The Walkability Indicator: A Case Study of the City of Boulder, CO

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Abstract:

Walkability is a measurement of the quality of pedestrian space. Our goal was to create an indicator of walkability and find evidence that improving walkability will alter the distribution of pedestrian traffic in the area. Theories of walkability assume that pedestrian demand is elastic and design interventions will increase the number of pedestrians, thus encouraging active transportation improving public health while discouraging use of automobiles. This concept describes urban planners' ability to increase pedestrian traffic by improving walkability in the built environment.

For this research, Walkability scores were collected for streets and pedestrian paths within the study area. The scores were input to GIS (Geographic Information Systems) and analyzed to produce a walking experience map from a sample origin point. Several design scenarios were tested by changing segment scores and comparing the results to existing conditions. Results suggest that walkability and pedestrian demand is not necessarily elastic. When walkability is improved, it alters the distribution of likely pedestrian traffic rather than increase the total number. This finding describes a scenario where specific design interventions will pull pedestrians from other areas rather than increase pedestrian traffic overall.

Keywords: urban planning, walkability, elasticity, sustainability, GIS, geographic information systems

Project History:

As many cities become increasingly demanding of natural, human and economic resources, urban planners are seeking ways to link their policies to real sustainable outcomes. In an environment where comprehensive planning can be abstract and difficult to quantify, it is important for planners to understand the practical outcome of their goals and objectives. The city of Boulder, Colorado currently has the intention of creating a system of sustainability indicators to link their comprehensive plan policy to its practical effects. The city planning department published its most recent comprehensive plan in 2010 with an expression of core values in a sustainability framework and described its intention to develop indicators to "measure progress in the health and well-being of the community, environment and economy" (BVCP 2010).

Among its core values the comprehensive plan describes several components of sustainability, which the department wishes to manifest in its planning and decision making processes. The components of sustainability describe a city which is: compact, complete, connected, distinct, inclusive, green and attractive (BVCP 2010). These six components are rather broad in their descriptive capacity and the City of Boulder planning department wishes to define and quantify these components as a part of their sustainability indicators project. In order to do this, the planning department teamed with the University of Colorado in hopes of utilizing students' creativity and knowledge to generate sustainability indicators. Students formed groups to address the demands of the sustainability indicator project and the walkability indicator group was created to measure the connected and complete components of sustainability.

The City of Boulder selected its downtown civic center park as the study area for this experiment. The civic center park is located in the center of the city and is home to great social diversity, as well as a diversity of land uses. Boulder Creek divides the study area and contains a significant amount of protected wetlands. A major transportation corridor, known as Canyon Street also divides the study area, running almost parallel to Boulder Creek. The study area as well as its location in Boulder, Colorado is shown in **Figure 1** below.

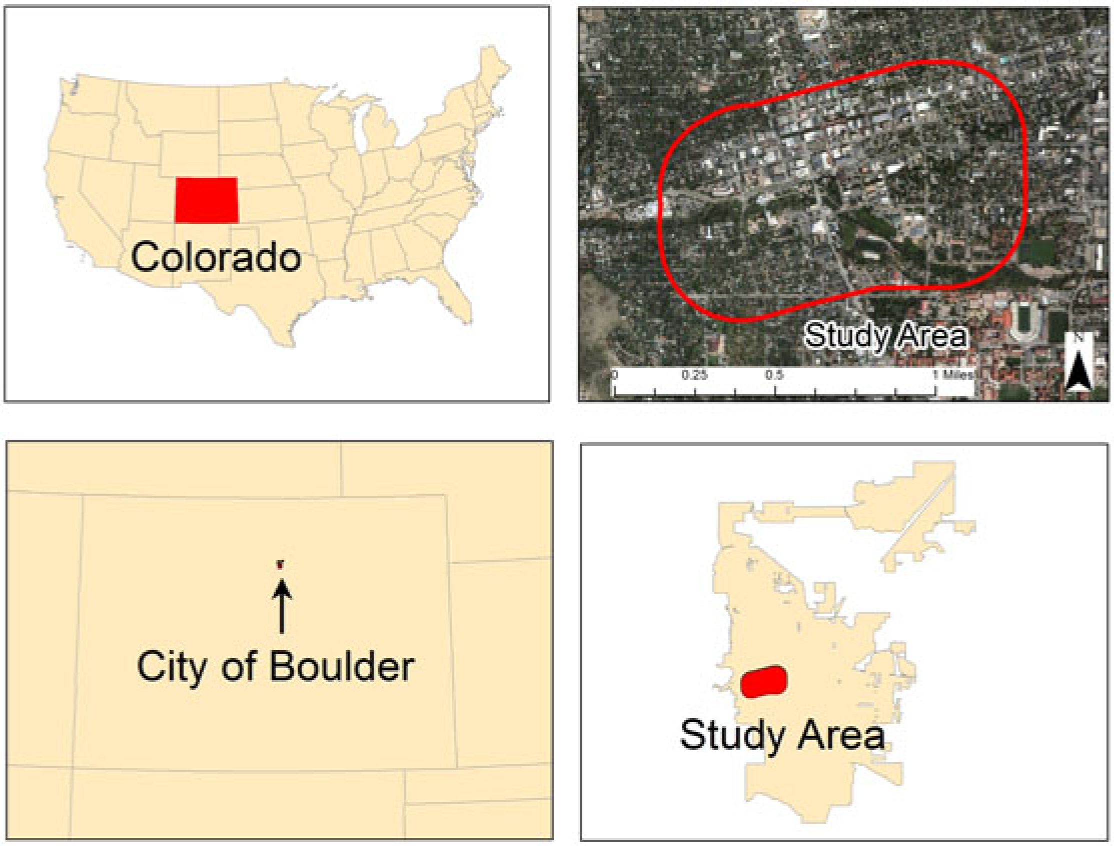

Figure 1: Civic center study area in Boulder, CO U.S.A.

Walkability:

The concept of walkability has been gaining the attention of many professionals and researchers in the field of urban planning and design. The term itself is broad and can be interpreted on different scales and used to describe different phenomenon. One useful definition of walkability is that it is a measure of the extent to which characteristics of the built environment and land use are conducive to neighborhood residents walking for either leisure, exercise, to access services, or to get to work. (Leslie et al., 2005) One scale of walkability describes the neighborhood as a whole and includes an understanding of large scale transportation networks that provide accessibility for pedestrians from one location to another. (Park 2008) Another scale of walkability defines the quality of design of paths on the street scale (Park 2008). A common theme in walkability is that it focuses on the qualitative and quantitative attributes of pedestrian space. For the purpose of this research, we have qualitatively evaluated the walkability of paths at the street level. Upon evaluation of street scale design, we performed a spatial analysis on a series of design scenarios to understand the network effect of improving individual paths. The network analysis of design scenarios allows for a quantitative observation of the neighborhood effects of improving individual block design.

Walkability and pedestrian oriented design have two primary connections to sustainability. pedestrian activity and active transportation have been related to lower Body Mass Index (BMI) in individuals and reduced air pollution through reduction of vehicle miles traveled. (Frank et al., 2006). Several other studies linking active transportation to public health were documented by Sallis et al. in 2004. The studies surveyed by Sallis et al. demonstrated relationships between active transportation and BMI, cholesterol and risk of mortality (Sallis et al. 2004). Based on the review of literature surrounding walkability and public health, it was decided that increased walkability and promoting active transportation was a worthwhile outcome of sustainable policy related to the connectivity and completeness of public spaces.

Elasticity:

The concept of elasticity is commonly used in many fields to describe the relationship between two variables. In general, elasticity is described as “the ratio of the percentage change in one variable associated with the percentage change in another” (Ewing and Cervero 2010). A recent study performed by Ewing and Cervero involved a meta-analysis of transportation planning literature to understand existing knowledge of the elasticity of multiple phenomenon related to transportation and the built environment. By examining existing literature, Ewing and Cervero found that walking and pedestrian travel have been tested with regards to their relationship with density, diversity, design, destination accessibility and distance to transit. The elements of the built environment found to have the most significantly positive relationship with walking were land-use mix, distance to destinations and intersection design/density. Several of the attributes that were measured, such as intersection design and land use mix, can be considered qualities of a walkable environment. A more recent study aimed at identifying transportation elasticities performed by the Victoria Transportation Policy Institute describes a positive elasticity between non-work walking trips and land use density, mix and intersection density (Litman 2012). From the comprehensive study performed by Ewing and Cervero as well as the recent findings of the Victoria Transportation Policy Institute, we concluded that current literature describes a positive elastic relationship between walkability and pedestrian demand.

Methodology:

Upon gaining an understanding of walkability and the characteristics of a walkable environment. A survey method was developed to collect data on key streets within the civic center study area. The survey was conducted using a score sheet on which walkability group members could rate walkability for each block within the study area. The score sheet criteria was gathered from a review of current concepts of pedestrian oriented design in landscape architecture, architecture and urban design as well as a review of Cook's examination of design quality indicators of the built environment and public health. (Cook 2010) Our walkability score sheet qualifies pedestrian space according to five criteria. The criteria are; Sidewalk Physical Qualities, Safety, Vegetation, Urban Design and Social Quality. A full description of the survey criteria is displayed by the survey score sheet in **Figure 2**.

Walkability Indicators **Observer:**

Segment: **Date:** **Start time:**

☐ Town Core ☐ Residential ☐ Commercial ☐ Mixed ☐ Other

		Poor (1pt)	Average (2pt)	Excellent (3pt)
Sidewalk physical qualities	1. Condition/Maintenance of path along this segment is well kept.			
	2. Path Material on this segment is attractive. (Brick or Stone path) 3pt, (Concrete path) 2pt, (No sidewalk or same path material as roadway) 1pt			
	3. Width of a walking path. Width over 8ft: 3pt, Width 5 - 8ft: 2pt, Under 5ft: 1pt			
	4. Vegetated detached buffer zone between Pedestrian and Roadway that provide separation 3pt, Detached sidewalks or attached planters: 2pt, Attached sidewalks with no buffer: 1pt			
	subtotal			
Safety	5. There is a physical difference between pedestrian and bike lanes: 3pt, There is no pedestrian and bike difference but no conflict: 2pt, Pedestrian and bikers have to make an effort to avoid each other: 1pt			
	6. Noise; Quiet residential area or park: 3pt, Normal conversation at 3ft: 2pt, Busy traffic same as Phone ringtone: 1pt			
	7. Street light; Layout by Pedestrian scale:3pt, Layout by Traffic scale: 2pt, Lack of street lights: 1 pt			
	Subtotal			
Vegetation	8. Street trees are present along this segment. Layout continuously with tree span less than 30ft: 3pt, Relatively continuous layout with tree span 30-45ft: 2pt, Scattered layout with tree span more greater than 45ft: 1pt			
	9. Street trees on this segment providing shade. Continuous shade: 3pt, Patches of shade: 2pt, No shade: 1pt			
	10. There is Public Green Space present on this block including other side of this street. Large green space: 3pt, small green space: 2pt, no green space: 1pt			
	Subtotal			
Urban design	11. Building volumes and setbacks Pedestrian oriented scale: 3pt, Relatively Pedestrian oriented scale: 2pt, Car oriented scale and pedestrian feel isolated or pressured by the building volumes and setbacks: 1pt			
	12. Ground level of building Façade on this segment are attractive to pedestrians; High area of non-mirrored windows and doors exist: 3pt, There are some non-mirrored windows and doors exist: 2pt, feeling of isolation: 1pt			
	13. There are Historical Buildings or buildings that have an Aesthetic design quality.			
	Subtotal			
Social quality	14. General Attractiveness			
	15.Interactive Social Spaces (Ex. Café, park, restaurant); Variety of Social Spaces with several uses in this block including other side of the street: 3pt, At least one Social Space in this block including other side of the street: 2pt, No Social Space: 1pt			
	16. Necessities (Ex. Grocery, convenience store). Variety of Necessities in this block including other side of the street: 3pt, At least one Necessities in this block including other side of the street 2pt, No Necessities: 1pt			
	Subtotal			
	Grand total			

Figure 2: Walkability score sheet

Due to time and resource limitations, the score for each criteria was collected for key blocks and classified to describe the entire site on a scale of one to three. The three score scale represents excellent, average, and poor performance related to the walkability survey criteria. For the purpose of GIS analysis, the scores had to be reversed so that a low score implied resistance to walkability. Excellent paths took low scores and poor paths took on the high values. Thus, after totaling scores for all criteria of a specific path segment, a high score would represent a path with high pedestrian resistance and an experience that feels longer and more strenuous to the pedestrian.

When the walkability score had been collected for each block in the study area, it was input to a GIS. The result of this initial data collection process was an existing conditions walkability score map. The resulting score map is displayed in **Figure 3** below.

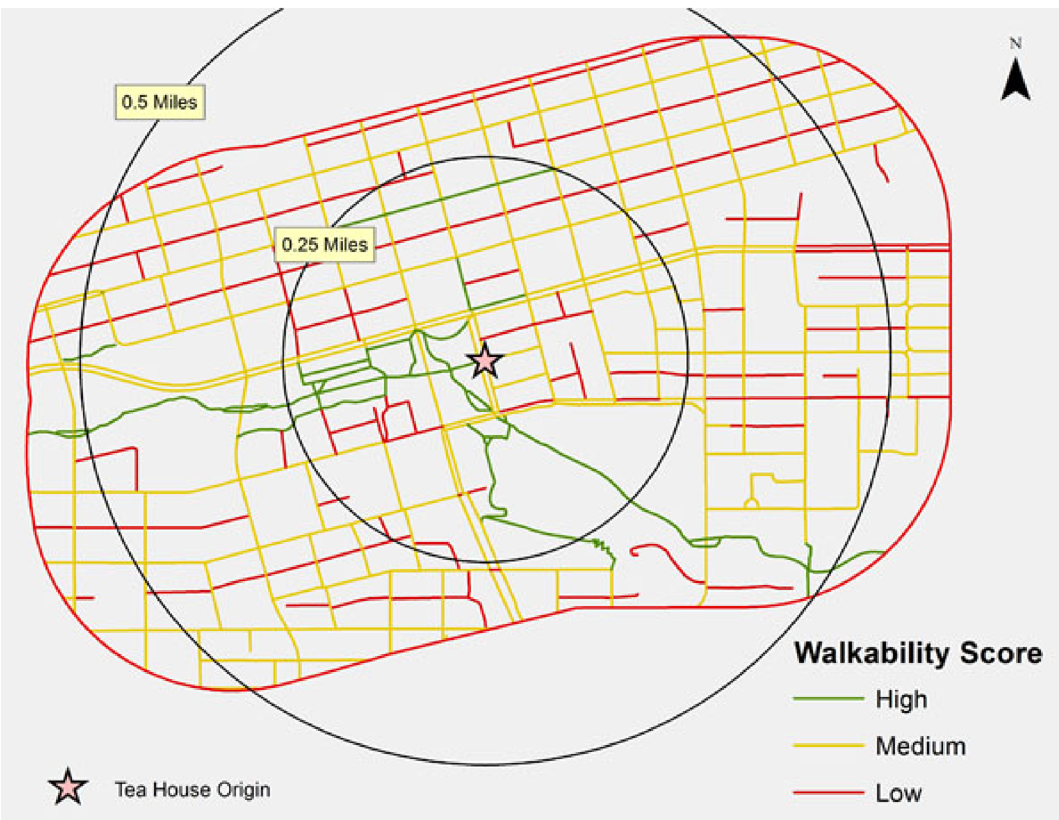

Figure 3: Walkability score map

The scored map serves as a visual indicator of the quality of walkability for the civic center study area. By itself, this map result provides information to planners and designers. It is a representation of the quality of pedestrian design at the individual block scale. The qualitative street scale results were used to analyze neighborhood scale network walkability. The scored map data was input to a GIS spatial analysis to identify walkable regions from a single origin point. A social gathering point near the center of the study area was selected. Using the walkability score as a function of resistance, a cost distance operation was performed to identify areas that a pedestrian may travel within the study area with little resistance. The results define both distance and area that a pedestrian may travel while having the most pleasant and easy experience. A flow chart of the spatial analysis process is displayed below in **Figure 4**.

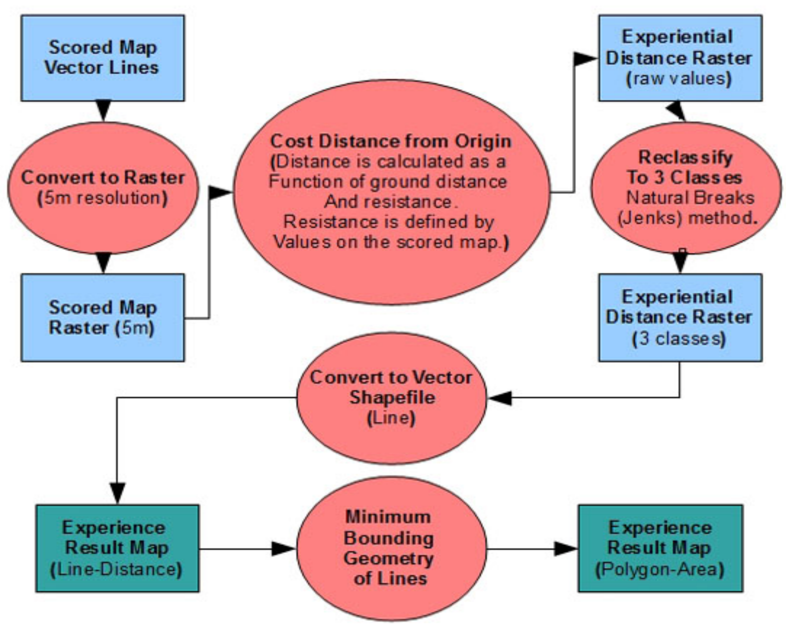

Figure 4: Spatial analysis flow chart

Upon performing spatial analysis on the scored map, a resulting experience map was generated for both area and distance. The resulting data was classified to represent poor, average and excellent network walkability from the origin point. The resulting map provides a visual reference for planners to understand areas that provide good pedestrian experience as well as areas that may need improvement. The path distances as well as the area enclosed by paths were calculated for each class. Area and distance measurements provide a quantitative indicator of walkability within the civic center study area.

In order to test the walkability indicator tool, as well as measure the effect of specific design changes to paths in the study area, a design scenario was created and input into the model. The design scenario was created and analyzed by changing the walkability score for key paths in the score map data. Key path scores were changed to perfect walkability scores which provide the least resistance when input to the spatial analysis model. Following the same analysis process, resulting distance and area maps were analyzed visually and data was recorded quantitatively.

The creation of a scenario result was the end of the intended walkability indicator collaboration project. However upon observation of results which contradict current transportation planning theories of elasticity, further scenario testing was performed. Additional scenarios were input to the spatial analysis model. Four scenarios were created to produce enough data to perform a thorough comparison of results. All scenario results were compared in order to observe whether or not our model demonstrates an elastic relationship between walkability and pedestrian demand.

Results:

The result of the existing conditions map portrays paths and areas within the civic center study area that provide excellent, average and poor walkability from the Tea House origin point. This map is intended to provide planners a visual and quantitative representation of the quality of pedestrian space within the study area. The existing conditions result map is portrayed below in **Figure 5**.

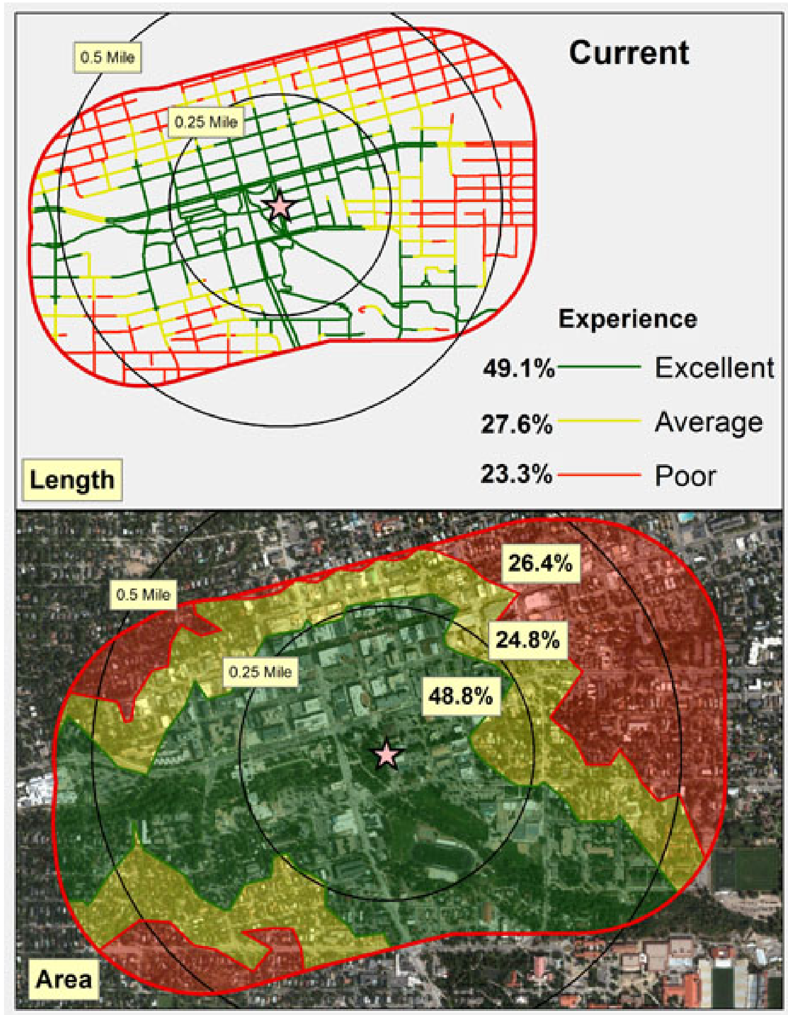

Figure 5: Current condition result map

It was noted that nearly half of the path distances and area within the study area was within an excellent walkable area from the origin. The excellent walking area includes most of the park area, as well as part of the commercial downtown area. Areas with the poor walkability from the origin include the eastern portion of the major transportation corridor, Canyon Street, as well as some of the residential areas in the northeast portion of the study area.

Scenario I incorporated an improvement in walkability along both sides of the western portion of Canyon Street. The location of path improvements to Canyon Street is portrayed in **Figure 6**.

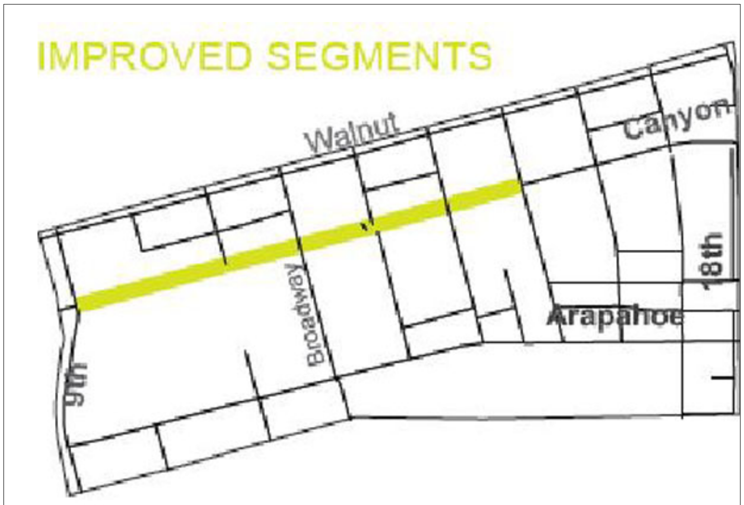

Figure 6: Paths improved for design scenario I

Based on common understanding of elasticity in pedestrian travel demand, it was assumed that improving key path segments of Canyon Street would increase both the path distance and area of excellent walkability from the origin. However, it was observed that the design scenario created slightly less excellent and average walkable areas and increased the distance and area measurements for poor walkable paths from the origin. The resulting walking experience map for Scenario I is displayed in **Figure 7**.

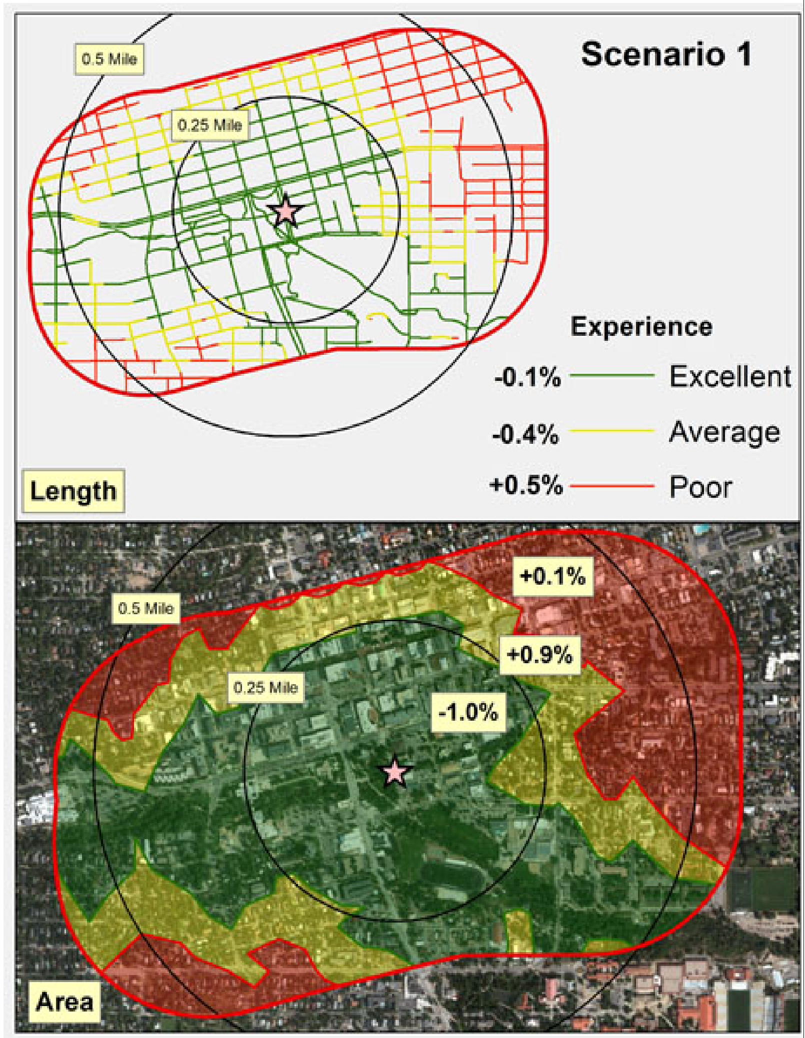

Figure 7: Scenario I result map

The result of Scenario I led us to question the theories of elasticity. We wanted to further test the relationship between walkability and pedestrian demand, and hypothesized that the relationship between walkability and pedestrian demand is not necessarily elastic. It seems that increasing the quality of pedestrian space creates a intensification of pedestrian activity for a specific area, rather than increasing pedestrian demand overall. To help confirm this theory, we developed and tested additional design scenarios with our walkability spatial model.

Scenario II involved expanding the design improvements to the entire length of Canyon Street in our study area. The improved areas for Scenario II are displayed in **Figure 8** below.

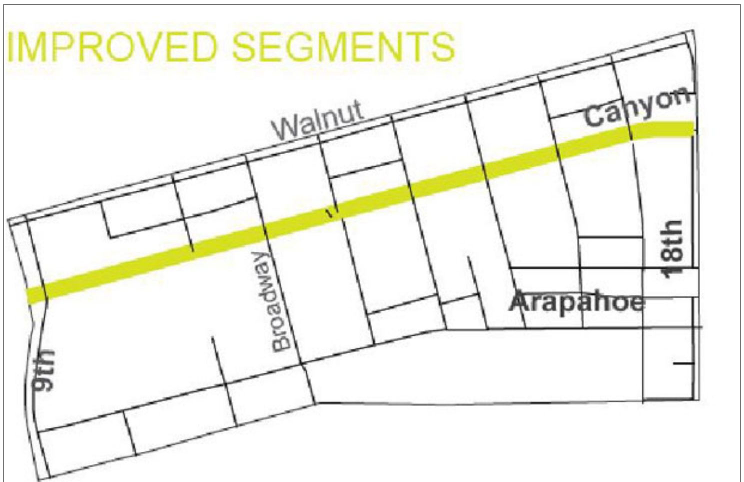

Figure 8: Paths improved for design scenario II

The design improvements represent a significant investment of financial, human and natural resources with the intention of creating more walkable space along Canyon Street. Evidence of an increase in pedestrian demand would be found in an expansion of excellent walking distance and area from the origin. However, when tested by the walkability indicator spatial model, we again observed the opposite result. The resulting area and distance of walkable space is displayed by **Figure 9** below

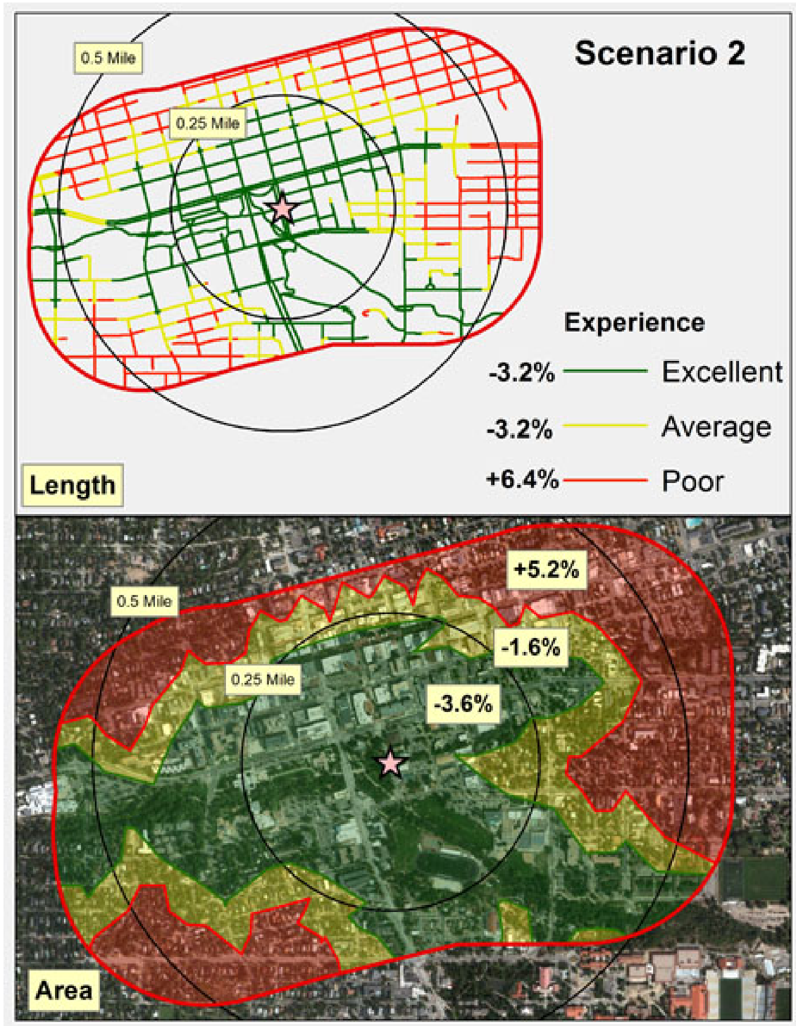

Figure 9: Scenario II result map

The resulting map visually displays a shrinking area of excellent walking area from the origin. It is also apparent that poor walkable areas are encroaching from the edges of the study area. Scenario II produced about 3% less excellent walkable distance and area while increasing the poor walkable distance and area measurements by 6.5% and 5.2%, respectively. This result describes an intensification of walkability near the improved path segments, and a relative loss of walkability for the civic center study area as a whole. Further testing occurred by implementing design improvements in Scenario III.

The paths improved in Scenario III included the segments on Canyon Street improved in Scenario I, as well as improvements along minor streets that intersect Canyon Street perpendicularly. In addition to improvements of existing streets, Scenario III included the development of a new path segment connecting the improved minor streets and running parallel to Canyon Street. The path improvements implemented in Scenario III are displayed by **Figure 10** below.

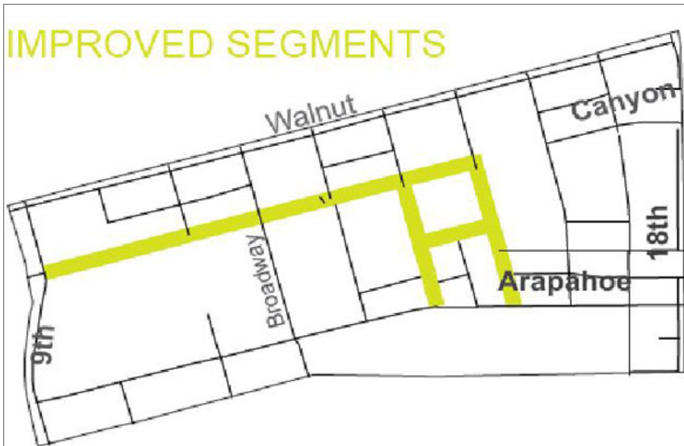

Figure 10: Paths improved for design scenario III

Design Scenario III did not yield a large change in walkable distance or area The excellent walking distance was increased by 1.4% while poor and average areas were decreased by 0.5% and 0.9% respectively. The results of Scenario III suggest that, despite a large investment in pedestrian and network infrastructure, there was not a great increase of walkable area or distance. This result is consistent with our hypothesis that pedestrian design and demand is not necessarily elastic. The results of the Scenario III analysis are displayed by **Figure 11**.

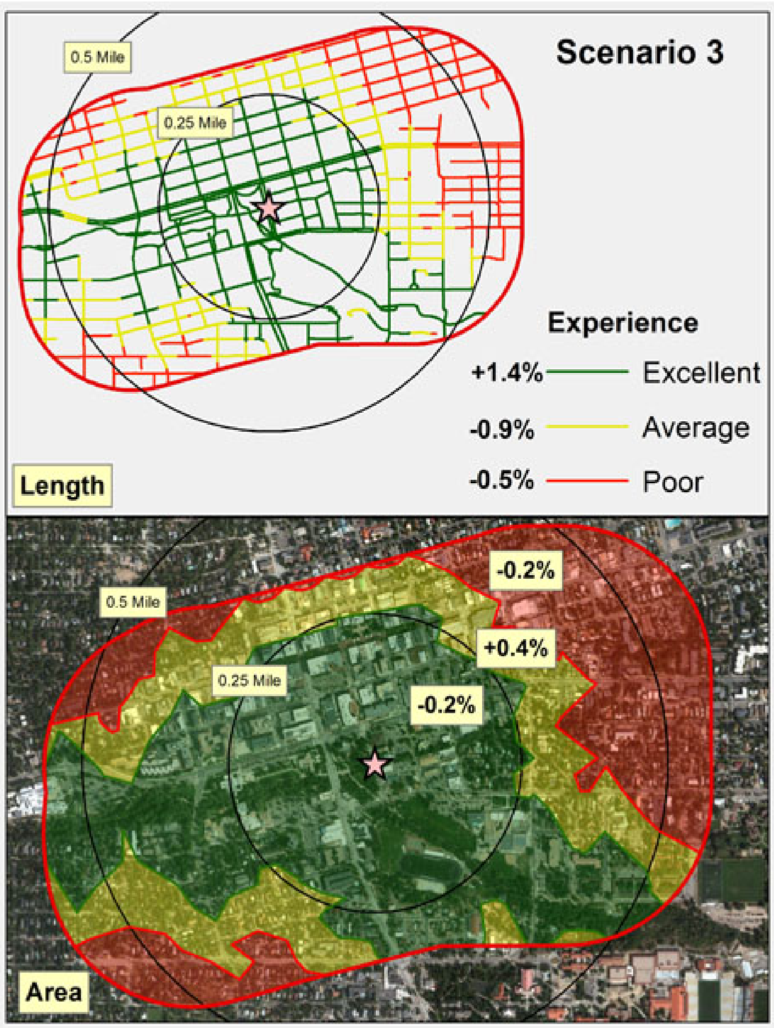

Figure 11: Scenario III result map

Scenario IV incorporated all design improvements from previous scenarios. The entire length of Canyon Street was improved as well as the two roads perpendicular to Canyon Street. The new street was also included in design Scenario IV to simulate an increase in network connectivity. Paths improved for design Scenario IV are displayed below in **Figure 12**.

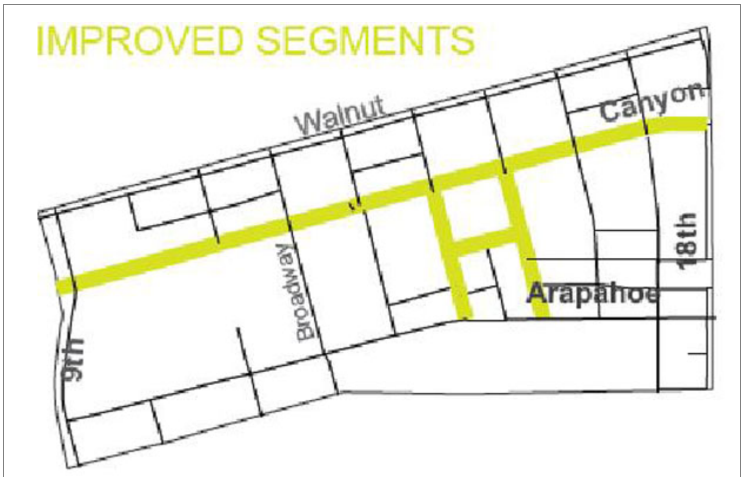

Figure 12: Paths improved for Scenario IV

The improvements made to paths in Scenario IV were intended to simulate the maximum investment in pedestrian infrastructure. By increasing the walkability of paths, Scenario IV generated results similar to Scenario II. The results portrayed a large decrease in excellent walking distance and area and an increase in poor walkable distance and area. The excellent walking area was decreased by nearly 3%, while poor walkable area was increased by nearly 5%. Distance measurements portrayed a similar trend. The results of spatial analysis for Scenario IV are displayed in **Figure 13**. These results suggest a concentration of pedestrian activity, rather than an overall increase in pedestrian demand within the study area.

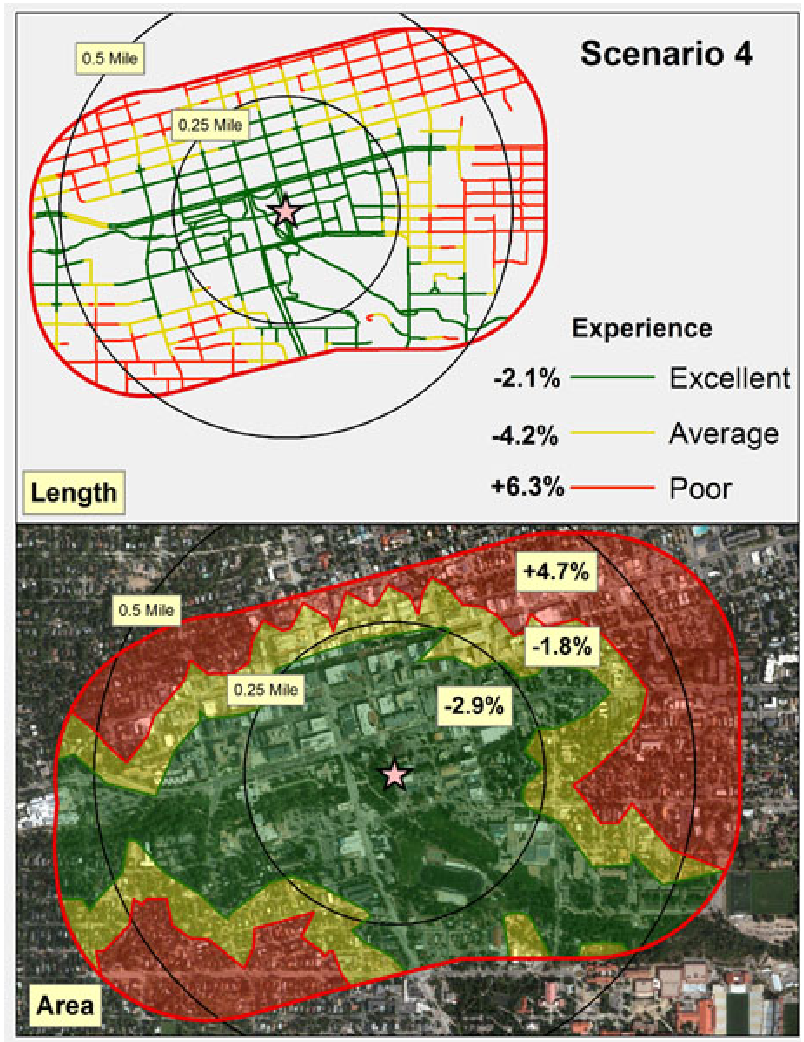

Figure 13: Scenario IV result map

In order to observe our results from another perspective, we organized our area and distance measurements into a chart to visually test for any correlation. As our design scenarios represent improvements to walkability by increasing investment, elasticity theory suggests the area of excellent walkability should also increase. Our results portray a different trend. Charting the area and distance results provided strong evidence that according to our spatial model, the relationship between pedestrian design and pedestrian activity are not necessarily elastic and dependent upon the scale of observation. **Figure 14** displays the charts of our area and distance results.

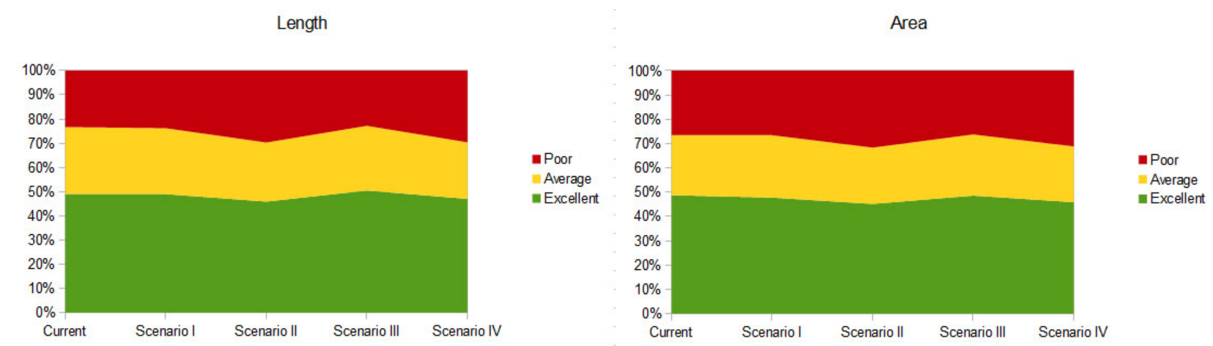

Figure 14: Distance and area by scenario result

Limitations:

It must be noted that the walkability indicator model was developed with limitations that may have effected the accuracy of results. First, the project was performed in a classroom setting and was subject to significant time and resource constraints. The participants had less than 16 weeks to conceptualize, create and perform the walkability indicator analysis. Human resources were limited to two undergraduate and two graduate level students. All other resources including technology, transportation and financial resources were limited to what the students were willing to donate to the project. These constrained the thoroughness of the site survey and data collection. The survey sheet was developed using criteria defined by existing literature. The time constraint limited the ability of the group to perform a complete review of the broad set of literature related to walkability and pedestrian demand. Further investigation of existing literature related to walkability may reveal different concepts of elasticity and the relationship between pedestrian oriented design and pedestrian demand.

As to the walkability indicator spatial model, the development of a new and unique indicator of walkability requires repeated testing and comparison with existing walkability indicators in order to evaluate its effectiveness and accuracy. The walkability indicator model is also limited to analyzing established paths and line vector data. It is, however, common for pedestrians to walk outside of designated paths and create their own social trails. The walkability indicator spatial analysis would be improved by including walkable areas such as fields, parking lots and other areas that provide shortcuts to the existing path network.

Implications:

The walkability indicator provides planners with a quantitative measurement which incorporates qualitative attributes of pedestrian oriented design. The development of this spatial analysis model has the potential to become a user friendly tool to aid planners, designers and decision makers in evaluating the outcomes of plans, designs and policy related to sustainable transportation. The practical results of the analysis of the civic center study area describe that paths near parks and other natural areas perform much better than paths in residential areas or along major transportation corridors.

The testing of design scenarios suggested that the relationship between walkability and pedestrian demand is not necessarily elastic. This finding implies that a city that makes significant investments in pedestrian walkability in order to encourage walking and convert drivers into pedestrians will not necessarily achieve their goal. According to our walkability indicator spatial model, the investment of financial and natural resources into walkable design may have the effect of concentrating existing pedestrian activity into improved areas, rather than increase the overall demand and total number of pedestrians in a specific area.

This finding suggests that city planning departments may better accomplish the sustainable goal of converting drivers to pedestrians by focusing on automobile oriented regulations. These regulations may include increased parking fees in areas of concern, lane restrictions on key roads, and gasoline taxes.(Litman 2012) It seems that by limiting the availability of automobile infrastructure and resources, cities can more efficiently accomplish sustainability goals than by investing significant resources into walkable design. Revenue generated by parking fees and other automobile regulations can be reinvested in walkable design to concentrate and direct pedestrian activity.

Conclusion:

As city planning departments seek new ways to comprehend the outcomes of sustainable policy, creativity and technological innovation may be combined to form new methods of understanding. The City of Boulder and University of Colorado collaboration effort set a foundation of spatial modeling that can be built upon and improved by future efforts. The development of the walkability indicator provided a unique spatial network approach to quantifying the results of a qualitative survey of street scale pedestrian design. The survey can be adapted to meet various design standards while the spatial analysis model can be used to convert the street scale walkability survey into a neighborhood scale quantitative result. The use of spatial technology allows for the generation of results that are easy to comprehend and present to decision makers. Though the spatial modeling process was performed with time and resource limitations, the methodology was developed to a satisfying degree and can be modified to evaluate specific pedestrian qualities at different spatial scales.

The design scenarios simulated specific pedestrian oriented designs and investment strategies. They were used to test the theory of elasticity in walkability and pedestrian demand. The results of our four design scenarios suggest that the relationship between walkability and pedestrian demand is not necessarily elastic and that specific design interventions are likely to concentrate existing pedestrians into improved areas rather than increase the cumulative walkability and pedestrian demand for a larger study area.

This finding can be used to inform city planners, designers and decision makers of the risks of implementing pedestrian oriented transportation improvements. It also suggests that a more effective approach to decrease driving and increase pedestrian activity may be to regulate automobile travel by imposing parking fees, gasoline taxes and restricting lane capacity. Funds earned by regulating automobiles can be reinvested into pedestrian transportation infrastructure in order to create walkable path networks in appropriate areas.

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