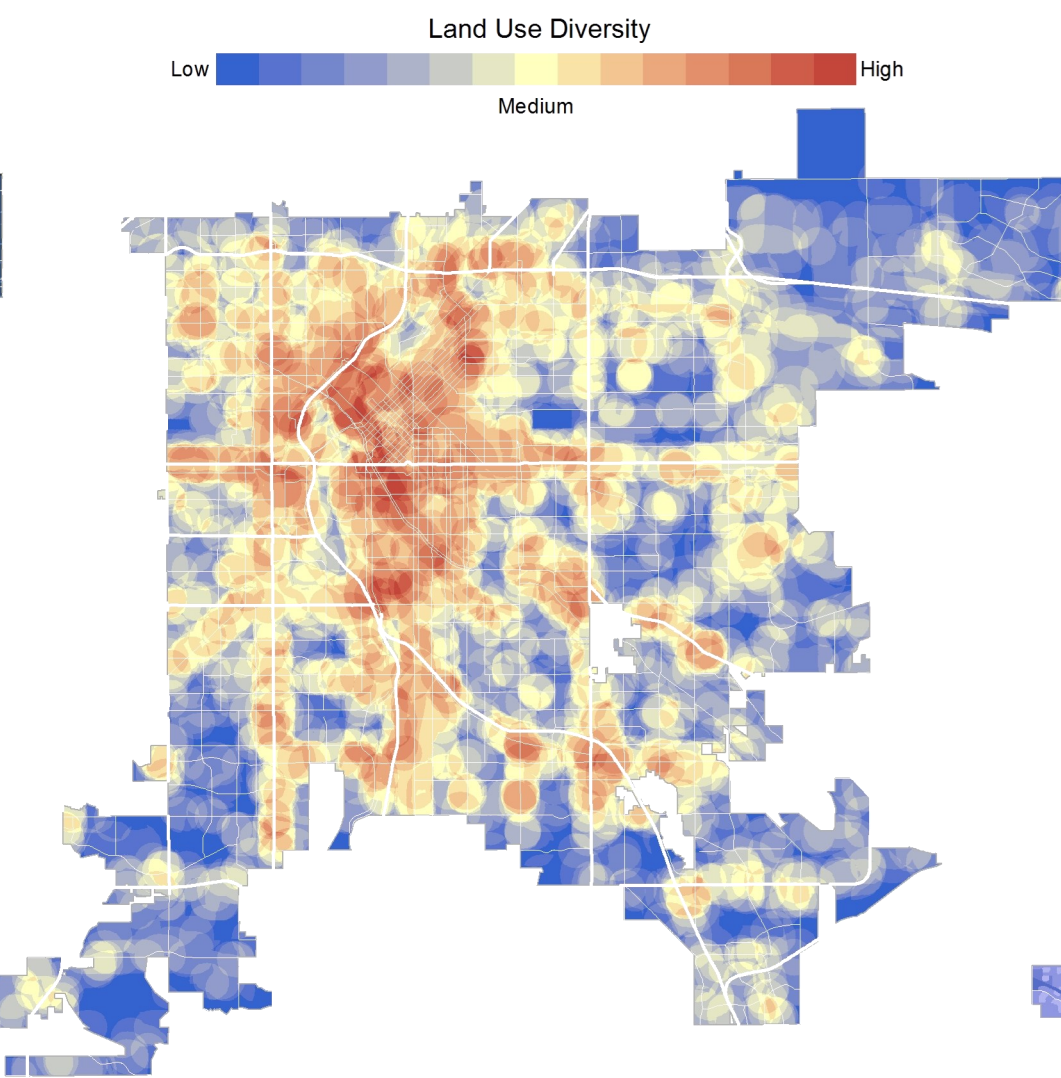
Access to Open Space & Floodplain Avoidance

It is required under LEED ND to build out of floodplains, and a credit is received for developments that build with 1/4 mile of parks and open spaces. In red is the 100 year flood risk (1% annual) in the City of Denver, provided by FEMA, as well as 1/4 mile buffer zones around City of Denver parks and open space data.



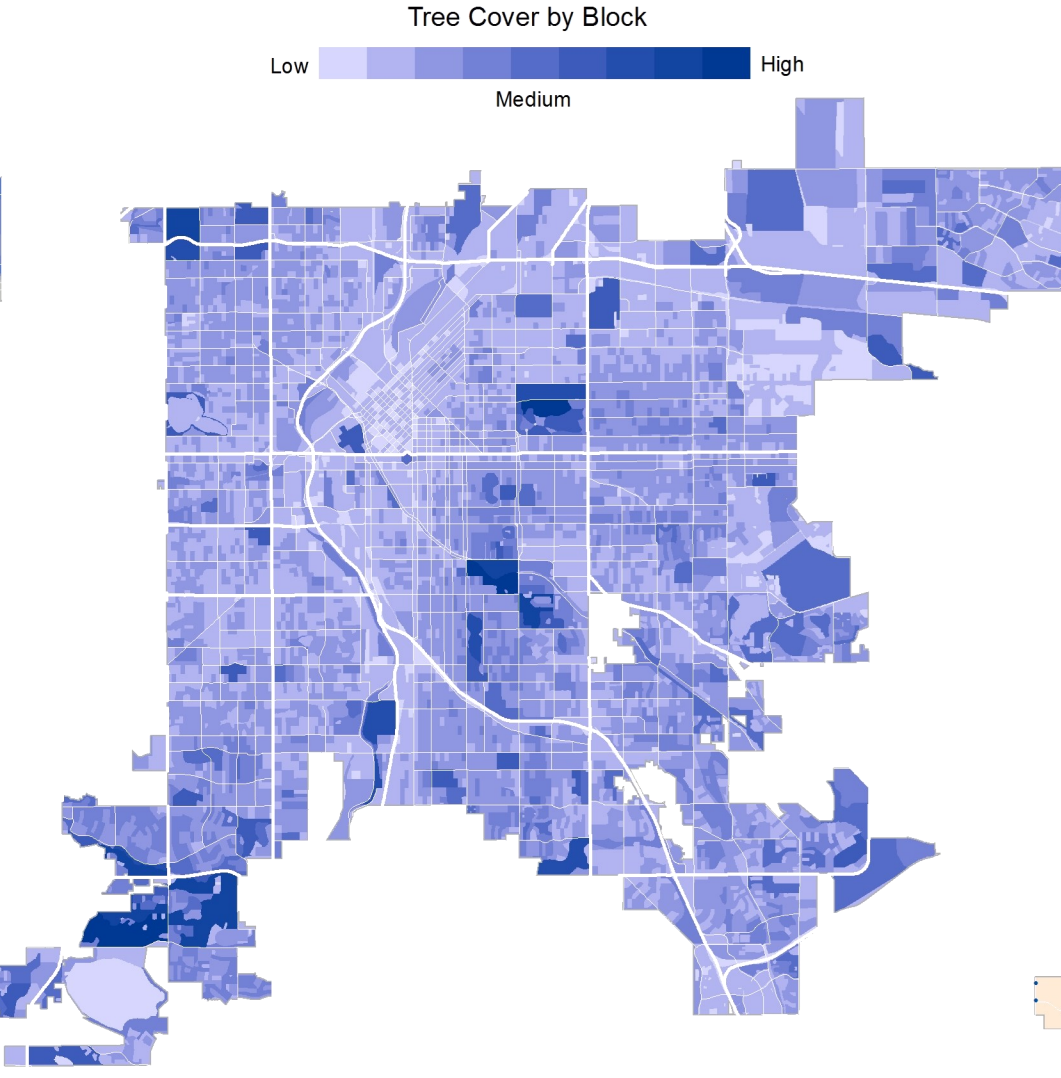
Housing and Job Proximity: Land Use Diversity

Though land use diversity, the amount of uses within a certain range of a site, contributes specifically to the mixed-use quality of a neighborhood, LEED also awards credits for proximity of housing to jobs, which depends on mixed use neighborhoods, access to quality transit, but above all on land use diversity. To measure land use diversity, City of Denver land use data was analyzed for variety of focal statics within a 1/4 mile radius of each city parcel. The results were graded on a scale to 15 to allow for greater variance in effective results, though it only received 3 points in the calculation.



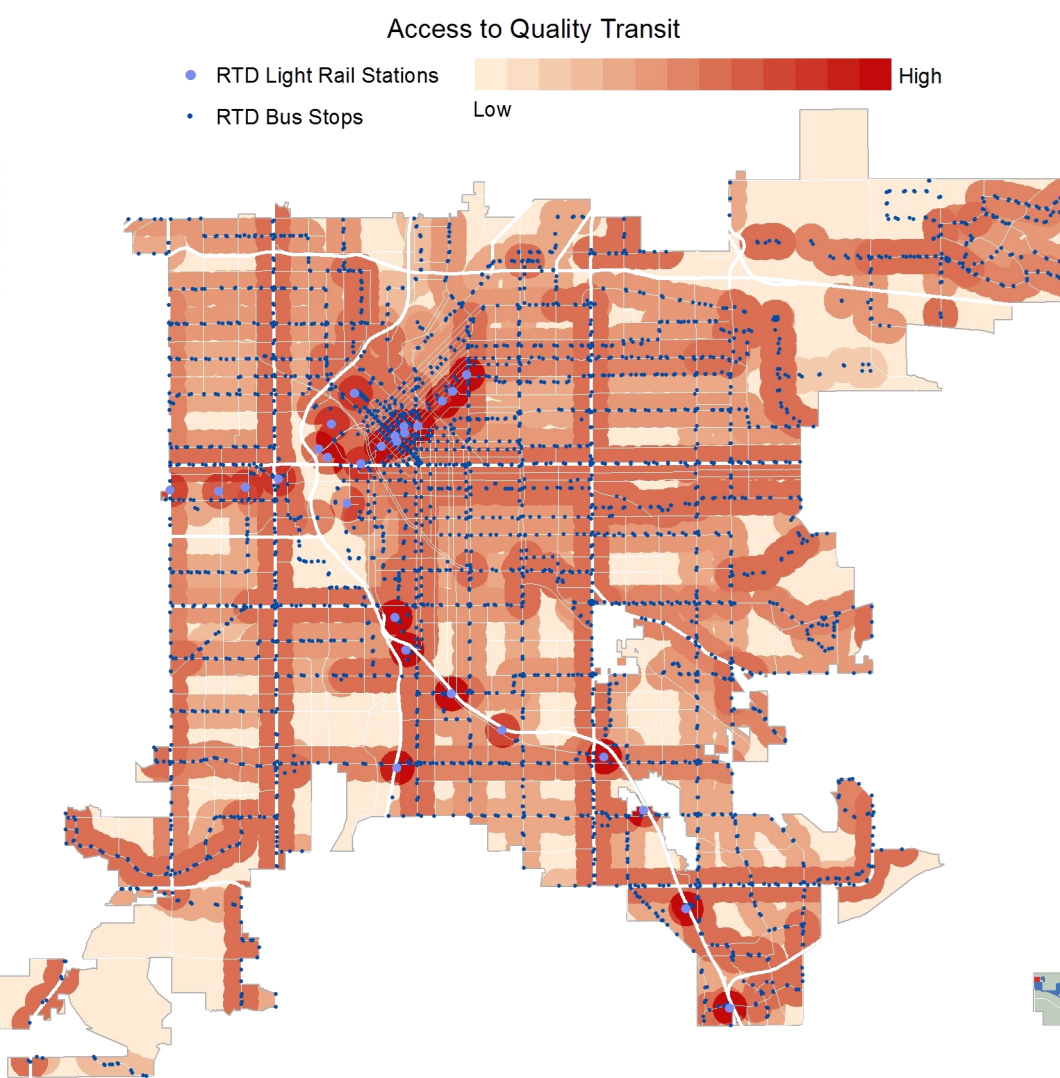
Tree-Lined and Shaded Streetscapes

LEED ND awards credits for development done in locations near tree-lined and shaded streetscapes, however the positive externalities of developing in areas with high levels of urban greenery has been seen to significantly increases the success of the development. To model the presence of urban tree cover in the City of Denver, tree canopy data was used to create a zonal statistic analysis at the 2010 US Census block level. Though this variable was only worth 2 points in the final calculation, the analysis was broke up into 8 parts to allow for more variance in effective results.



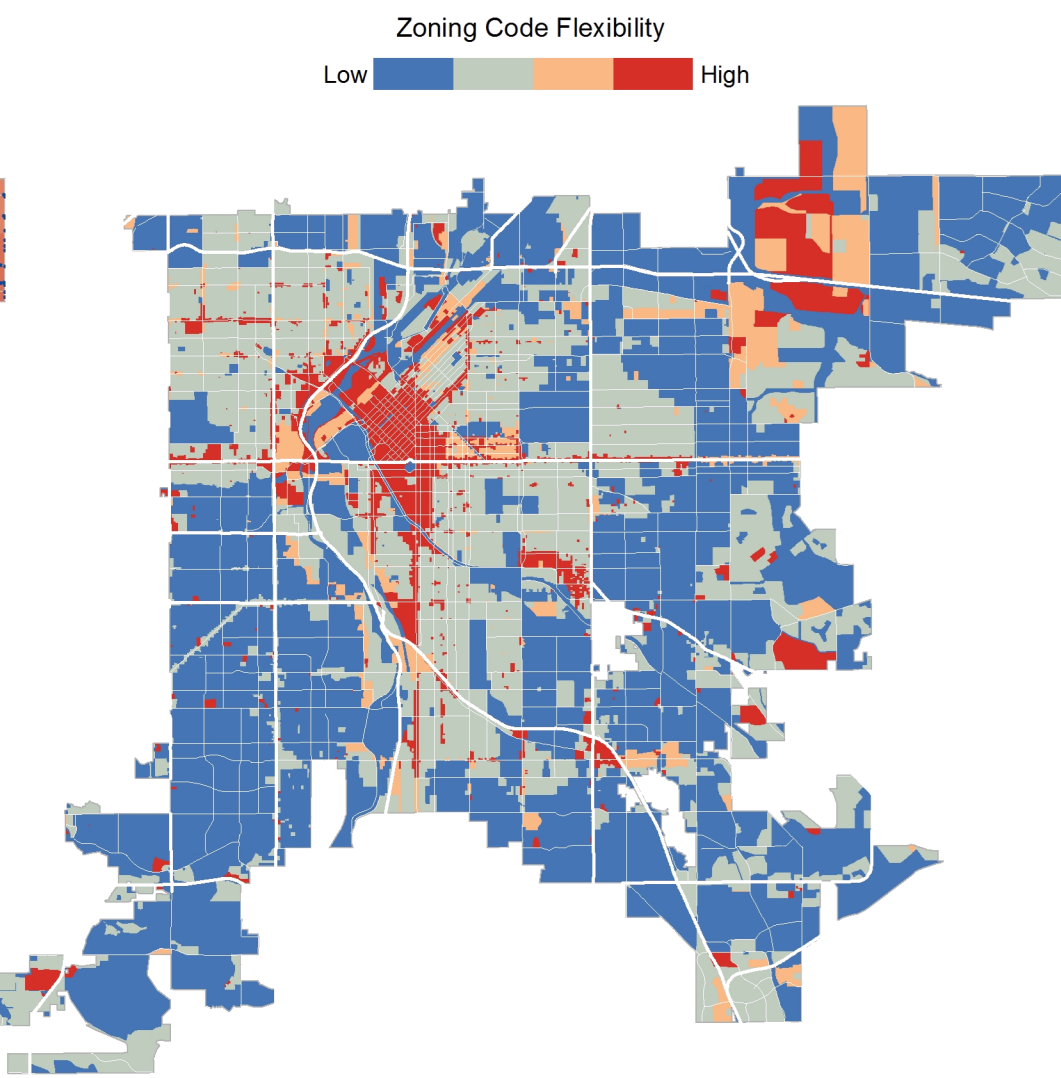
Access to Quality Transit

Access to sustainable public transit is highly valued in the LEED ND accreditation system, and it absolutely fundamental to the success of urban infill developments in highly sprawled cities. Transit accessibly depends both on its location within a walkable range (1/4 mile) and the regularity of service. To analyze sustainable transit in Denver, RTD bus stops and light rail stops were first coded on a scale of 1-7 based upon frequency of weekly service. Then buffer layers for each were created prioritizing distance to service, and finally added to get a final score out of 14.



Zoning Code Flexibility

The potential for multi-use infill development relies greatly on the existing flexibility of the zoning code at the parcel to be developed, and LEED ND awards points for multiple uses within a certain walking distance of a development. To grade zoning code flexibility, City of Denver zoning data was coded subjectively into 4 categories based upon perceived flexibility, prioritizing “Main Street” and “Mixed Use” classifications and zoning categories, such as “Urban Core” and “Downtown,” that allowed for the greatest levels of urban density.



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Data and Sources

Data:	Scholarly and web resources:
OpenColorado: http://opencolorado.org/	Abdullah, S. & Pradhan, B. (2015). Sustainable brownfields and new change modeling using GIS-based weight-of-evidence approach. <i>Applied Spatial Analysis and Policy</i> , 9(1), 21-38. doi:10.1007/s12061-015-0191-5
US Census Bureau: http://www.census.gov/	Kyria, M., Kahlis, M., & Boberg, A. (2010). Perceived environmental quality as an input to urban infill policy-making. <i>URBAN DESIGN International</i> , 16(1), 19-35. doi:10.1080/1360191.2010.49
Base Flood Elevation (FEMA.gov): https://www.fema.gov/bfe-basins-data	Nyssen, P., & Gluck, S. (2014). Understanding infill: Towards new policy and practice for urban regeneration in the established urban of Australia's cities. <i>Urban Policy and Research</i> , 32(2), 121-143. doi:10.1080/08911146.2013.877889
EPA - Geospatial Data Download Service: http://www.epa.gov/geospatial/data-download-service	Thomas, M. R. (2002). A GIS-based decision support system for brownfield redevelopment. <i>Landuse and Urban Planning</i> , 58(1), 7-23. doi: 10.1016/s0169-2046(01)00229-8
RTD Denver - Developer Resources: http://www.rtd-denver.com/Developer.shtml	Gottgens know LEED Neighborhood development (U.S. Green building council, 2014, January 13 Retrieved April 16, 2016)
CDOT Online Transportation Information System: http://cdotgis.coloradodot.net/foia	

Selected Outcomes

A 	Location: 16th & Wynkoop Neighborhood: Union Station/LODO Score: 18.13 (out of 21) Status: Brownfield Current condition: Under construction for FirstBank commercial/office development.
B 	Location: 20th & California Neighborhood: Five Points Score: 20.35 (out of 21) Status: Greyfield Current condition: Paid surface parking.
C 	Location: Tremont & Parker Ave. W. Neighborhood: Five Points Score: 18.20 (out of 21) Status: Brownfield (past) Current condition: Redeveloped and current site of Denver Urban Land Institute.
D 	Location: 1950 S. Lincoln St Neighborhood: North Capital Hill Score: 20.35 (out of 21) Status: Greyfield Current condition: Surface parking.

Results & Conclusions

The analysis identified 4578 vacant or underutilized parcels suitable for infill development. These parcels were normally distributed with a mean point value of 11.448 (out of 21) with a standard deviation of 3.723, with the greatest amount of high-value parcels located in or around the area of Denver’s central Business District. Of these parcels, 75 were identified using EPA ACRES brownfield data to be current or remediated brownfield sites. Of these sites, the mean point value was 12.582 (out of 21) with a standard deviation of 3.126. Though these results were similarly distributed, these findings reinforce the benefit of focusing on brownfield sites for the infill development of vacant urban parcels.

The location of the majority of highly suitable potential sites in and around the Denver’s Central Business District indicate that maintaining relative levels of monocentricity with infill development may be most beneficial to the growth of the city in the long run. However other areas of high suitability such as Washington Park West, West Colfax and the Cherry Creek neighborhood indicate that with continued investment in reliable public transit and work to increase zoning flexibility, Denver can benefit from filling the gaps across the city.