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Abstract:

Public health initiatives have made important but relatively modest gains with individual-level and non-ecological health promotion efforts aimed at increasing physical activity. The previously overlooked built environment is now being considered as facilitating or hindering one's ability to be active. The multi-use greenway is an example of a facility which can support physical activity, but its level of use may be influenced by the accessibility characteristics of areas surrounding the greenway. In this study, an unobtrusive methodology using GPS and GIS technology was employed to test whether two variables used to measure accessibility, *proximity* (population density) and *opportunities* (land use mixture), predicted the use of greenway segments. The results presented here allow us to confirm that smaller walking and biking scales of analysis are better predictors of physical activity behavior. The results also suggest that solely bringing environmental supports for physical activity closer to concentrated areas of population does not necessarily equate to more use. It is important that areas with increased population density also have increased levels of land use mixture if increasing use is the goal.

The influence of one's environment on health and the recognized role urban planning has on shaping our environment is of increasing interest within the field of public health. As greater numbers of people live in urbanizing and more intensively planned environments, public health practice will become increasingly connected to planning in the creation of healthy environments.

An increasing number of population-level health promotion efforts have begun adopting an ecological paradigm (Duhl and Sanchez, 1999), accepting that both individual *and* environmental determinants play a role in health behaviors. This new, arguably revisited, public health paradigm accounts for not only the compositional (who you are) but also the contextual (where you are) influences on health (Macintyre, Ellaway and Cummins, 2002). A contemporary urban planning/public health research focus is reflected in the study of the contextual influences on physical activity. The fact that there has only been a slight increase in American's level of physical activity (Transportation Research Board [TRB], 2005) with years of individual level interventions implies that there are forces beyond individual motivation that influence this health promoting behavior. Creating an environment that supports physical activity is increasingly recognized as an important complement to counteract American's increasingly inactive lifestyles and the contributing effect this inactivity has on the current epidemic of obesity.

An ecological approach to promoting physical activity posits that the configuration of the environment one inhabits may influence his or her ability to be active. This study was designed to examine ecological factors of the built environment that may hinder or facilitate the performance of physical activity. This was accomplished by applying the concept of accessibility to examine how the area surrounding a *behavior setting* (Sallis, Bauman and Pratt, 1998) influences physical activity. The behavior setting examined in this study was the multi-use greenway. A greenway is a "linear open space established along either a natural corridor, such as a riverfront, stream valley, or ridgeline, or overland along a railroad right-of-way converted to recreational use, a canal, a scenic road, or other route" or, alternately, an "open space connector linking parks, nature reserves, cultural features, or historic sites with each other and with populated areas" (Little, 1990, p.1). A greenway becomes a multi-use greenway when the trail surface and other amenities support multiple forms of non-motorized locomotion.

Although planning a greenway route or corridor is often, but not always, determined by a natural feature such as a river, ridgeline, or abandoned rail corridor, a consideration of accessibility can still assist planners in prioritizing locations of new greenway construction or expanding existing systems for maximum community benefits.

Why Greenways?

The increasing popularity of greenway construction, both nationally and internationally (Fabos and Ahern, 1995), is being spurred by the numerous cultural, educational, ecological, and potential health-supporting functions of these ecological corridors. In addition to protecting assets of cultural or historical significance, providing an outdoor laboratory for environmental education, creating habitat for wildlife migration, and reclaiming brownfields, river greenways in particular have the dual-edged anthropocentric benefits of ensuring the quantity and quality of water resources *and* providing an attractive setting in which to perform non-motorized forms of activity. This social perspective not only acknowledges the potential human benefits of a functioning ecosystem and the conservation of natural resources, but also recognizes the greenway's potential for significant use by persons performing multiple forms of non-motorized locomotion (Lindsey and Nguyen, 2004). The multi-use greenway with a maintained path has great potential to act as venue for physical activity as the presence of accessible trails are not only associated with maintaining and increasing activity achieved through walking but also with meeting recommended levels of physical activity (Brownson, Baker, Housemann, Brennan and Bacak, 2001; Brownson, Housemann, Brown, Jackson-Thompson and King, 2000; Sharpe, Granner, Hutto and Ainsworth, 2004). Although greenways can be used as useful tools to achieve myriad community goals, what is unknown is how the characteristics of areas surrounding these nonmotorized "green freeways" influence their level of use.

Simply creating a supportive environment through the mere presence or availability of physical supports, such as a greenway, is not sufficient alone to encourage physical activity (Greenwald and Boarnet, 2001; Lee and Moudon, 2004; Sallis, Bauman and Pratt, 1998). An environmental support must be not only be present but also accessible. Beyond the increasing the presence or quantity of these facilities, accessibility can contribute to the quality of the greenway environment with a subsequent influence on its use.

Greenway Accessibility

Although the greenway potential for use is great in a city setting due to its "localness" (Gobster, 1995) or proximity to a large number of people, it has not yet been established how the greenway can complement the built environment to encourage its use. The built environment may create barriers to physical activity depending upon the land uses the greenway provides access to and between. There may be a balance between how accessible a greenway is (e.g. proximity of residential land uses (population centers) to the greenway) and how accessible the greenway makes other destinations (e.g. intersection with a mixture of land uses (potential destinations)), or one of these considerations for greenway route determination may override the other. These environmental factors influence activity achieved through either recreational or utilitarian purposes[1].

Recreational physical activity is influenced by the *proximity* of residentially zoned lands to the greenway and the convenience that this spatial proximity offers (Giles-Corti and Donovan, 2002; Gold, 1980; Humpel, Owen, Leslie, Marshall, Bauman and Sallis, 2004; Owen, Humpel, Leslie, Bauman and Sallis, 2004). For transportation, both short distances to reach the greenway (King, Blair, Bild, Dishman, Dubbert and Marcus, 1992) and the *opportunities* afforded by potential destinations may have implications for physical activity achieved on a utilitarian trip (Handy, 1996; Handy and Clifton, 2001; King, Brach, Belle, Killingsworth, Fenton and Kriska, 2003). If maximizing usage and physical activity is one of the goals of a greenway designer, should he or she focus on population density near the greenway, providing opportunities to access certain types or varieties of land uses, or is achieving the difficult and potentially expensive goal of doing both worth the community health benefits of increased usership?

To answer this question, this study tested the following hypotheses:

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[1]Reflecting the objective and observational design of this study, data on trip purpose was not collected, but greenways that can support activity performed for these two purposes are accepted in this study as having a cumulative impact on maximizing its overall use.

Hypothesis 1: An increased level of greenway segment accessibility, as measured by proximity of residential population and destination opportunities along the greenway, increases the rate people using it as a setting for physical activity.

Hypothesis 2: Greenway segments that have a high degree of proximity *but* a low level of opportunities are used less for physical activity than greenway segments that are high in both proximity *and* opportunity.

What this paper intends to address is if the urban planning concept of accessibility can be applied to the unique setting of the greenway to describe physical activity achieved on it. This urban planning concept of accessibility differs from one's ability to reach a destination quickly (mobility) because it considers both the trip generating effect that proximity offers and the potential attractive effect of destinations.

Methods

A multiple-case study design (Yin, 1994) was used to examine two study sites in the state of Michigan, the cities of Lansing and Battle Creek. These two river greenways could be considered local facilities under city management, and they intersected city centers where the highest concentration of commercial activity was located. The respective river greenways were also contiguous, relatively long for greenways that intersect cities (Battle Creek = 12 miles, Lansing = 8 miles), and extended for many miles through areas with changing accessibility characteristics. The two cases were also similar in their topography (Rodriguez and Joo, 2004; Troped, Saunders, Pate, Reininger, Ureda and Thompson, 2001), trail surface (Antonakos, 1994; Gobster, 1995; Lindsey, 1999), and aesthetics (Gobster, 1995; Lindsey, 1999) which have been shown previously to be associated with greenway and/or trail use. Both of the greenways under study had limited variation in slope (Battle Creek σ=17.6 feet elevation, Lansing σ=16.8 feet elevation) and largely consisted of an asphalt trail surface six feet in width. In selected areas where there was no space along the riverbank for an asphalt path, boardwalks maintained the continuity of the trail. The greenways in both cities avoided intersections with streets through the presence of underpasses and occasional overpasses at road and railroad intersections. The aesthetic was consistently maintained in both cases by a narrow strip of brush, grass, and/or small trees separating the asphalt trail from the river. The natural environment aesthetic was also enhanced in both cases due to the intersection of the path with both small and large city parks.

Aside from the similarities in natural beauty, both cities had made attempts to improve the aesthetic appeal of structures. Along the greenway route in both cities, when the trail came within close proximity of structures or streets, aesthetics had often been enhanced by covering potentially empty views with art.

In order to isolate the accessibility characteristics on different sections of the extensive greenways, the greenways in both cities were divided into segments based on the location of greenway access points. The mid-point in between access points determined the bounds of the segment. This resulted in segments of varying length but this was deemed a better approximation of how greenway users actually use the trail and enter and exit the system. Although it could be argued that more people are more likely to be recorded on a longer segment, a longer segment only has one access point and is therefore operating under the same constraints as a shorter segment. This segmentation procedure was deemed an improvement on arbitrarily dividing the greenway into segments that may or may not contain access points and therefore would not represent the reality of either entering or exiting the system. The segmentation procedure resulted in 14 segments in Lansing and 16 segments in Battle Creek. Since the entire greenway in each city was divided into segments, the total number of segments in each city constitutes a census of segments rather than a sample. The following steps were taken to attribute proximity, opportunity, and use for physical activity data to each segment.

First, *proximity* reflected the population density within three mode-determined "usersheds" surrounding each greenway access point. Previous studies reveal that between 67% and 84% of greenway users report living no more than 10 minutes from the trail (Lindsey, Drew, Hurst and Galloway, 2001). The three usersheds captured the population density within a 10-minute walking, biking, and driving trip road network distance of each greenway access point. This step produced measures which were used to reveal a potential relationship between the concentration of city residents within the usershed buffer and physical activity performed on corresponding greenway segments. The population data used in this study was derived from U.S. Census 2000 block and block group data. Smaller block level units were used to alleviate the geographic mismatch between the census units and the walking and biking defined usershed bounds. Larger block group units were used to determine the characteristics of persons within the driving usershed. If the majority of the census unit overlapped the usershed bounds and the part of the census unit that fell within the bounds contained residential land uses, it was included.

Second, *opportunity* reflected the mixture of land uses which could be reached from a given greenway segment. Calculating the land use mixture within a ¼ and ½ mile road network distance from each greenway access point accounted for the fact that persons could either walk or bike to opportunities surrounding the greenway. A Herfindahl-Hirschman Index (HHI) was used as a measure of land use mixture (Song and Rodriguez, 2004). This measurement achieved more specificity than simply counting the number of land uses because it took into account the percent area of each land use (single family residential, multi-family residential, commercial, industrial, park, open land, church, and school) in the two mode-defined areas extending from an access point. This step produced measures which were used to reveal a potential relationship between the mixture of destinations within buffers along the greenway route and physical activity performed on corresponding greenway segments.

Third, the *uses* (number of persons performing physical activity) on different greenway segments was observed and recorded by making multiple bicycle passes over the entire length of the greenway. A bicycle handlebar-mounted Garmin GPS Map 60® Global Positioning System handheld receiver unit was used to mark the geographic location of each person performing physical activity. Persons that were found along the greenway not performing some form of physical activity (e.g. those that were fishing, picnicking) were not recorded as a use. Both greenways were traversed on two separate occasions on each of the seven days of the week. Two passes per data collection day multiplied by 14 days of data collection on each greenway accrued to 28 data collection trips per city greenway. Data were collected during the same peak use periods (4-6 p.m. weekdays, 10-2 p.m. weekends) in both locations. This step produced measures which were used to determine the volume and location of greenway uses for physical activity. The potential confounding effect of weather on use was accounted for by collecting use data on days with similar climatic conditions. These were days that could be considered pleasant spring weather by most Michiganders (>60°F or 16°C).

The GIS data used in the analysis were gathered from multiple sources. The base data features of rivers, roads, lakes, railroads, and county boundaries were collected from the State of Michigan Geographic Information Library as part of the Michigan Geographic Framework Version 5a. The 1999 Lansing and 2004 Battle Creek land use data were collected from the respective city planning offices. The accuracy of the land use data was confirmed through a windshield assessment of existing land uses performed on March 14, 2006 in Lansing and on March 4, 2006 in Battle Creek.

A GIS procedure and mixed model regression analysis of areas surrounding the two greenways were performed to determine whether the accessibility of the greenway itself and the accessibility of destinations along the greenway were factors in persons achieving some level of physical activity on it. First, uses were displayed in a chloropleth map to provide a visual representation of the percent distribution of uses along the greenway in both cities. These maps provided a descriptive account of the types of land uses surrounding individual greenway segments. Second, a mixed model regression analysis was performed to test the effect of population density and land use mixture on use for physical activity adjusting for the sociodemographic characteristics of median age, sex (% female), and race (% white) of the proximal population. These characteristics have long proven to be associated with variations in not only health status but also the performance of health behaviors such as physical activity.

The use on each segment (i) took into account the observation period (j), or pass on the bike, in which the use data were collected. For example, if 10 uses were found on segment 15 in the sixth observation period (pass on the bike) Y_{ij} would be represented as: $10_{15\ 6}$. The age, sex, and race control variables and proximity and opportunity main effects variables do not vary by pass. These static variables used to describe the area surrounding a given segment were simply repeated for each pass. The following models were run for each of the three modes (walking, biking, and driving) to determine which mode-defined area characteristics were significant when predicting the use of a segment. The walking model took into account the population density and land use mixture within walking distance of an access point. The biking model took into account the population density and land use mixture within biking distance of an access point. The driving area analysis took into account the population density proximal to segments with parking and, separately in two driving models, the land use mixture within walking and biking distances of the greenway.

Hypothesis 1 model:

$$Y_{ij} = \beta_{oi} + \beta_1 Age_{ij} - \beta_2 Sex_{ij} + \beta_3 Race_{ij} + \beta_4 P_{ij} + \beta_5 O_{ij} + e_{ij}$$

Y= number of persons on segment i on j pass
Age= median age of population in area surrounding segment i
Sex= % female of population in area surrounding segment i
Race= % white of population in area surrounding segment i
P= population density in area surrounding segment i
O= land use mixture in area surrounding segment i
i= segment
j= observation period when data is collected (pass)
e= error term

Using the same base model applied in the analysis of hypothesis 1 above, the $\beta_6 P_{ij} O_{ij}$ term was added to the following equation to test hypothesis 2 and account for the potential interaction between proximity and opportunity.

Hypothesis 2 model:

$Y_{ij} = \beta_{oi} + \beta_1 Age_{ij} - \beta_2 Sex_{ij} + \beta_3 Race_{ij} + \beta_4 P_{ij} + \beta_5 O_{ij} + \beta_6 P_{ij} O_{ij} + e_{ij}$

PO= interaction of population density and land use mixture in area surrounding segment i.

Results

The results from this study support the theory that measures of the built environment are useful when examining the health behavior of physical activity. Population density and land use mixture surrounding various segments of the greenway are significant in predicting activity performed on the greenway. In addition, there are a few interesting caveats in the applicability of these variables more readily understood and interpreted by examining the interaction between population density and land use mixture. Examining this interaction reveals that simply having higher population densities or land use mixture does not necessarily lead to increased use. A positive effect on use is dependent upon the level at which these two variables are examined and the degree to which these two variables complement one another.

Examining the descriptive distribution of uses along the greenway, it appears that most of the uses occur in either the downtown area or in parks or other areas with natural features such as those that are wooded (Figures 1 and 2 *color figures to be made available online). The percentage ranges were divided into four classes using a natural breaks classification. The descriptive distribution of uses suggests that the greenway has an increased appeal in settings that are either “green” or when the trail intersects the increased level of opportunities created by high levels of land use mixture. It also appears that uses are relatively high on segments that connect these two types of areas. If it is assumed that the downtown area also has higher population density in addition to its high degree of land use mixture, it appears that greater accessibility does translate into higher use, but the regression results testing hypothesis 1 add an interesting and counterintuitive twist to this apparent relationship.

The regression analysis from hypothesis 1 in Battle Creek confirms that greater land use mixture (opportunities) is significant in predicting the use of the greenway for physical activity but only at the walking scale representing the immediate environs of the greenway (Table 1). The analysis assessing hypothesis 1 in Lansing confirms that population density (proximity) is significant at both the walking and biking scales when predicting the use of the greenway for physical activity. These findings support previous findings that smaller scales of analysis are better at predicting neighborhood walkability (Moudon, Lee, Cheadle, Garvin, Johnson, Schmid, Weathers and Lin, 2006), and, although not directly, walking and biking as forms of transport (Krizek and Johnson, 2006). At the same time, the significant result of population density on uses in Lansing is in the negative, and opposite, direction. More uses of the greenway for physical activity occur on segments with lower population densities. This result contradicts a previous finding that "all other factors equal, trail traffic is greater in neighborhoods with *greater* [italics added] population density" (Lindsey, Han, Wilson and Yang, 2006, p. 152).

If the results from hypothesis 1 are taken at face value, they would suggest that there is no relationship between increasing accessibility—operationalized in this study with a consideration of both the trip-generating effect of higher population density and the trip attracting effect of greater land use mixture—and increasing use. The results produced when testing hypothesis 1 in Battle Creek provide affirmation of the importance of land use mixture at the walking level, but there is no evidence of a significant trip generating effect from higher population densities. In Lansing, the destination opportunities created through land use mixture is not significant, and there appears to be exactly the opposite effect of population density on use that we would expect. These findings could be interpreted as suggesting that building greenways through areas of lower population density in Lansing or routing them through areas of more intense land use mixture in Battle Creek would increase physical activity on the respective city greenways. The increased accessibility brought about by the concert of higher population density and land use mixture could have been discarded as insignificant, but the results from the interaction analysis help us in understanding how this rather counterintuitive result is possible and how it actually supports hypothesis 2.

Examining the interactions between population density and opportunities in Lansing, where lower population density appeared to be predicting higher use, confirms the importance of accessibility (Table 2). Having both high levels of proximity and opportunity resulted in significantly higher uses, but when the level of opportunities varied, this relationship changed. This dynamic is apparent in the plot of the two-way interaction between low and high levels of population density and land use mixture. Low, medium, and high levels were defined by thresholds at the 25th, 50th and 75th percentiles. In the Lansing biking model, in spite of increasing levels of population density, the use of segments remains relatively constant in areas that also have low levels of land use mixture (Figure 3). Simultaneously, we see a positive increase in uses as both population density and land use mixture act in concert at increasingly higher levels. High levels of land use mixture make a noticeable difference at medium levels of population density and an even greater difference at high levels of population density. Even at low levels of population density, there are more uses on parts of the greenway that have higher levels of land use mixture. Although these interactions were also significant at the driving levels in Lansing, the data could not support plotting the interaction. This was so because the driving analysis only included segments that had parking available. Thus, there were few too segments from which to derive meaningful plots.

Although none of these interactions were significant in Battle Creek, this case still offers some useful information. As the degree of land use mixture within walking distance of a segment increased, so did the uses of the segment holding the population density and control variables constant. Acknowledging the heavy use on segments of the Battle Creek greenway that intersect parks or areas with natural qualities supports the attractive effect of the park evident in Lansing. The notable practical application of this finding is that this effect did not supersede the importance of having a high degree of land use mixture within walking distance of the greenway. The segment experiencing high levels of use in Battle Creek (segment 2) was not a formal park with amenities but rather a wooded conservation buffer along the river. The importance of these extensive natural areas is clear, but the Battle Creek case confirms the importance of also connecting the greenway to areas of higher land use mixture and the increased level of utilitarian opportunities these areas afford the greenway user.

Conclusions

Municipalities must make local decisions about who could benefit from greenway development but should not necessarily operate under the assumption that more people benefit *solely* by bringing it closer to more of them. Areas with lower population densities immediately surrounding the greenway can actually instigate higher use on the corresponding greenway segments. The attractive effect of city parks can lend a practical explanation for this. The area consumed by the park causes a lower population density and land use mixture when analyzing the immediate environment of the greenway, and these parks experience a high level of use. Parks are an important component of a greenway system when attempting to boost use for physical activity. At the same time, the interaction results reveal that uses steadily increased in areas of higher population density if there are also high levels of land use mixture, but there was no noticeable effect on uses in areas of higher population density if these areas have a low level of land use mixture. Therefore, maximizing the use of a system that includes parks as an important component would also involve connections to areas with high population density and land use mixture.

Discussion

There are several limitations to this study that should be noted when interpreting the results. The generalizability of these findings should be tempered by the fact that this census of greenway segments was performed on two greenways in two relatively small cities (<150,000 persons). The dynamic in a major metropolitan area may vary.

Although not tested directly, the potential effect of autocorrelation was determined to by minimal. Although the distribution of uses per segment reveals that in some cases segments that are used heavily are adjacent to other segments experiencing higher percentages of overall use, I would argue that this is due to the similar environments surrounding adjacent segments and not due simply to the fact that these segments are adjacent to one another. An argument for the effect of spatial autocorrelation on uses could stem from noting the influence of the social environment on behavior. The influence that high use begets more use is plausible and was not examined in this study. Also, these results should not be used to infer that higher population density and land use mixture encourage more physical activity at the population, or in this case at the city, level.

Taking these limitations into account, these results should be encouraging to municipalities constructing or expanding greenway networks. The added community health benefit of increased greenway use for physical activity may provide the impetus for protecting the river corridors many municipalities find under their management. These results should also be encouraging to those attempting to capitalize on opportunities for joint urban planning and pubic health research and practice (Malizia, 2005). This study reveals that the urban planning concept of accessibility is useful in understanding the contextual influences on health behavior performed in a unique setting.

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Figure 1

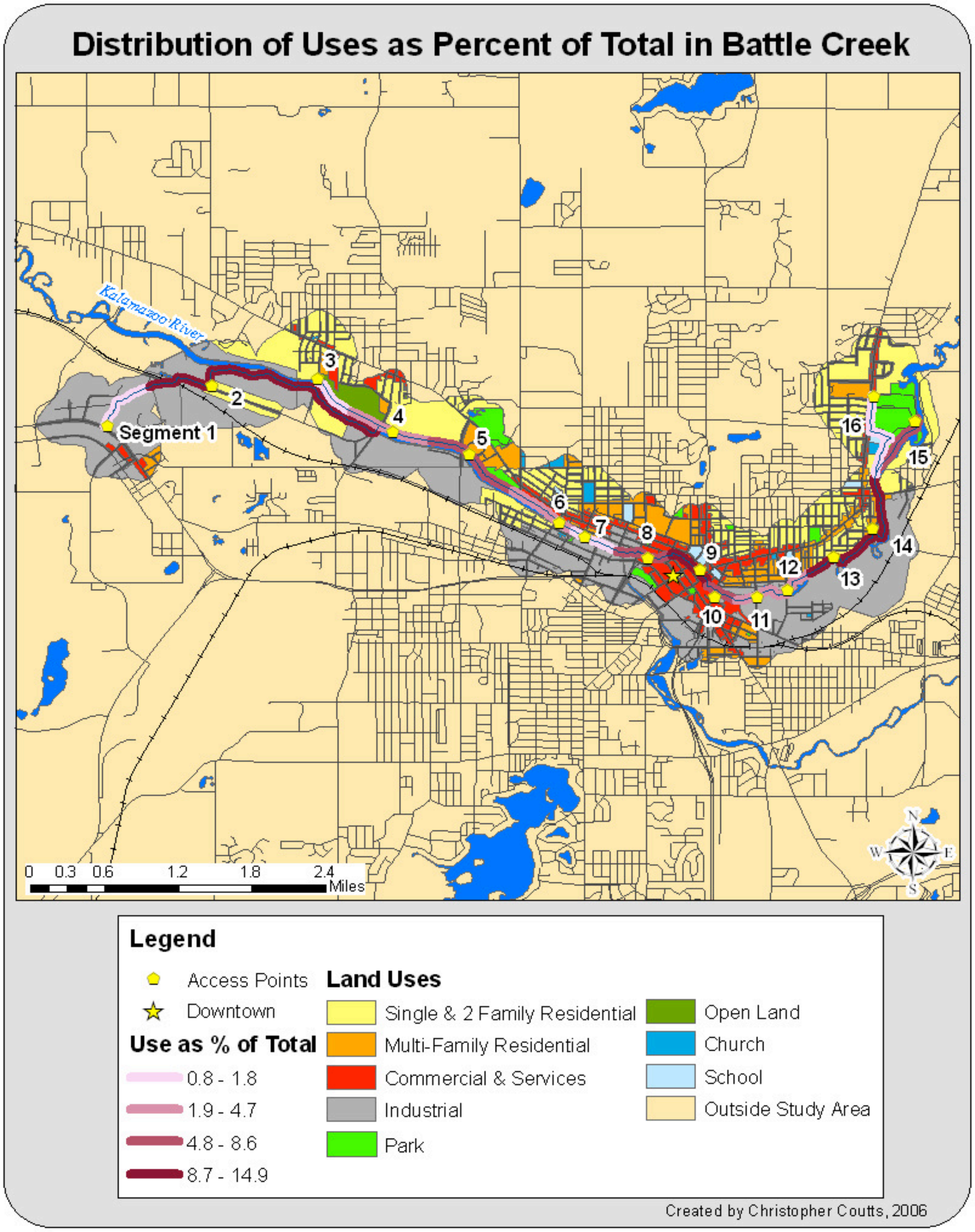

Distribution of Uses as Percent of Total in Battle Creek
Kalamazoo River
Segment 1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
0 0.3 0.6 1.2 1.8 2.4
Miles
N
W
E
S
Legend
Access Points
Downtown
Use as % of Total
0.8 - 1.8
1.9 - 4.7
4.8 - 8.6
8.7 - 14.9
Land Uses
Single & 2 Family Residential
Multi-Family Residential
Commercial & Services
Industrial
Park
Open Land
Church
School
Outside Study Area
Created by Christopher Coutts, 2006

Figure 2

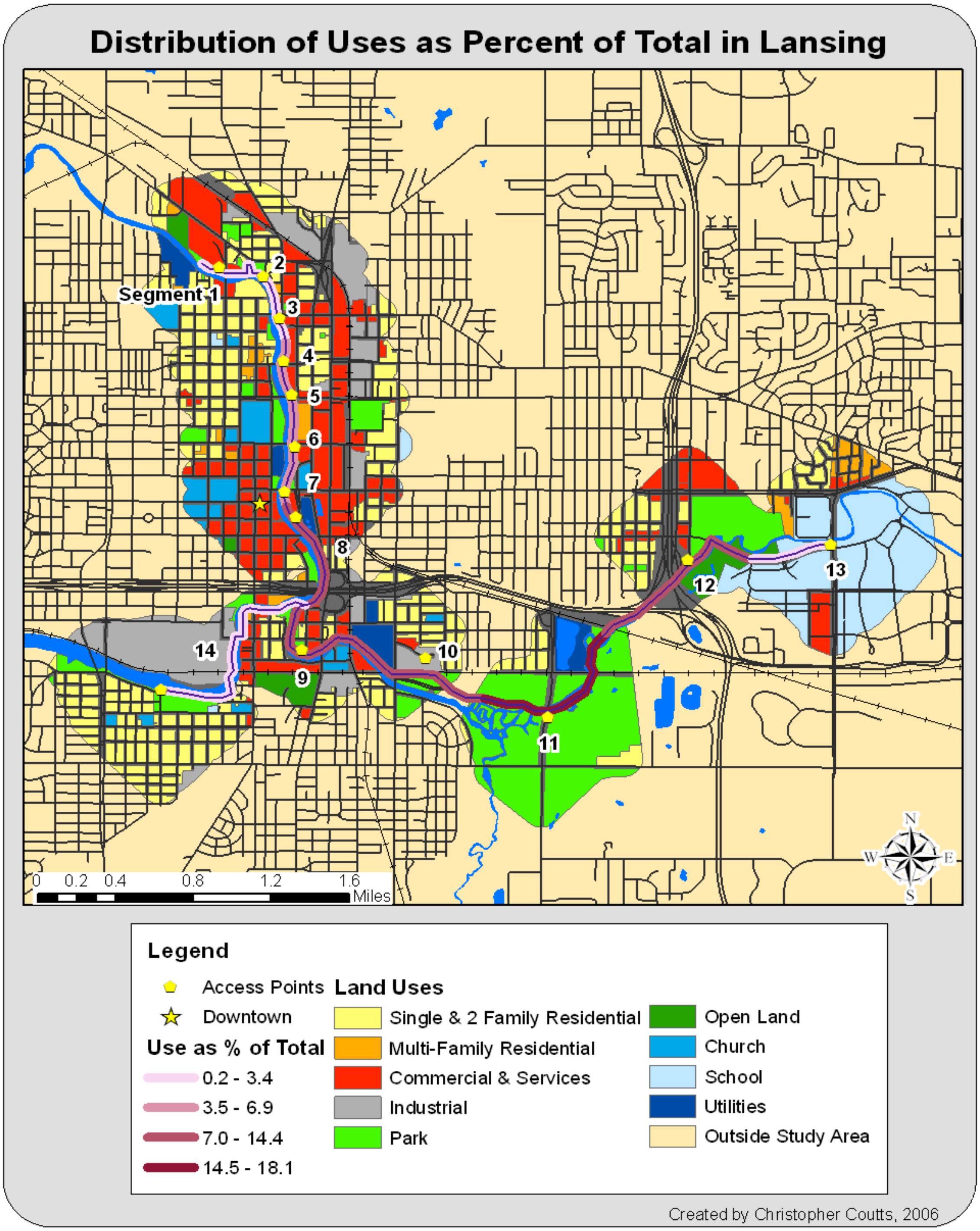

Distribution of Uses as Percent of Total in Lansing
Segment 1
2
3
4
5
6
7
8
9
10
11
12
13
14
0 0.2 0.4 0.8 1.2 1.6
Miles
N
S
E
W
Legend
Access Points
Downtown
Use as % of Total
0.2 - 3.4
3.5 - 6.9
7.0 - 14.4
14.5 - 18.1
Land Uses
Single & 2 Family Residential
Multi-Family Residential
Commercial & Services
Industrial
Park
Open Land
Church
School
Utilities
Outside Study Area
Created by Christopher Coutts, 2006

Table 1. Models testing the effect of population density (proximity) and land use mixture (opportunities) on the dependent variable of use of greenway segments

Variable	Walk model	Bike model	Drive with opportunities within walking distance model	Drive with opportunities within biking distance model
	Models representing mode-defined areas surrounding access points			
Battle Creek				
Age	0.0007 (0.0321)	0.1161 (0.0905)	0.0095 (0.4421)	-0.0473 (0.5991)
Sex	-0.0172 (0.0237)	-0.0689 (0.0762)	-0.6863 (0.9069)	-0.4519 (1.2355)
Race	0.0144* (0.0066)	0.0039 (0.0142)	-0.0523 (0.1523)	0.0022 (0.1998)
Proximity	3.85e-05 (0.0002)	0.0006 (0.0005)	-0.0015 (0.0046)	-0.0026 (0.0079)
Opportunity	0.0002* (0.0001)	0.0003 (0.0002)	0.0002 (0.0001)	0.0004 (0.0004)
Lansing				
Age	-0.0844 (0.0740)	-0.2155 (0.1261)	-2.7770 (2.3776)	-2.7548 (3.3281)
Sex	0.0065 (0.0523)	-0.6492 (0.2661)	3.2450 (2.7835)	3.1474 (4.0287)
Race	0.0209 (0.0324)	0.2062** (0.0455)	-0.6543 (0.6944)	-0.6330 (0.9720)
Proximity	-0.0009* (0.0004)	-0.0033** (0.0010)	-0.0104 (0.0182)	-0.0097 (0.0259)
Opportunity	-0.0844 (0.0740)	-0.2155 (0.1261)	-2.7770 (2.3776)	-2.7548 (3.3281)

Note. Regression results are in the form of coefficient (standard error). The coefficients are small in magnitude due in part because the dependent variable of uses was transformed to the square root of uses. This transformation, common when using count data, proved to be necessary to better conform to the assumption of $\beta \sim N(\sigma, \sigma^2_o)$.

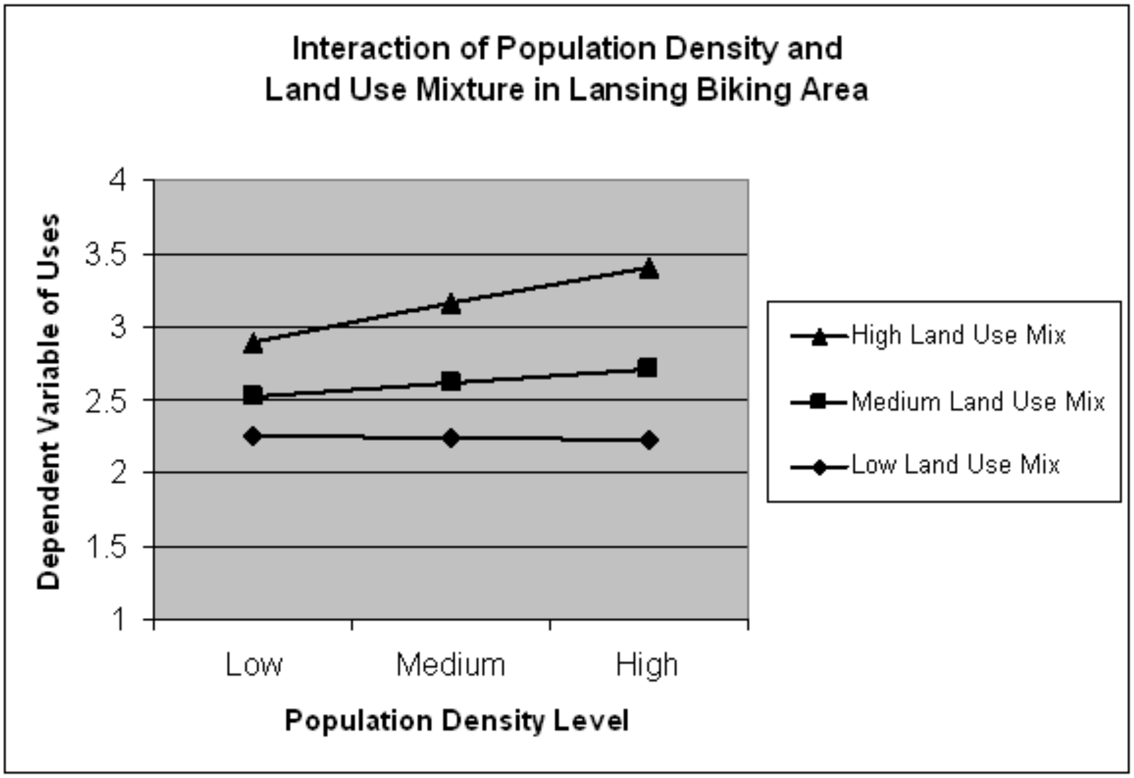
*$p<0.05$. **$p<0.01$

Table 2. Models testing the effect of the interaction between population density (proximity) and land use mixture (opportunities) on the dependent variable of use of greenway segments

	Models representing mode-defined areas surrounding access points			
Variable	Walk model	Bike model	Drive with opportunities within walking distance model	Drive with opportunities within biking distance model
Battle Creek				
Age	-0.0005 (0.0342)	-0.0218 (0.1331)	-1.2221 (0.9992)	0.9535 (1.4488)
Sex	-0.0188 (0.0258)	0.0711 (0.1257)	-0.0650 (0.9012)	-1.0058 (1.5514)
Race	0.0143* (0.0069)	0.0154 (0.0160)	0.6625 (0.5527)	-0.6296 (0.8415)
Proximity	0.0001 (0.0004)	0.0025 (0.0015)	-0.0323 (0.0235)	0.0329 (0.0464)
Opportunity	0.0002 (0.0001)	-0.0003 (0.0005)	0.0045 (0.0032)	-0.0041 (0.0058)
Proximity*Opportunity	3.11e-08 (1.35e-07)	6.87e-07 (5.02e-07)	-7.99e-06 (6.01e-06)	8.88e-06 (1.14e-05)
Lansing				
Age	-0.1116 (0.0857)	-0.8175** (0.2908)	-0.5715 (1.3159)	-5.2707** (1.8701)
Sex	-0.0025 (0.0555)	0.8231 (0.6996)	1.2668 (1.4579)	6.6372** (2.3291)
Race	0.0226 (0.0336)	0.1097 (0.0573)	0.1301 (0.4071)	-1.2729* (0.5337)
Proximity	-0.0013 (0.0007)	0.0055 (0.0040)	0.0273 (0.0143)	-0.0088 (0.0131)
Opportunity	0.0004 (0.0007)	-0.0040* (0.0018)	-0.0136** (0.0041)	-0.0206** (0.0066)
Proximity*Opportunity	-1.71e-07 (2.42e-07)	3.07e-06* (1.39e-06)	1.05e-05** (3.15e-06)	1.60e-05** (5.15e-06)

Note. Regression results are in the form of coefficient (standard error). See Figure 1 caption for explanation of small coefficient magnitude.
*p<0.05. **p<0.01

Figure 3


Interaction of Population Density and
Land Use Mixture in Lansing Biking Area
Dependent Variable of Uses
4
3.5
3
2.5
2
1.5
1
Low
Medium
High
Population Density Level
High Land Use Mix
Medium Land Use Mix
Low Land Use Mix