February 2008

# Community Trails in Community Context: GIS Analysis of Associations between Trail and Neighborhood Characteristics

Ellen K. Cromley
*University of Connecticut Center for Geographic Information and Analysis*, ellen.cromley@icrweb.org

Philip J. Troped
*Purdue University*, ptroped@purdue.edu

Steven J. Melly
*Harvard School of Public Health*, sjmelly@hsph.harvard.edu

F. Tyler Huffman
*Eastern Kentucky University*, tyler.huffman@eku.edu

UCCGIA
Papers and Proceedings

Number 4

2008

# *Community Trails in Community Context: GIS Analysis of Associations between Trail and Neighborhood Characteristics*

*Ellen K. Cromley*
*The Institute for Community Research*

*Philip J. Troped*
*Department of Health and Kinesiology*
*Purdue University*

*Steven J. Melly*
*Exposure Epidemiology and Risk Program*
*Harvard School of Public Health*

*F. Tyler Huffman*
*Department of Geography*
*Eastern Kentucky University*

**Abstract:** This research examines the site and situation characteristics of community trails as landscapes promoting physical activity. Trail segment and neighborhood characteristics for six trails in urban, suburban, and exurban towns in northeastern Massachusetts were assessed from primary Global Positioning System (GPS) data and from secondary Census and land use data integrated in a geographic information system (GIS). Correlations between neighborhood street and housing density, land use mix, and sociodemographic characteristics and trail segment characteristics and amenities measure the degree to which trail segment attributes are associated with the surrounding neighborhood characteristics.

**Keywords:** community trails, neighborhood environmental characteristics, physical activity, Massachusetts

**University of Connecticut**
**Center for Geographic Information and Analysis**
**Storrs, Connecticut**

*Advancing the use of geographic data and spatial analytic techniques*
*at the University of Connecticut and in the region it serves*

Cataloging Data
Cromley, Ellen K.
Community trails in community context: GIS analysis of associations between trail and neighborhood characteristics / Ellen K. Cromley, Philip J. Troped, Steven J. Melly, F. Tyler Huffman.

i, 23 p. : ill. ; 28 cm.
Includes bibliographical references.
(UCCGIA papers and proceedings ; no. 4)
1. Trails—Public use—Massachusetts. 2. Community life--Massachusetts. 3. Exercise—Massachusetts . 4. Recreation—Massachusetts. 5. Recreational surveys—Massachusetts. 6. Cities and towns—Massachusetts. 7. Massachusetts—Population. I. Troped, Philip J. II. Melly, Steven J. III. Huffman, F. Tyler. IV. University of Connecticut. Center for Geographic Information and Analysis.
G70.2 .U3 no. 4

Suggested Citation:
Cromley, Ellen K., Troped, Philip, J., Melly, Steven J., and Huffman, F. Tyler. 2008. Community Trails in Community Context: GIS Analysis of Associations between Trail and Neighborhood Characteristics. UCCGIA Papers and Proceedings, No. 4. Storrs, Connecticut: University of Connecticut Center for Geographic Information and Analysis.

Copies of this publication are available at the Map and Geographic Information Center, Homer Babbidge Library, University of Connecticut, Storrs, Connecticut and through *Digital* Commons@UConn at http://digitalcommons.uconn.edu/uccgia_papers/4/

**Table of Contents**

## Introduction

Places that promote well-being and maintain health are recognized as "therapeutic landscapes" and there is an evolving literature exploring this theme (Gesler, 1992; Kearns and Collins, 2000; Milligan et al., 2004; Gesler, 2005). Neighborhood environments, including community trails, that support walking and other forms of physical activity have been studied to identify the specific qualities that promote health (Krenichyn, 2006). The role of these environments as determinants of physical activity is now a focus of research to address the problem of obesity and overweight by decreasing sedentary behavior (Brownson et al., 2000).

Obesity is one of the most important public health concerns in the US, and it now ranks with smoking in importance as a public health issue. In 2000, 20.1% of adults in the US were obese and 36.7% were overweight (Lopez, 2004). Childhood obesity rates are also increasing rapidly. The increase in obesity in the US emerged first in the southern states, but higher rates are now in evidence in all areas of the country. Weight is a function of dietary intake and physical activity, modified by characteristics of the individual (US Department of Health and Human Services, 2001).

Walking is by far the most commonly reported form of physical activity in the US (Siegel et al, 1995; US Department of Health and Human Services, 1996; Eyler et al., 2003) and walking in the local neighborhood accounts for a large share of total physical activity among adults (Humpel et al., 2004). Smart Growth and New Urbanism approaches to planning and neighborhood design emphasize higher densities, greater land use mix, and more interconnected streets accommodating pedestrians and bicyclists as alternatives to suburban sprawl (Ewing and Cervero, 2001; Handy et al., 2002). Perceived and objective measures of these neighborhood characteristics are used as indicators of neighborhood "walkability" in studies of the built environment, physical activity, and obesity (Handy et al., 2002; Saelens et al., 2003a; Saelens et al., 2003b; Lopez, 2004; Wilson et al., 2004; Leslie et al., 2005).

More attention is now being paid to the characteristics of community trails and their role in supporting physical activity (Brownson et al., 2000; Troped et al, 2001; Reed et al., 2004; Troped et al., 2005; Pierce et al., 2006; Krizek and Johnson 2006; Reed and Wilson, 2006). The need to investigate the characteristics of community trails that support physical activity is underscored by research indicating that the presence of parks and trails for leisure-time walking, in addition to the number of destinations for utilitarian walking, is positively associated with higher physical activity levels (King et al., 2003). A review of eighteen studies concerned with environmental influences on walking concluded that the features of places associated with walking for recreation were different in some cases from those associated with walking to get to and from places (Owen et al., 2004). Because community trails are themselves embedded in parks and within neighborhoods, the associations between characteristics of trails and the characteristics of the neighborhoods where they are located are an important area for research. Differences in the characteristics of trails associated with differences in neighborhood environments may attract different types of trail users engaging in different physical activities. This issue is, to our knowledge, largely unstudied.

The aim of this study is to explore associations between the site and situation characteristics of community trails as landscapes promoting physical activity. Site characteristics are features of the trails themselves, including characteristics such as trail width, surface material, amenities, and land use mix in the immediate trail corridor. Situation characteristics are neighborhood contextual factors including street network density, land use mix, housing density, and sociodemographic composition. Trail segment and neighborhood characteristics associated with trail segments (henceforth referred to as trail segment neighborhood characteristics) of six trails in northeastern Massachusetts were assessed from primary GPS data and from secondary Census and land use data integrated in a GIS. Correlation analysis was used to test hypotheses about the relationships between trail segment neighborhood characteristics and trail segment characteristics. Data from surveys conducted with trail users at five of the six facilities highlight the connections between trail and neighborhood characteristics and trail use.

## Methods

### Site Descriptions

The six trails selected for this study differ in their configurations and community settings (Figure 1), so that associations between trail and neighborhood characteristics can be analyzed for linear and loop trails in urban, suburban, and exurban environments. Three of the trails—Southwest Corridor, Minuteman Commuter Bikeway, and Nashua River Rail Trail—are essentially linear trails. In the typology suggested by Searns (1995), they would be considered second generation greenways that are trail-oriented and provide access to rivers, rail beds, or transportation corridors within the urban fabric. Southwest Corridor consists of 21 hectares of linear parkland, fields, and community gardens surrounded by dense urban development. The Massachusetts Bay Transportation Authority (MBTA) Orange rapid transit line and a commuter rail line from Forest Hills Station in Jamaica Plain to Back Bay Station near Copley Square in Boston run through the Corridor (Crewe, 2001). This area was originally to have been the site of a major radial interstate highway. At the end of the 1960s, community activists fought construction, and a moratorium on all highway construction inside the Route 128 beltway around Boston was enacted in 1970. The project was completed in 1987. Along most of the length of the linear park, a trail for bicyclists runs parallel to a trail for pedestrians. In some places, the pedestrian trail merges with the sidewalk paralleling the street.

The Minuteman Commuter Bikeway runs west from the MBTA rapid transit Alewife Station in Cambridge through suburban Arlington and Lexington to Bedford. The trail roughly parallels Massachusetts Avenue and links the main commercial centers of Arlington and Lexington. It was built by the state on a rail bed after service was discontinued in 1981. Construction was completed in 1993. It is managed jointly by the communities it links.

The Nashua River Rail Trail, the most recently completed trail of the six studied, travels south from the New Hampshire border to Ayer, Massachusetts, in the least developed neighborhood setting of the six facilities. It provides access to the small town centers of Pepperell, Groton, and Ayer. The right-of-way contained the Hollis Branch of the Boston & Maine Railroad. The line was last used in 1982. The trail was officially dedicated in 2002.

The other three trails—at Franklin Park, Cutler Reservation, and Danehy Park—are characterized by closed connecting loops and are embedded in recreation areas. Franklin Park is part of Boston's Emerald Necklace designed by Frederick Law Olmstead. These parks run through Boston and Brookline and suffered decline over the last fifty years. Franklin Park is 173 hectares and includes a golf course, one of the oldest public courses in the U.S., and a zoo. It is situated in a densely developed urban area.

The Cutler Reservation site is 283 hectares and includes the largest freshwater marsh on the middle section of the Charles

River. It is a wetland preserve at one time managed by the local water authority but now managed by the Massachusetts Department of Conservation and Recreation. It is adjacent to an office park in a suburban location in the towns of Needham and Dedham. Route 128 forms its western border. The unpaved trails at Cutler Reservation include one primary trail that loops around a large pond and other secondary trails through the marsh.

Danehy Park is a 20-hectare facility built on the site of the former city landfill in Cambridge. The landfill was closed in the early 1970s and the city reclaimed the space as a recreational area. The paved trails at Danehy Park loop around athletic fields and courts for basketball, softball, soccer, and football and play areas with equipment for children. The main axis of the trail system contains parallel trails for bicyclists and pedestrians and connects a residential neighborhood to a shopping center.

Although these trails developed in different eras for different purposes, they were all intentionally developed to create healthier environments. The Southwest Corridor substituted a public transit line and linear park for a highway that would have disrupted city neighborhoods and contributed to air pollution. The rail trails, Minuteman Bikeway and Nashua River Rail Trail, replaced unused railway properties with useable space for utilitarian or recreational walking and cycling. Danehy Park reclaimed contaminated land for recreational use. Cutler Reservation allowed recreational use compatible with wetland preservation. The parks and community neighborhoods within which these trails were developed, however, were essentially given. The data collected for this study make it possible to assess associations between neighborhood characteristics and trail characteristics.

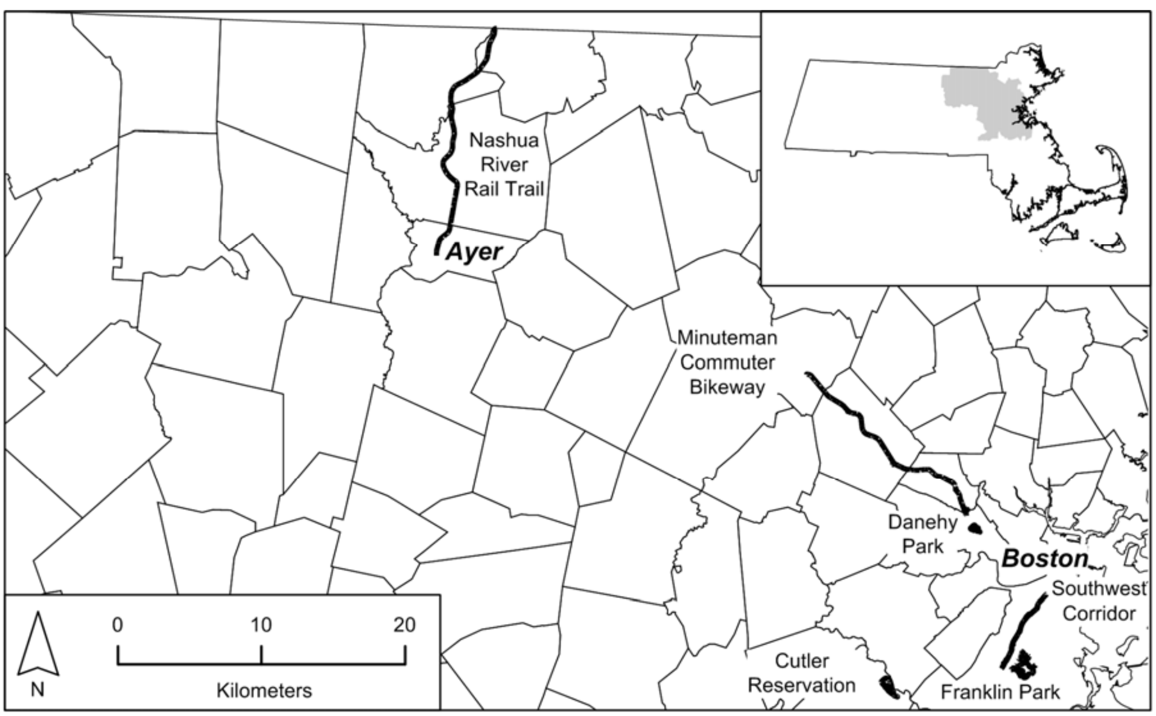


**Figure 1.** The study area and six trail sites.

## Trail Segment and Segment Neighborhood Variables

Data on thirteen variables were collected for the study and used to analyze correlations between trail segment and trail segment neighborhood characteristics (Table 1). Seven variables describe the characteristics of the community trails. Data collected by field observation using GPS were imported into a GIS for analysis and integration with other spatially-referenced databases. Six variables measure the characteristics of the neighborhoods surrounding the trails. "Spatiophysical" variables of this type are used in instruments for conducting environmental audits of neighborhood features that support walking and cycling (Moudon and Lee, 2003). Neighborhoods were defined by network analysis. Distance from each trail access point was measured along the street network to identify segments within 800 m of the access point. Finally, various correlations measure associations between the neighborhood contextual variables and trail segment characteristics.

## Trail Segment Definition and Data Collection

A major obstacle in comparative studies of community trails is data availability. Maps and digital spatial databases of community trails and neighborhoods are generally compiled at the local level in different formats at different scales and at different points in time. Digital data offer the advantage of integration with other data on street networks and land use in a GIS. Although maps, design plans, and digital databases existed for some of the trails in this study, no map or digital database was available for Cutler Reservation. Several of the available paper maps were too small-scale for the purposes of the study. Some of the existing street network or rail databases like the Census Tiger/Line files and databases distributed by various Massachusetts state agencies included some segments for some of the trails.

To overcome this obstacle, GPS was used to collect data in the field so that consistent data at the same scale would be available for all sites to develop the GIS database of trails. A trail segment entity was selected as the basic unit of observation for which attributes were defined and observed (Worboys and Duckham, 2004). Trail segments were defined based on intersection with other trails, level of circulation, intersection with other surfaces, trail width, and surface material. Because trails are much like a street network, the trails database was designed with explicit start and end nodes (Chang, 2006) and segments were defined to represent different levels of circulation. Based on preliminary field observation, it was clear that trail segments intersected other surfaces over the course of the trail. In some places, the trail disappeared as it traversed a parking lot, intersecting road, or athletic field or ran along overpasses or underpasses of streets or other trail segments. In order to capture these relationships, change in trail intersecting surface was used to identify start and end points of trail segments.

Trail width in meters is another trail characteristic tied to intended uses. Rail trail design specifications recognize the minimum trail width needed to accommodate pedestrians, bicyclists, and wheelchair users passing in opposite directions on the trail (Flink et al., 2000). Trail width was measured directly in the field at the start of each trail segment and checked periodically. Whenever trail width changed by more than approximately 10 percent, a new trail segment was identified even if the trail did not intersect with any other trail segment or traverse an intersecting road.

Finally, surface material was used as a basis for identifying and characterizing trail

**Table 1**
**Trail Segment, Trail Segment Neighborhood, and Trail/Neighborhood Association Variables and Measures**

| Object | Variable/Measure | Domain | Source |
|---|---|---|---|
| Trail Segment | Length | x.x (meters) | GPS |
| | Circulation Level | Access; Primary; Secondary; Bike Primary; Bike Secondary; Wheelchair | GPS |
| | Intersecting Surface | Athletic Field; Intersecting Road; Overpass; Parking Lot; Trail; Underpass | GPS |
| | Width | x.x (meters) | GPS |
| | Surface Material | Asphalt; Brick; Composite; Concrete; Dirt; Dirt/Grass; Dirt/Gravel; Grass; Metal; Recycled Plastic; Sand; Stone Dust; Wood; Wood Chips | GPS |
| | Trail Amenities | Trail amenity mix | GPS |
| | Trail Land Use Mix | Land use mix of five land uses within 100 m buffer | MassGIS |
| Neighborhood | Street Density | Length (km) of street per square km | MassGIS Granit |
| | Neighborhood Land Use Mix | Land use mix of five land uses | MassGIS |
| | Housing Density | Occupied housing units per square km | Census 2000 |
| | Race | Percent population African American | Census 2000 |
| | Ethnicity | Percent population of Hispanic origin | Census 2000 |
| | Family Income | Percent of families with income below US $50,000 | Census 2000 |
| Trail/ Neighborhood | Street Connectivity Correlation | Correlation between Neighborhood Street Density and Trail Segment Length and Intersecting Roads | Derived |
| | Land Use Mix Correlation | Correlation between Neighborhood Land Use Mix and Trail Segment Corridor Land Use Mix | Derived |
| | Neighborhood/ Amenities Correlations | Correlation between Neighborhood Street and Housing Densities, Neighborhood Demographics and Trail Segment Amenity Mix | Derived |

segments. Like trail width, surface material is a factor that affects the suitability of the trail for various types of physical activity. Whenever the surface material changed, a new trail segment was identified.

The trail segment variables identified in Table 1 were used to create a data dictionary for data collection on trails and trail amenities in the field using GPS. During July, 2003, a three to four person team walked the length of each trail system except at Cutler Reservation and Franklin Park. At Cutler Reservation, only the main trail loop around a reservoir and selected secondary trails were surveyed. In Franklin Park, GPS data were collected on only the main walking loop, a set of secondary trail segments leading to an overlook of the golf course, and access segments connecting the main loop to the perimeter of the park. In addition to trail segment data and characteristics, a wide range of trail amenities and design features including trail access points were marked using the GPS receiver. Data were collected by GPS for approximately 71 kilometers of primary trails for walking or cycling, secondary trails, and access trails and more than 2,800 trail amenities including lights, benches, and signs (Table 2).

GPS trail segments were further processed to create segments with uniform characteristics and a target length of 400 m. These segments are referred to as PEAT segments after the Path Environment Audit Tool, a computer-based tool developed and tested by our team to assess trail characteristics using trained observers (Troped et al., 2006). Intersecting road segments were coded as individual PEAT segments.

Data on trail amenities were exported from the GPS software as point shapefiles. Once the trail segment database was processed, the locations of the amenities were displayed in the GIS. Because the locations of the amenities were captured as field observers walked past them on the trail, they are approximations of the true locations of the amenities.

Amenities were assigned to PEAT segments using ArcGIS 9.1. In some places, dedicated bicycle trail segments parallel multi-purpose trail segments and amenities service both. A 3 m buffer was created around multi-purpose trail PEAT segments and a 10 m buffer was created around bicycle trail PEAT segments. Amenities that fell within the buffer were assigned to the associated PEAT segment. If an amenity fell within more than one buffer it was assigned to all the associated PEAT segments.

Microsoft Access was used to group the records by PEAT segment and calculate the count of each type of amenity for each segment. Since an ideal trail has not only an adequate number of amenities, but also a mixture of amenities that serve the needs of a wide range of users, a measure of trail amenity mix was developed. This measure is a measure of diversity analogous to measures of land use mix used in studies of neighborhood walkability (Frank et al., 2004) Trail amenity mix (TAM) was calculated as:

$$TAM = -\left(\sum_{i=1}^{n} p_i \ln p_i\right) / \ln n$$

where $p_i$ is the proportion of amenities attributed to amenity type $i$ associated with the trail segment and $n$ is the number of amenity type categories. The index ranges from 0 to 1 with high values indicating a high mix of amenities and low values indicating the presence of only some amenities. Trail segments with no amenities were assigned a TAM value of 0. The index was calculated based on seven selected amenities: emergency call boxes, lights, public telephones, signs, drinking water, seating, and trash receptacles. These amenities were selected because of their

**Table 2**
**Count of selected common trail amenities/features by study site**

| | Linear Urban | Linear Suburban | Linear Exurban | Loop Urban | Loop Urban | Loop Conservation |
|---|---|---|---|---|---|---|
| Trail amenities/ features | Southwest Corridor | Minuteman Commuter Bikeway | Nashua River Rail Trail | Franklin Park | Danehy Park | Cutler Reservation |
| Features | | | | | | |
| Access points | 100 | 86 | 22 | 36 | 9 | 3 |
| Amenities | | | | | | |
| Safety Amenities | | | | | | |
| Bollards/Boulders | 27 | 32 | 26 | 33 | 6 | 0 |
| Curb cuts | 65 | 59 | 20 | 21 | 10 | 5 |
| Emergency call boxes | 0 | 0 | 0 | 0 | 2 | 0 |
| Gates | 2 | 21 | 1 | 3 | 1 | 1 |
| Lights | 466 | 46 | 0 | 59 | 21 | 0 |
| Public telephones | 0 | 1 | 0 | 0 | 3 | 0 |
| Signs | 186 | 116 | 113 | 29 | 32 | 8 |
| Traffic signals | 18 | 70 | 41 | 4 | 0 | 1 |
| Wheelchair cutouts | 0 | 4 | 0 | 0 | 2 | 0 |
| Convenience Amenities | | | | | | |
| Bicycle stands | 18 | 8 | 4 | 0 | 9 | 0 |
| Dog litter bags | 0 | 0 | 0 | 0 | 2 | 0 |
| Drinking water | 0 | 2 | 0 | 3 | 4 | 0 |
| Parking areas | 1 | 11 | 6 | 6 | 4 | 1 |
| Seating | 101 | 21 | 7 | 71 | 42 | 5 |
| Shelters | 0 | 0 | 0 | 2 | 2 | 0 |
| Tables | 1 | 3 | 0 | 36 | 32 | 0 |
| Toilets | 0 | 3 | 2 | 7 | 5 | 0 |
| Transit stops | 10 | 1 | 0 | 5 | 0 | 0 |
| Trash receptacles | 158 | 21 | 2 | 123 | 31 | 3 |
| Recreation Amenities | | | | | | |
| Play areas | 9 | 2 | 0 | 5 | 4 | 0 |
| Exercise areas | 9 | 1 | 0 | 2 | 3 | 0 |
| Aesthetic Amenities | | | | | | |
| Public art | 9 | 3 | 0 | 0 | 3 | 0 |
| Views/overlooks | 0 | 0 | 4 | 6 | 2 | 0 |
| Total Amenities | 1,080 | 425 | 228 | 415 | 220 | 27 |
| Total Length (km)[a] | 13.6 | 18.6 | 18.3 | 10.3 | 4.8 | 5.4 |
| Amenity Density (/km)[b] | 79.4 | 22.8 | 12.7 | 40.3 | 45.8 | 5.0 |

[a] Length of all access, primary, bicycle, and secondary trail segments
[b]Calculated as Total Amenities/Total Length (km)x100

importance as safety or convenience features that might affect trail use.

To describe the immediate land use in the trail corridor, the trail segments were buffered to a width of 100 m. Detailed land use data for Massachusetts based on 1999 aerial photographs was obtained from the Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs, a state government repository for public GIS data. The 100 m buffer for each PEAT segment was intersected with the land use database and the area and percent of the buffer for each land use was calculated. Land use mix (LUM) was calculated following the procedure described in Frank et al. (2004):

$$LUM = -\left(\sum_{i=1}^{n} p_i \ln p_i\right) / \ln n$$

where $p_i$ is the proportion of square meters attributed to land use $i$ inside the buffer and $n$ is the number of land use categories. Five land use categories were included: residential, commercial, industrial, recreational, and urban public land. Because the land use categories used to classify the MassGIS land use data did not match those used by Frank from a county tax assessment database, the MassGIS industrial category substituted for Frank's office category and the MassGIS urban public category substituted for Frank's institutional category. Recreational land use, though not included by Frank, was used in this study because many of the trail segments are located in or adjacent to areas set aside for recreational use.

## Segment Neighborhoods Definition and Data Collection

Neighborhood contextual variables for trail segments were developed for neighborhood areas defined around trail access points. These neighborhoods are areas where trail users potentially live or pass through on the way to the trails. Network buffers from trail access points extending 800 m along the street network were constructed using the ArcGIS 9.1 Network Analyst extension (Figure 2). The street network database was constructed from 1:24000/25000 scale street data available from agencies in Massachusetts and New Hampshire (Office of Geographic and Environmental Information (MassGIS), 2003; New Hampshire Geographically Referenced Analysis and Information Transfer System (NH Granit), 2003). Interstate highways were excluded from the street network prior to creating the network buffers because pedestrians and cyclists would not travel along these segments to access the trails. All but one access point neighborhood area fell completely within Massachusetts.

Street network density was measured by determining the length of each street segment that fell completely within the neighborhood network, summing the segment lengths, and dividing by the area of the neighborhood buffer.

To assess land use characteristics of the neighborhoods, land use data were intersected with network buffers and the area and percent of the network buffer for each land use was calculated. Land use mix (LUM) was calculated following the procedure described for calculating land use mix within the trail segment corridor.

Neighborhood contextual variables derived from US Census data for 2000 were also used. These included a measure of housing density, family income, and the race and ethnicity of the neighborhood populations. Neighborhood measures were estimated using simple areal interpolation (Chang, 2006), assuming that housing and population were uniformly distributed within the Census geographical reporting units. Census blocks and block groups were intersected with the neighborhood network buffers and the proportion of each census

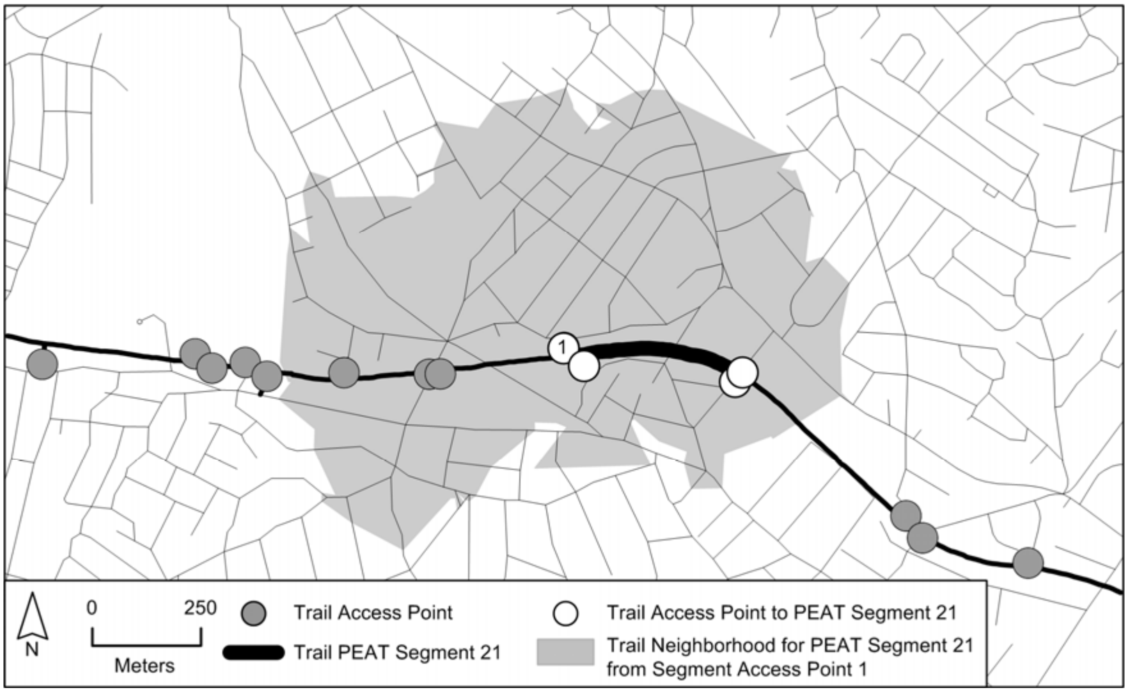


**Figure 2.** The 800 m network neighborhood of defined for one of the four access points to PEAT segment 21 of the Minuteman Commuter Bikeway.

area that fell within the buffer was calculated. This proportion was used as a weight to estimate the value for the neighborhood.

Number of occupied housing units and population count by race and Hispanic origin are reported for census blocks. Family income is reported for block groups. To compute housing density, the number of occupied housing units in the neighborhood area was summed and divided by the area of the neighborhood. For race and Hispanic origin, the population by race and Hispanic origin was summed and the percent of the total estimated neighborhood population was calculated. For 1999 household income, the percent of families with income less than US $50,000, which is approximately the median income in the state, was calculated. These neighborhood measures were included to address the issue of differential access to trails among socioeconomic groups (Lindsey et al., 2001).

Neighborhood characteristics were associated with trail segments by first assigning the characteristics of each neighborhood to its associated trail access point. All PEAT segments were associated with access points (Figure 2). If an access point marked the beginning or end of a PEAT segment or a point on a PEAT segment, the access point was assigned to the PEAT segment. Otherwise, PEAT segments were associated with access points on intersecting access trails or with the access point nearest to an end point of the PEAT segment. PEAT segments were assigned up to 4 access points. In the few cases where there were more than 4 access points associated with a trail, the 4 closest access points to the trail segment were assigned. PEAT segments were assigned the average of all associated access point neighborhood variables.

## Statistical Analysis

Correlation analysis to calculate Pearson's r was used to test several hypotheses about the relationships between trail segment characteristics and trail segment neighborhood characteristics:

- High neighborhood street density is associated with shorter trail segment lengths for linear trails, but not for loop trails embedded in parks
- High neighborhood land use mix is associated with higher land use mix within the trail corridor for linear trails, but not for loop trails embedded in parks
- High neighborhood street and housing densities found in urban environments are associated with higher presence and mix of trail amenities
- High neighborhood family incomes and low neighborhood minority populations are associated with higher mix of trail amenities.

Once the trail segment and trail neighborhood segment variables were derived for each PEAT trail segment, correlations between neighborhood and trail segment characteristics were calculated for PEAT trail segments as the units of analysis. For this analysis, 199 PEAT primary trail segments were included. Access trail segments, intersecting road segments, and secondary trail segments were excluded. These analyses were performed using PROC CORR in SAS 9.1.

### Integrating Trail User Data

The development of a community trail is an environmental intervention with the potential to affect levels of physical activity in the population. Ogilvie et al. (2006) point out the challenges of evaluating the impacts of these interventions as natural experiments. It is important, nevertheless, to integrate research on characteristics of the built environment with the community's perspective on trails and trail use behavior. Partly for this purpose, trail user surveys were conducted at five of the six facilities during the Fall of 2004 and Spring/Summer of 2005. Adult trail users (18 years of age and older) who were walking, jogging/running, bicycling, or in-line skating on the trails were approached by research staff and asked to complete a brief survey. The survey included sociodemographic items (e.g., age, race/ethnicity) and a series of questions related to use of the trail for recreation and/or transportation. The specific trail location for intercepts, time of day, and day of the week were systematically varied to reduce bias. Surveys were conducted on at least two weekdays and two weekend days during the Fall of 2004 and Spring/Summer of 2005. A total of 1,194 surveys were completed.

## Results

### Trail Segment Characteristics

Descriptive statistics on trail segment characteristics by trail are summarized in Table 3. Excluding primary trail segments that cross intersecting roads, lengths of primary trail segments vary by type of trail and by community setting. The three linear trails had longer trail segments than the three loop trails. Trail segment lengths for both types of trails increased as the level of urbanization decreased. At Southwest Corridor, an urban linear trail, mean trail segment length was more than 100 m shorter than at the Nashua River Rail Trail. Similarly, trail segments at Franklin Park were shorter than trail segments at Cutler Reservation.

Width and surface materials showed little variability for segments within a trail. The median trail width ranged from 2.0 m at Danehy Park to 3.6 m at the Minuteman Commuter Bikeway. Standard deviations in trail width were all less than half a meter except at Franklin Park, an urban loop trail, and Southwest Corridor, an urban linear trail. These parks, along with Danehy, also exhibited a greater mix in trail surface material. Franklin Park's trails were a mix of asphalt and concrete; Danehy Park's a mix of asphalt and brick. Along Southwest Corridor, trail segments were a mix of asphalt, concrete, and brick. The other linear trails, however, were asphalt (98% of total primary trail at Minuteman and 100% at Nashua). At Cutler Reservation, the trail segments were all dirt or dirt and gravel.

The land use mix within each 100m trail corridor shows that land use mix is highest for the trails in urban and suburban areas, as compared to either exurban or conservation areas (Table 3). Of note, the levels of land use mix along the trail segment corridor are consistently higher for the linear trails across community settings than for the loop trails. The land use mixes for Southwest Corridor and Minuteman Commuter Bikeway are higher than the mixes for Franklin Park and Danehy Park, while the mix for Nashua River Rail Trail is higher than the mix for Cutler Reservation.

In terms of amenities, the average count of selected trail amenities by primary trail segment (Table 3) shows that Southwest Corridor trail segments had by far the highest mean number of amenities. This is due primarily to the presence of lights along the trail. The average trail amenity mix, however, was highest at Danehy Park. Trail segments from urban and suburban trails had higher presence and mix of amenities than exurban trails regardless of whether the trail was a linear or a loop trail.

## Segment Neighborhood Characteristics

Descriptive statistics on trail segment neighborhood characteristics by trail are summarized in Tables 4 and 5. Neighborhood contextual variables differ from trail to trail but can also vary considerably for trail segments of the same trail (Figures 3, 4, and 5). Neighborhood street density is lower in less urbanized areas. These differences are seen across trail facilities and within facilities. For example, as the Minuteman Bikeway passes southeast to northwest from Arlington to Bedford, the neighborhood street density falls dramatically (Figure 3). Neighborhood housing density characteristics are similar to the patterns for street density.

Neighborhood land use mix is particularly high for urban trail segments (Figure 4). An exception to this is the northern part of the main loop at Franklin Park. Land use mix is lowest for the long stretches of Nashua River Rail Trail outside the town centers of Pepperell, Groton, and Ayer. These sections of the trail run through woodland areas with low density residential development. On average, neighborhood land use mix is higher than land use mix within the immediate trail corridor for the same trail.

Neighborhood income characteristics are more homogeneous for segments of the same trail in suburban and exurban areas. The two trails in Boston and adjacent suburbs, Southwest Corridor and Franklin Park, however, both serve neighborhoods with a broader range of family income characteristics (Figure 5). Southwest Corridor and Franklin Park trail segments have the lowest income neighborhoods and the greatest variability in neighborhood incomes.

## Correlations between Trail Segment and Segment Neighborhood Characteristics

For all primary trail segments, there was a statistically significant negative

**Table 3**
**Trail Segment Characteristics by Study Site**

| | | Linear | | |
|---|---|---|---|---|
| | | Urban | Suburban | Exurban |
| Trail Segment Variable | | Southwest Corridor (n = 40 ) | Minuteman Commuter Bikeway (n = 56 ) | Nashua River Rail Trail (n = 48) |
| Trail Segment Length m | Mean | 268.3 | 287.9 | 377.2 |
| | Median | 255.3 | 308.2 | 398.7 |
| | SD | 138.6 | 110.9 | 114.1 |
| | Min | 50.6 | 30.4 | 69.3 |
| | Max | 524.5 | 575.8 | 588.1 |
| Trail Segment Corridor Land Use Mix | Mean | 0.48 | 0.44 | 0.18 |
| | Median | 0.48 | 0.43 | 0.18 |
| | SD | 0.14 | 0.18 | 0.57 |
| | Min | 0.00 | 0.02 | 0.00 |
| | Max | 0.66 | 0.85 | 0.15 |
| Selected Amenity Count [a] | Mean | 17.1 | 3.6 | 2.5 |
| Trail Amenity Mix | Mean | 0.27 | 0.18 | 0.03 |
| | Median | 0.41 | 0.11 | 0.00 |
| | SD | 0.26 | 0.20 | 0.09 |
| | Min | 0.00 | 0.00 | 0.00 |
| | Max | 0.67 | 0.57 | 0.46 |

| | | Loop | | |
|---|---|---|---|---|
| | | Urban | Urban | Suburban |
| | | Franklin Park (n = 29) | Danehy Park (n = 15) | Cutler Reservation (n = 11) |
| Trail Segment Length | Mean | 195.8 | 257.4 | 239.4 |
| | Median | 203.9 | 206.0 | 222.5 |
| | SD | 97.6 | 147.4 | 98.3 |
| | Min | 65.6 | 36.9 | 109.4 |
| | Max | 409.3 | 528.1 | 431.6 |
| Trail Segment Corridor Land Use Mix | Mean | 0.21 | 0.33 | 0.07 |
| | Median | 0.18 | 0.35 | 0.00 |
| | SD | 0.11 | 0.18 | 0.10 |
| | Min | 0.02 | 0.02 | 0.00 |
| | Max | 0.41 | 0.61 | 0.20 |
| Selected Amenity Count | Mean | 4.7 | 7.6 | 0.7 |
| Trail Amenity Mix | Mean | 0.14 | 0.39 | 0.09 |
| | Median | 0.00 | 0.33 | 0.00 |
| | SD | 0.18 | 0.29 | 0.16 |
| | Min | 0.00 | 0.00 | 0.00 |
| | Max | 0.54 | 0.78 | 0.36 |

[a] Includes emergency call boxes, lights, public telephones, signs, drinking water, seating, and trash receptacles.

**Table 4**
**Trail Segment Neighborhood Street, Land Use, and Housing Characteristics by Study Site**

| Trail Segment Neighborhood Variable | | Linear: Urban<br>Southwest Corridor | Linear: Suburban<br>Minuteman Commuter Bikeway | Linear: Exurban<br>Nashua River Rail Trail |
|---|---|---|---|---|
| Street Density | Mean | 17.7 | 10.9 | 4.9 |
| | Median | 17.4 | 10.2 | 3.8 |
| | SD | 1.6 | 4.1 | 3.0 |
| | Min | 15.0 | 3.7 | 1.8 |
| | Max | 20.7 | 17.4 | 11.1 |
| Land Use Mix | Mean | 0.67 | 0.47 | 0.29 |
| | Median | 0.67 | 0.43 | 0.26 |
| | SD | 0.07 | 0.12 | 0.15 |
| | Min | 0.06 | 0.28 | 0.13 |
| | Max | 0.55 | 0.68 | 0.56 |
| Housing Density | Mean | 3,591.6 | 900.7 | 149.4 |
| | Median | 2,521.8 | 456.8 | 65.6 |
| | SD | 2,273.3 | 760.9 | 162.5 |
| | Min | 1,744.0 | 23.2 | 12.5 |
| | Max | 9,032.3 | 2,559.8 | 531.1 |

| Trail Segment Neighborhood Variable | | Loop: Urban<br>Franklin Park | Loop: Urban<br>Danehy Park | Loop: Suburban<br>Cutler Reservation |
|---|---|---|---|---|
| Street Density | Mean | 11.1 | 13.7 | 5.0 |
| | Median | 9.3 | 15.4 | 5.3 |
| | SD | 4.1 | 2.4 | 0.3 |
| | Min | 6.8 | 10.3 | 4.6 |
| | Max | 21.3 | 16.3 | 5.3 |
| Land Use Mix | Mean | 0.48 | 0.70 | 0.31 |
| | Median | 0.46 | 0.70 | 0.33 |
| | SD | 0.13 | 0.05 | 0.03 |
| | Min | 0.22 | 0.63 | 0.28 |
| | Max | 0.72 | 0.78 | 0.33 |
| Housing Density | Mean | 670.3 | 1,908.6 | 47.9 |
| | Median | 157.2 | 2,480.0 | 56.5 |
| | SD | 943.9 | 1,000.2 | 9.9 |
| | Min | 0.1 | 503.6 | 37.5 |
| | Max | 2,730.8 | 2,896.7 | 56.5 |

**Table 5**
**Trail Segment Neighborhood Sociodemographic Characteristics by Study Site**

| | | Linear | | |
|---|---|---|---|---|
| | | Urban | Suburban | Exurban |
| | | Southwest Corridor | Minuteman Commuter Bikeway | Nashua River Rail Trail |
| Percent African American | Mean | 30.2 | 2.0 | 0.9 |
| | Median | 30.7 | 1.5 | 0.2 |
| | SD | 12.4 | 4.5 | 1.6 |
| | Min | 13.8 | 0.1 | 0.0 |
| | Max | 53.6 | 34.6 | 5.4 |
| Percent Hispanic | Mean | 27.7 | 2.0 | 1.0 |
| | Median | 25.8 | 1.8 | 0.5 |
| | SD | 11.3 | 1.6 | 1.1 |
| | Min | 7.4 | 0.7 | 0.0 |
| | Max | 48.5 | 13.3 | 3.5 |
| Percent Low Income | Mean | 62.6 | 22.3 | 23.3 |
| | Median | 62.6 | 20.0 | 22.0 |
| | SD | 11.9 | 8.3 | 11.5 |
| | Min | 32.0 | 12.2 | 10.4 |
| | Max | 81.5 | 53.1 | 50.2 |
| | | Loop | | |
| | | Urban | Urban | Suburban |
| | | Franklin Park | Danehy Park | Cutler Reservation |
| Percent African American | Mean | 45.7 | 23.7 | 1.7 |
| | Median | 37.9 | 23.9 | 1.2 |
| | SD | 20.1 | 5.0 | 0.6 |
| | Min | 25.6 | 17.4 | 1.2 |
| | Max | 81.0 | 30.5 | 2.3 |
| Percent Hispanic | Mean | 18.8 | 5.3 | 1.2 |
| | Median | 18.2 | 4.3 | 1.0 |
| | SD | 3.6 | 1.5 | 0.2 |
| | Min | 15.2 | 4.2 | 1.1 |
| | Max | 26.8 | 7.6 | 1.4 |
| Percent Low Income | Mean | 50.3 | 43.7 | 15.9 |
| | Median | 51.4 | 43.1 | 16.0 |
| | SD | 18.6 | 4.2 | 11.0 |
| | Min | 29.4 | 37.2 | 15.8 |
| | Max | 82.6 | 49.9 | 16.0 |

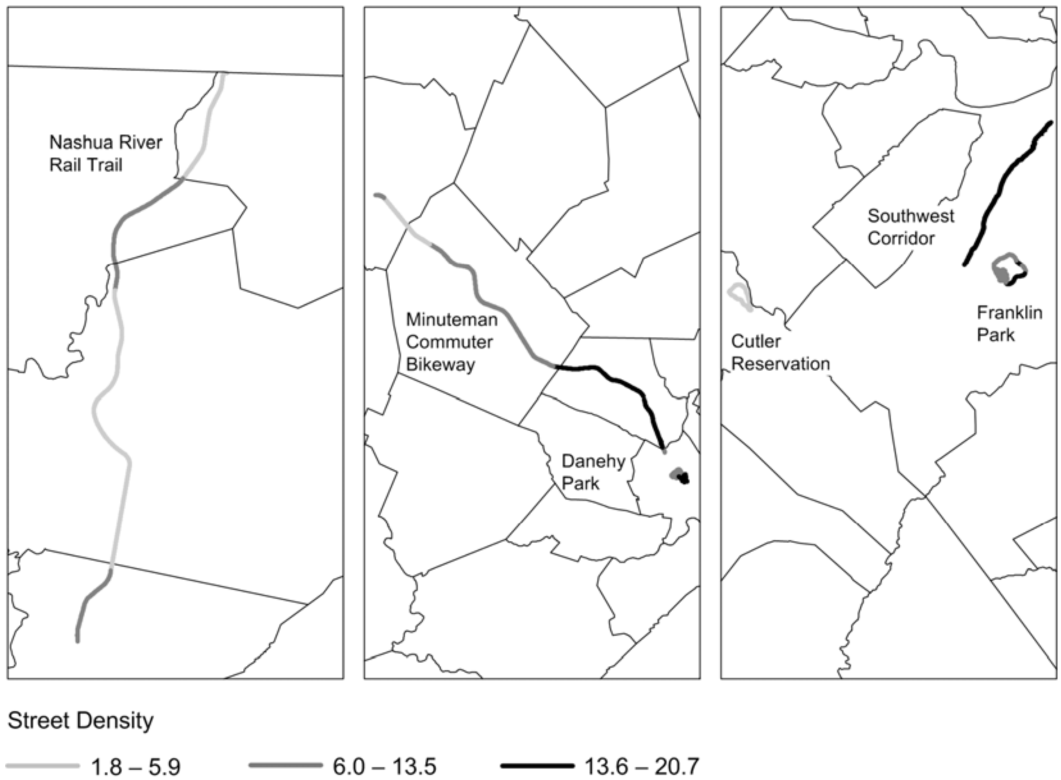


**Figure 3.** Variability in trail segment neighborhood street network density across and within study sites.

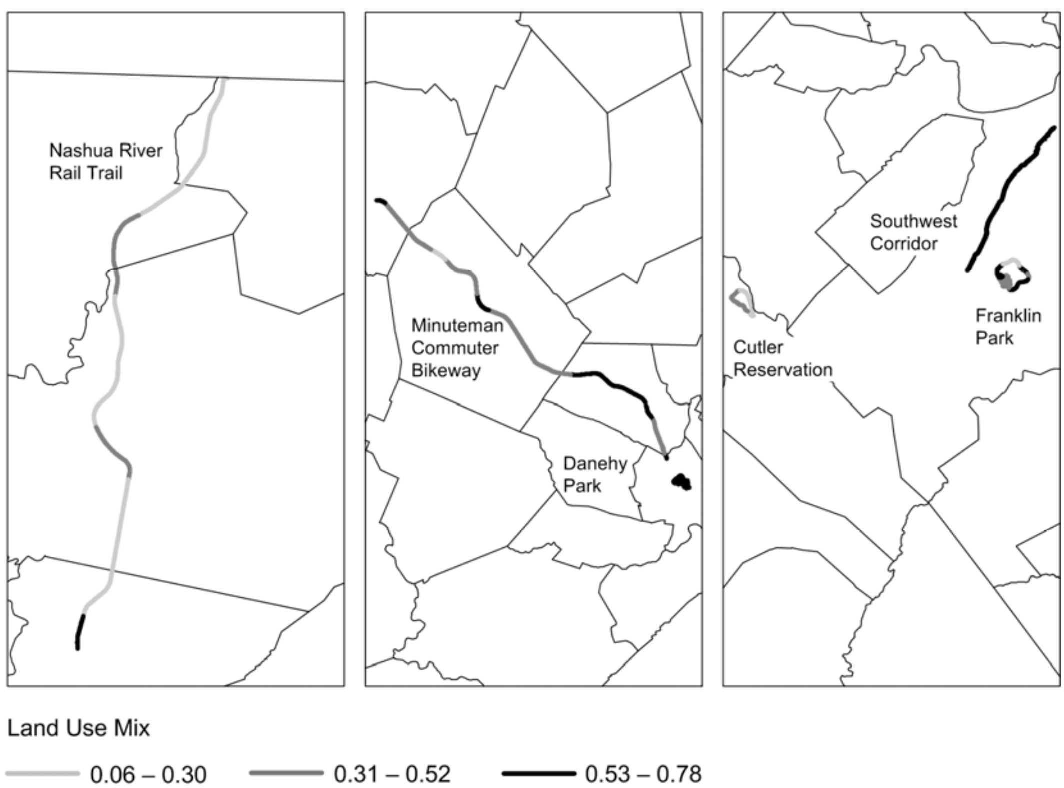


**Figure 4**. Variability in trail segment neighborhood land use mix across and within study sites.

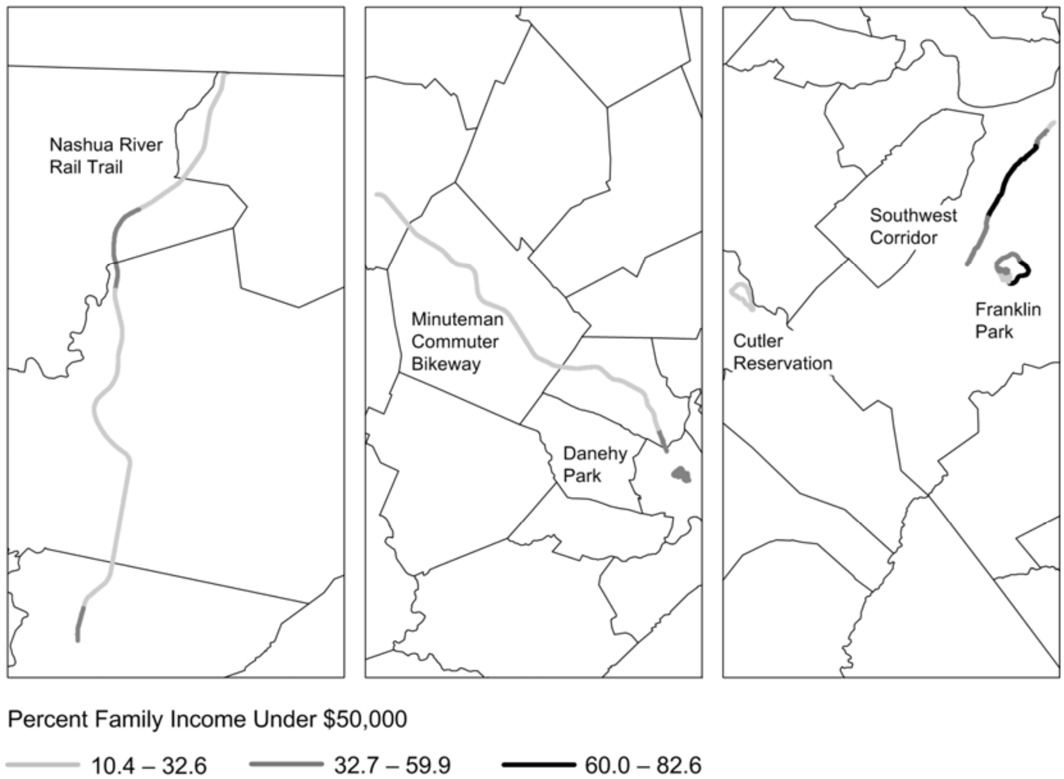


**Figure 5.** Variability in trail segment neighborhood income across and within study sites.

**Table 6**
**Correlations between Trail Segment and Trail Segment Neighborhood Characteristics**

| Trail Characteristic | Neighborhood Characteristic | All Trail Segments | Linear Trail Segments | Loop Trail Segments |
|---|---|---|---|---|
| Segment Length m | Street Density | r =-0.22844<br>p < 0.0012 | r = -0.28713<br>p < 0.0005 | r = -0.08401<br>p < 0.5420 |
| Corridor Land Use Mix | Neighborhood Land Use Mix | r = 0.56593<br>p < 0.0001 | r = 0.67271<br>p < 0.0001 | r = 0.50647<br>p <0.0001 |
| Trail Amenity Mix | Neighborhood Street Density | r = 0.42459<br>p < 0.0001 | r = 0.34424<br>p < 0.0101 | r = 0.46228<br>p < 0.0001 |
| Trial Amenity Mix | Neighborhood Housing Density | r = 0.35563<br>p < 0.0001 | r = 0.37544<br>p < 0.0001 | r = 0.42804<br>p < 0.0011 |
| Trial Amenity Mix | Neighborhood Percent Low Income | r = 0.28268<br>p < 0.0001 | r = 0.28802<br>p < 0.0005 | r = 0.23584<br>p < 0.0830 |
| Trail Amenity Mix | Neighborhood Percent African American | r = 0.25392<br>p < 0.0003 | r = 0.30173<br>p < 0.0002 | r = 0.15819<br>p < 0.2487 |
| Trail Amenity Mix | Neighborhood Percent Hispanic | r = 0.20079<br>p < 0.0045 | r = 0.29372<br>p < 0.0004 | r = -0.16279<br>p < 0.2350 |

correlation between the length of the trail segment and neighborhood street density (Table 6). There was no correlation between segment length and neighborhood street density for loop trail facilities.

Two of the linear trails are rail trails and overpasses and underpasses along these trails mean that trail segments are interrupted less frequently by intersecting roads. The total length of primary trail in Southwest Corridor is 6.2 kilometers, including only the multi-purpose (not the parallel bicycle) primary trail segments. A trail user walking the entire length of trail would traverse 17 intersecting roads. This is the same number of intersecting roads that a person walking or cycling the entire length of the Minuteman Bikeway would cross but over a distance two and half times as great. The loop trails embedded in parks do not intersect with roads and provide more continuous surfaces for walking or cycling except for places where trails segments intersect with other trail segments.

The correlation between trail segment corridor land use mix and land use mix in the trail segment neighborhoods is strong and positive. The association is stronger for trail segments in linear trails and weaker for trail segments in loop trails embedded within parks.

The correlations between trail amenity mix and neighborhood built environment characteristics support the hypothesis that there is a positive association between street network and housing density and trail amenity mix. Urban trails like the neighborhoods they serve are more likely to have lights, trash receptacles, and other amenities. Trails in exurban areas or on conservation land, on the other hand, had no lights and few other amenities.

The relationships between amenities and neighborhood demographic and socioeconomic characteristics were not consistent with the original hypotheses that higher income neighborhoods with few minorities would be served by trails with higher presence and mix of amenities. High proportion of neighborhood population with incomes below US $50,000 per year is positively associated with trail amenity mix. This suggests that trails serving low income populations are more likely to have street lights, trash receptacles, seating, signs, and other selected amenities. The correlation is significant for all trail segments, for trail segments from linear trails, and for trail segments from loop trails.

Similarly, the percent of the trail segment neighborhood population that is African American and the percent that is of Hispanic origin are also positively correlated with trail amenity mix. The relationships are significant for all trail segments and for trail segments from linear trails but the relationships are not significant for trail segments from loop trails. These correlations are probably spurious and reflect the concentrations of low income and minority populations in urban neighborhoods where trails have higher amenity mix like the surrounding built environment.

## Discussion and Limitations

The analysis of the six study sites suggests that there is an association between trail segment length and neighborhood street density for linear trails and a resulting trade-off between trail access and trail continuity. High street network density has been identified as an attribute of the built environment that enhances walkability. The presence of numerous intersections and short block lengths means, however, that linear trails in neighborhoods with high street network densities and high traffic volumes require walkers and cyclists to make frequent stops and starts which may make these areas less attractive for recreational physical activity. The trail user survey (Table 7) showed that most users at Southwest Corridor, the trail that crossed the highest number of streets,

**Table 7**
**Trail User Profiles for Five Trail Facilities**

| Trail User Characteristics | Southwest Corridor | Minuteman Commuter Bikeway | Nashua River Rail Trail | Franklin Park | Cutler Reservation |
|---|---|---|---|---|---|
| Number of users surveyed | 207 | 248 | 326 | 186 | 227 |
| Average age (years) | 38.9 ± 12.3 | 43.5 ± 12.3 | 48.2 ± 11.3 | 44.8 ± 12.3 | 46.8 ± 12.6 |
| Gender (% female) | 44.7 | 37.4 | 41.1 | 57.0 | 45.1 |
| Predominant racial/ethnic group (group and %) | White 88.2 | White 94.7 | White 98.5 | African American 77.7 | White 94.7 |
| Proportion of users usually traveling to trail from home (%) | 73.9 | 90.3 | 95.7 | 80.1 | 70.5 |
| Predominant mode of travel to trail (mode and %) | Walk 57.0 | Bike 53.4 | Car 72.1 | Car 72.6 | Car 76.3 |
| Travel time from home to trail < 15' (%) | 93.4 | 80.0 | 46.5 | 81.8 | 79.4 |
| Proportion using trail for recreation, versus transportation (%) | 27.5 | 74.5 | 98.5 | 96.8 | 100 |
| Predominant type of activity on trail (type and %) | Walk 59.9 | Cycle 67.1 | Cycle 81.3 | Walk 91.9 | Walk 75.7 |
| Used 2 or more days in past 7 days for recreation (%) | 71.0 | 63.3 | 47.2 | 69.2 | 49.5 |
| Used 2 or more days in past 7 days for transportation (%)[a] | 79.3 | 69.2 | 20.0 | 100.0 | 0.0 |

[a] Calculated for trail users who reported using the trail for transportation purposes only.

use it for utilitarian rather than recreational purposes. This is in marked contrast to trail use at Franklin Park, a nearby loop trail in a park setting, where trail use is almost exclusively recreational.

Because trail-street intersections at grade create access points to the trail, there is clearly a trade-off between access and trail continuity. In urban areas where the street network is denser, there will be more access points for linear facilities. This probably enhances the desirability of the trail for utilitarian purposes because there are more opportunities to access and exit the trail closer to residences and other destinations, but it may diminish the attractiveness of the trail facility for recreational walkers and cyclists. Southwest Corridor had the highest percentage of users living within fifteen minutes of travel time from the trail and it was the only trail where the predominant mode of travel to the trail was walking. Despite the availability of designated bicycle trail segments in the Southwest Corridor, it is the only linear trail for which cycling was not the predominant activity. If most users of greenway trails use them for recreation rather than utilitarian walking (Shafer et al., 2000), the development of trails in urban areas poses a design challenge. Planning research and practice would be enhanced if we could create spatial databases and analytical procedures capable of modeling how individuals combine driving, public transportation, cycling, or walking in utilitarian and recreational trips. Research to assess the demand for off-road trails highlighted the importance of considering a connected series of trails as a single unified route (Wigan et al., 1998).

The land use mix variables suggest that mix in the immediate trail corridor is associated with mix in the trail segment neighborhood but that the level of the mix in the trail corridor is generally lower than the mix in the surrounding neighborhoods. This may differentiate the trail environment sufficiently from alternate routes comprised of neighborhood streets to encourage or discourage trail use. Some walkers may prefer the more varied land use provided by their neighborhood over a more natural yet uniform trail corridor. In Franklin Park, the trail user surveys suggest that the women who use the trail may be attracted to the lower land use mix in the trail corridor compared to the surrounding neighborhood. Most users drive less than 15 minutes from home to walk in the park for recreation two or more days per week.

More than 50% of the users of trails in urban or suburban settings reported using the trails more than 2 days in the last week for recreation. The more remote trails, Nashua River Rail Trail and Cutler Reservation, were used almost exclusively for recreation but were used less frequently by individual trail users. Most users of these trails traveled by car and these trails had the lowest percentages of users who lived within 15 minutes of travel time to the trails. These trails also had the lowest percentages of users who were minorities. In contrast, the trail at Franklin Park was the only trail where the majority of users were African American. The trail segment neighborhoods for Franklin Park had the highest percentages of African American residents.

The relationships between trail amenity mix and neighborhood built environment and population characteristics are complex. These relationships likely reflect the concentrations of low income and minority populations in urban neighborhoods where trails have higher amenity mix like the surrounding built environment. While this is positive in one sense, it also means that low income and minority populations living in urban areas may have less access to the kinds of trails that provide opportunities for pursuing recreational activities like hiking and cycling in more natural settings unless trails are surrounded by extensive park areas.

Only two trails in the study, Southwest Corridor and Franklin Park, had trail segment neighborhoods with a wide range of income levels and high levels of racial and ethnic diversity. For the trail segments of these two trails alone, there were no significant relationships between trail segment amenity mix and trail segment neighborhood incomes or sociodemographic characteristics.

Community trails are complex features in the landscape with many characteristics that might influence their use. This research was limited to an investigation of only six trails in a large region. Nevertheless, investigating the site and situation characteristics of these trails entailed field observation of 57 kilometers of primary trail segments for multi-purpose physical activities and hundreds of trail amenities and analysis of the neighborhoods around more than 200 trail access points.

## Conclusions

This research draws on measures of neighborhood characteristics that influence walking reported in the literature, but moves beyond describing the characteristics of community trails and neighborhoods to assess the extent to which the characteristics of the trails differ depending on neighborhood context. Important differences emerged from the analysis of the interface between the trails and the surrounding street networks for linear versus loop trails in urban, suburban, and exurban settings. Both the characteristics of the trails themselves and the surrounding neighborhoods vary, not just across trails but within trails. This is especially true for linear trails.

Studies of trails as landscapes promoting physical activity need to take these variations into account. Trail user profiles indicate that trail and trail neighborhood characteristics work in association with each other to influence trail use. Further research is needed to examine how the interactive effects of trail and neighborhood characteristics influence physical activity choices, both recreational and utilitarian.

## Acknowledgements

This transdisciplinary study developed and implemented a methodology, grounded in geospatial data technologies, for describing trails and developing reliable objective measures of their characteristics. It was conducted as part of the Active Living Research Program funded by The Robert Wood Johnson Foundation to develop measures of environmental characteristics that are associated with high levels of physical activity (Torres et al., 2001). We acknowledge support from The Robert Wood Johnson Foundation, Active Living Research Program. We wish to thank our Boston-area consultants, Deneen Crosby, Aldo Gherin and Jim Purdy, and Dr. Ross Brownson, St. Louis University, and Dr. Hope Hasbrouck, University of Texas, for their input into the design and implementation of this study.

## References

Brownson, R.C., Chang, J.J., Eyler, A.A., Ainsworth, B.E., Kirtland, K.A., Saelens, B.E., Sallis, J.F. 2003. Measuring the environment for friendliness toward physical activity: A comparison of the reliability of 3 questionnaires. *American Journal of Public Health* 94(3), 473-483.

Brownson, R., Hoehner, C., Brennan, L., Cook, R., Elliott, M., McMullen, K. 2004. Reliability of two instruments for auditing the environment for physical activity. *Journal of Physical Activity and Health* 1(3), 189-207.

Brownson, R.C., Housemann, R.A., Brown, D.R., Jackson-Thompson, J.J., King, A.C., Malone, B.R., Sallis J.F. 2000. Promoting physical activity in rural communities: Walking trail access, use, and effects. *American Journal of Preventive Medicine* 18(3): 235-241.

Chang, K. 2006. *Introduction to Geographic Information Systems*. Third Edition. Boston: McGraw Hill, pp. 49, 238, 374.

Crewe, K. 2001. The quality of participatory design: The effects of citizen input on the design of the Boston Southwest Corridor. *Journal of the American Planning Association* 67(4), 437-453.

Ewing, R., Cervero, R. 2001. Travel and the built environment: A synthesis. *Transportation Research Record* 1780: 87-113.

Eyler, A.A., Brownson, R.C., Bacak, S.J., Housemann, RA. 2003. The epidemiology of walking for physical activity in the United States. *Medicine & Science in Sports and Exercise* 35(9): 1529-1536.

Flink, C., Olka, K., Searns, R. 2000. *Trails for the twenty-first century*. Second Edition. Washington, DC: Island Press.

Frank, L.D., Andresen, M.A., Schmid, T.L. 2004. Obesity relationships with community design, physical activity, and time spent in cars. *American Journal of Preventive Medicine* 27(2): 87-96.

Gesler, W.M.1992. Therapeutic landscapes: Medical issues in light of the new cultural geography. *Social Science & Medicine* 34(7): 735-746.

Gesler, W. 2005. Therapeutic landscapes: An evolving theme. *Health & Place* 11, 295-297.

Handy, S.L., Boarnet, M.G., Ewing, R., Killingsworth, R.E. 2002. How the built environment affects physical activity: views from urban planning. *American Journal of Preventive Medicine* 23(2S), 64-73.

Humpel, N., Owen, N., Leslie, E., Marshall, A. L., Bauman, A.E., Sallis, J. F. 2004. Associations of location and perceived environmental attributes with walking in neighborhoods. *American Journal of Health Promotion* 18(3), 239-242.

Kearns, R., Collins, D.C.A. 2000. New Zealand children's health camps: therapeutic landscapes meet the contract state. *Social Science and Medicine* 51(7):1047-1059.

King, W.C., Brach, J.S., Belle, S., Killingsworth, R., Fenton, M., Kriska, A.M. 2003. The relationship between convenience of destinations and walking levels in older women. *American Journal of Health Promotion* 18(1), 74-82.

Krenichyn, K. 2006. 'The only place to go and be in the city': Women talk about exercise, being outdoors, and the meanings of a large urban park. *Health & Place* 12(4): 631-643.

Krizek, K. J., Johnson, P. J. 2006. Proximity to trails and retail: Effects on urban cycling and walking. *Journal of the American Planning Association* 72(1): 33-42.

Leslie, E., Saelens, B., Frank, L., Owen, N., Bauman, A., Coffee, N., Hugo, G. 2005. Residents' perceptions of walkability attributes in objectively different neighbourhoods: a pilot study. *Health & Place* 11(3), 227-236.

Lindsey, G. Maraj, M., Kuan S. 2001. Access, equity, and urban greenways: An exploratory investigation. *Professional Geographer* 53(3): 332-346.

Lopez, R. 2004. Urban sprawl and risk for being overweight or obese. *American Journal of Public Health* 94(9), 1574-1579.

Milligan C., Gatrell A., Bingley A. 2004. 'Cultivating health': therapeutic landscapes and older people in northern England. *Social Science & Medicine* 58(9), 1781-1793.

Moudon, A.V., Lee, C. 2003. Walking and bicycling: An evaluation of environmental audit instruments. *American Journal of Health Promotion* 18(1), 21-37.

New Hampshire Geographically Referenced Analysis and Information Transfer System. 2003. *Granit*. University of New Hampshire Institute for the Study of Earth, Oceans, and Space. http://www.granit.sr.unh.edu.

Office of Geographic and Environmental Information (MassGIS). 2003. *Massachusetts Geographic Information System*. Comm. of Massachusetts Executive Office of Environmental Affairs. http://www.mass.gov/mgis/ massgis.htm.

Ogilvie, D., Mitchell, R. Mutrie, N., Petticrew, M., Platt, S. (2006). Evaluating health effects of transport interventions: Methodologic case study. *American Journal of Preventive Medicine* 31(2): 118-126.

Owen, N., Humpel, N., Leslie, E. Bauman, A., Sallis, J.F. 2004. Understanding environmental influences on walking: Review and research agenda. *American Journal of Preventive Medicine* 27(1), 67-76.

Pierce, J.R., Denison, A.V., Arif, A.A., Rohrer, J.E. 2006. Living near a trail is associated with increased odds of walking among patients using community clinics. *Journal of Community Health* 31(4): 289-302.

Reed, J.A., Ainsworth, B.E., Wilson, D.K., Mixon, G., Cook. A. 2004. Awareness and use of community walking trails. *Preventive Medicine* 39(5), 903-908.

Reed, J.A., Wilson, D.K. 2006. Awareness and use of a university recreational trail. *Journal of American College Health* 54(4): 227-230.

Saelens, B.E., Sallis, J.F., Frank, L.D. 2003a. Environmental correlates of walking and cycling: Finding from the transportation, urban design, and planning literatures. *Annals of Behavioral Medicine* 25(2), 80-91.

Saelens, B.E., Sallis, J.F., Black, J.B., Chen, D. 2003b. Neighborhood-based differences in physical activity: an environmental scale evaluation. *American Journal of Public Health* 93(9), 1552-1558.

Searns, R.M. 1995. The evolution of greenways as an adaptive urban landscape form. Landscape and *Urban Planning* 33, 65-80.

Shafer, C.S., Bong, K.L., Turner, S. 2000. A tale of three greenway trails: user perceptions related to quality of life. *Landscape and Urban Planning* 49, 163-178.

Siegel, P.Z., Brackbill, R.M., Heath, G.W. 1995. The epidemiology of walking for exercise: implications for promoting activity among sedentary groups. *American Journal of Public Health* 85(5): 706-710.

Southworth, M. 1997. Walkable suburbs? An evaluation of neotraditional communities at the urban edge. *Journal of the American Planning Association* 63(1), 28-44.

Torres, G., Hollander, M., Kraft, M., Henry, E. 2001. *Active living through community design*. Princeton, NJ: The Robert Wood Johnson Foundation.

Troped, P.J., Cromley, E.K., Fragala, M.S., Melly, S.J, Hasbrouck, H.H., Gortmaker, S.L., Brownson, R.C. 2006. Development and reliability and validity testing of an audit tool for trail/path characteristics: The Path Environment Audit Tool (PEAT). *Journal of Physical Activity and Health* 3(Suppl. 1), S158-S175.

Troped, P.J., Saunders, R.P., Pate, R.R., Reininger, B., Ureda, J.R., Thompson, S.J. 2001. Associations between self-reported and objective physical environmental factors and use of a community rail-trail. *Preventive Medicine* 32(2): 181-200.

US Department of Health and Human Services. 1996. *Physical Activity and Health: A Report of the Surgeon General.* Atlanta, GA: Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion.

US Department of Health and Human Services. 2001. *The Surgeon General's Call to Action to Prevent and Decrease Overweight and Obesity*. Rockville, MD: Office of the Surgeon General.

Wigan, M., Richardson, A., Brunton, P. 1998. Simplified estimation of demand for nonmotorized trails using geographic information systems. *Bicycle and Pedestrian Research* 1998(1636): 47-55.

Wilson, D.K., Kirtland, K.A., Ainsworth, B.E., Addy, C.L. 2004. Socioeconomic status and perceptions of access and safety for physical activity. *Annals of Behavioral Medicine* 28(1), 20-28.

Worboys, M., Duckham, M. 2004. *GIS: A Computing Perspective*. Second Edition. Boca Raton, FL: CRC Press.