Obtaining Longitudinal Built Environment Data Retrospectively across 25 years in Four US Cities

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Background: Neighborhood transportation infrastructure and public recreational facilities are theorized to improve the activity, weight, and cardiometabolic profiles of individuals living in close proximity to these resources. However, owing to data limitations, there has not been adequate study of the influence of timing and placement of new infrastructure on health over time.

Methods: This protocol details methods of the four cities study to perform retrospective field audits in order to capitalize on existing longitudinal health data from the coronary artery risk development in young adults (CARDIA) study. We developed and verified measures of recreation facilities (trails, parks) and transportation infrastructure (bus, light rail, bicycle parking, bicycle paths) in Birmingham, AL; Chicago, IL; Minneapolis, MN; and Oakland, CA (USA). We identify introductions, renovations, and closures between 1985 and 2010 to develop measures of facility and infrastructure change. Ultimately, these data were linked to CARDIA sites’ respondents’ geographic locations over the 25-year study period to examine associations with health behaviors and outcomes.

Results: Data available for retrospective audits was inconsistent by city, primarily due to record-keeping differences. We found large increases in bicycle infrastructure, with the exception of Birmingham, AL, USA. Excluding the addition of a new rail line in Minneapolis, MN, USA, few changes occurred in bus service, rail, and parks.

Conclusion: Our method represents innovation toward the collection of retrospective neighborhood data for use in longitudinal analyses. The data produced give insight into the way neighborhood infrastructure has changed over time and the potential relationship between these changes and health behaviors.

Keywords: community design, field audit, transportation, infrastructure, parks, GIS, longitudinal, methods

Abbreviations: CARDIA, coronary artery risk development in young adults; CIP, capital improvement plan; GIS, geographic information systems; PCIP, park capital improvement program; TIP, transportation improvement plan; UNC, University of North Carolina.
BACKGROUND

A large body of literature suggests that some neighborhood characteristics can influence cardiovascular health (1–4). Neighborhoods that offer access to safe and accessible recreational facilities and transportation infrastructure are theorized to improve the diet, physical activity, weight, and cardiometabolic profiles of individuals living in close proximity to these resources (5–7). Observational studies to identify the specific factors and pathways linking neighborhood environments to cardiometabolic risk factors, however, have been largely cross-sectional and have produced mixed results (8–23). The major limitations of this current body of research are selection bias and reverse causation, largely due to the faulty assumption that neighborhood resources are placed independent of all other factors and that no selective migration occurs to take advantage of these resources (24–26).

There have been dramatic changes in the US physical activity and infrastructure environments during the past few decades (27–29). Studying changes in neighborhoods over time with respect to health behaviors and outcomes could improve our understanding of how changes in environments may shape changes in behaviors, thus providing insight into the potential for community investments in infrastructure and recreational facilities. Yet, minimal longitudinal evidence exists (30–45), much of it focusing on changes due to residential relocations (33, 44, 45) rather than environmental changes around stable residents. Although policies and changes to the built environment could be evaluated as “natural” or “quasi” experiments, a recent review found only 18 studies evaluating policy or change impacts on nutrition/diet, 17 on physical activity, and 3 on body mass index, with a wide variety in the quality of the study designs (46). The largest issue is the lack of high quality, longitudinal data, and methods to study retrospective data on neighborhood infrastructure changes that could be linked to existing longitudinal cohorts of health behaviors and outcomes. This leaves fundamental gaps in our ability to study the influence of timing and placement of new infrastructure on activity behaviors, obesity, and cardiometabolic risk over time.

To this end, we created a methodology to collect, verify, and process data on dynamic infrastructure changes and quantify associations between infrastructure and health behaviors and outcomes in four US cities over a 25-year period, which we linked to high quality, longitudinal clinic data from the coronary artery risk development in young adults (CARDIA) study from 1985–1986 to 2010–2011. Specifically, we generated data to allow the development of a model to investigate how the timing and placement of changes in recreation facilities and transportation infrastructure influence: (a) individual-level physical activity, (b) patterns of weight maintenance and gain, and (c) cardiometabolic risk measures over 25 years, controlling for the purposive placement of recreation facilities and transportation infrastructure and for the selective migration of individuals to locate near such resources.

In order to accomplish this larger research goal, we developed and verified measures to capture introductions, renovations, and closures representing changes in (1) recreation facilities (e.g., trails and parks) and (2) transportation infrastructure (e.g., light rail, bike parking, and bike paths) in the NIH-funded CARDIA four cities study (R01-HL114091). We performed retrospective field audits to enhance our assessment of above mentioned facility and infrastructure data in the four original CARDIA field sites over the period from 1985–1986 to 2010–2011. In this paper, we present our protocol to perform these field audits, as well as verify and process the data collected.

METHODS/DESIGN

A flow chart of the overall process used for retrospective field audits can be found in Figure 1.

CARDIA Study

The four cities study is an ancillary study of the CARDIA study, a prospective cohort study initiated to investigate life-style and other factors that influence the evolution of coronary heart

![Flow chart of the overall process used for retrospective field audits.](image-url)
disease risk factors during young adulthood (47). CARDIA includes 5,115 participants, aged 18–30 years, who were recruited and examined in four urban areas: Birmingham, AL; Chicago, IL; Minneapolis, MN; and Oakland, CA (USA) (48) in 1985–1986 with 8 waves of data collection until 2010–2011. The four cities in our sample are emblematic of different types of US cities and represent three distinct geographic regions (South, Midwest, and West). Study data were collected under protocols approved by Institutional Review Boards at each study center and UNC at Chapel Hill.

**Neighborhood Definition and Coverage**

In studies using geographic information system (GIS)-derived environment variables, neighborhood definitions can be generally classified into administrative boundaries [e.g., counties (49), Metropolitan Statistical Areas (50), zip codes, census tract (51), or block groups (1, 52, 53)] and buffers [e.g., Euclidean (34, 43) or street network (54, 55) distances around a point of interest like a residence or employment site]. Although these boundaries are readily and inexpensively available, they are somewhat arbitrary and may not correspond with what the population itself may consider as a neighborhood. By contrast, there are also conceptually defined neighborhoods, often used by local planners, such as the community areas created by the Social Science Research Committee at University of Chicago that has divided the City of Chicago into 77 well defined and consistent community areas (56). Analogous data are available from city planning departments for the other three cities (Birmingham: 99; Minneapolis/St. Paul 81/17; Oakland: 57 neighborhoods). In this project, we used administrative neighborhoods, Euclidean, and network buffer-based neighborhoods, as well as conceptually defined neighborhoods from the Regional Planning Commission of Greater Birmingham (Birmingham) and Zillow (Chicago, Minneapolis, and Oakland). Thus, the four cities database allows for a variety of neighborhood geographies for flexibility and tailoring relative to specific research questions. All neighborhood measures were based around the place of residence of participants.

The nominal geographic areas covered in the data collection effort were constrained to the official administrative boundaries of each of the four cities. The enclave city of Piedmont was included with the Oakland, CA, USA site, and the Norridge and Harwood Heights enclaves were included with the Chicago, IL, USA site. The particular geographic coverage of the different feature types varies to some degree, however, and some features also extend beyond each city boundary. Coverage maps of the areal extent per feature type are provided in Figures S1–S5 in Supplementary Material. Although approximately 25% of the CARDIA sample has moved outside of the four cities over the past 25 years, the four cities sample was restricted to the core four cities due to the resource intensity of the data collection process.

**Field Audit Team and Training**

Field site auditors \( (n = 5) \); one for Oakland, Minneapolis, and Birmingham and two at UNC who collected data in Chicago and coordinated the other field auditors) were recruited through personal contacts of the researchers and selected based on experience and professional training in city/regional planning and/or transportation engineering as well as familiarity with and connections in each of the four cities. The field auditors were instructed to collect data on introductions, renovations, and closures representing changes in recreation facilities (e.g., trails and parks) and transportation infrastructure (e.g., light rail, bike parking, and bike paths) over the period from 1985–1986 to 2010–2011. In January, 2012, UNC investigators and team members hosted an in-person orientation and training for all of the four cities field auditors. The protocol was developed by the four cities study investigators and reflected state-of-the-art in built environment knowledge and methods at the time (literature, experience of investigators). Training included a background to study and study objectives, descriptions of data features sought, instruction on data sources, and study guidelines on data management, as well as contingencies for possible challenges in the field. During active data collection, there was a weekly conference call with all field auditors and four cities’ investigators to discuss progress, address challenges, and share successful approaches for data collection, with ongoing daily support for auditors to ensure that data collection protocols were implemented with fidelity and to aid in data collection efforts. The protocol document was amended to reflect changes in protocol as a result of field experience.

**Field Audit Data Collection Protocol**

The four cities protocol outlined three main elements of data collection: (1) data to collect, (2) methodology for data collection, and (3) organization of data into a consistent study format. Features identified for data collection efforts included on-street bicycle lanes, off-road paved trails for bicycles or pedestrian use, bicycle parking, parks, rail stations, and routes, and city bus routes (Table 1). Field audit data collection began in January 2012 and lasted through August 2012.

Auditors first met with field representatives from local organizations, such as city planners and transportation engineers, to locate appropriate data. Auditors were instructed to collect data on the current status of each feature (e.g., bike lanes) and on feature changes of a substantial degree (e.g., changes in bike lanes) over the 25-year study period. For four cities definitions of feature changes of a substantial degree, see Table 2. Note that definitions of substantial changes vary by domain. Substantial changes in features were recorded, including data on the timing, location, and nature of change (e.g., number and length). A conservative approach was taken wherein all data on changes were collected with review by the study PIs and team to evaluate whether changes were indeed of a substantial degree.

For each substantial change in a built environment feature, auditors were instructed to provide a GIS layer and data elements for an associated attribute table. GIS layers included standard metadata for each feature, including the projection, original data source and date, and units of scale (see Table 3). The attribute table design was specified in the data collection protocol to ensure compliance with the study’s coding convention. Each feature ID number began with an indicator for the city (2 = Birmingham, 3 = Chicago, 4 = Minneapolis, and 5 = Oakland), followed by a feature code (1–7 for, respectively, bicycle parking, bicycle lanes/
TABLE 1 | Sources of information for the four cities study field audit.

| Feature                     | Chicago, IL, USA                          | Minneapolis, MN, USA                  | Oakland, CA, USA                        | Birmingham, AL, USA                         |
|-----------------------------|------------------------------------------|---------------------------------------|----------------------------------------|--------------------------------------------|
| Bike parking                | • Chicago Bike Program                    | • Paper Maps                          | • City of Oakland                      | • Regional Planning Commission of Greater  |
|                             |                                          | • University of Minnesota             | • Field Checks or Funding Sources      | Birmingham                                  |
|                             |                                          | • Commuter Connection                 |                                        | Campus Planning Department of University   |
|                             |                                          | • Downtown Biking Guide               |                                        | of Alabama Birmingham                       |
|                             |                                          | • Metro Transit Website               |                                        | Personal contact                           |
| Bike lane and off-road trail| • Chicago Bike Program                    | • Paper Maps                          | • City of Oakland                      | • Regional Planning Commission of Greater  |
|                             | • Personal Contact                       | • University of Minnesota             | • Personal Contact                     | Birmingham                                  |
|                             |                                          |                                      |                                        | Campus Planning Department of University   |
|                             |                                          |                                      |                                        | of Alabama Birmingham                       |
|                             |                                          |                                      |                                        | Personal contact                           |
| Rail stations and routes    | • Chicago Transit Authority               | • City of Minneapolis                 | • Alameda-Contra Costa Transit (AC     | • Birmingham-Jefferson County Transit      |
|                             | • Metra Rail                              |                                        | Transit)                               | Authority (BJCTA)                          |
|                             | • Local Newspapers                       |                                        | • Bay Area Rapid Transit (BART)        | Paper Maps                                 |
| Bus routes                  | • Chicago Transit Authority               | • Paper Maps                          | • Alameda-Contra Costa Transit (AC     | • Local Newspapers                         |
|                             | • City of Chicago (GIS website)          | • City of Minneapolis                 | Transit)                               | • Personal Contact                         |
|                             |                                          | • Twin Cities Metropolitan            |                                        |                                           |
|                             |                                          | Area Transit GIS data                 |                                        |                                           |
| Parks                       | • City of Chicago (GIS Website)          | • Minneapolis Park and Recreation      | • City of Oakland                      | • Campus Planning University of Alabama    |
|                             | • Chicago Park District                   | Board                                 | • City of Oakland                      | Birmingham                                 |
|                             | • Local Newspapers                       |                                       | • City of Piedmont                     | City of Birmingham                         |
|                             |                                          |                                       | • Personal Contact                     |                                           |
|                             |                                          |                                       | • Local Newspapers                     | Birmingham Park and Recreation Board        |

TABLE 2 | Guidelines for determining whether a built environment feature changed to a substantial degree over the 25-year study period.

| Feature                     | Criteria for defining a substantial change in the feature |
|-----------------------------|----------------------------------------------------------|
| Bicycle lanes and on-road trails | During the time period of interest, was there a deliberate policy or effort to build additional lanes or on-road trails ≥300 ft in the area? Or whether the newly added one substantially increased the connectivity of the network (this also includes changes to regional connectivity)? If yes to either question, then it is a substantial change |
| Off-road paved trails       | See on-road trails                                         |
| Bicycle parking             | During the time period of interest, was there a deliberate policy or effort to build additional bicycle parking with 3 or more racks? Has the supply of bicycle parking increased or decreased substantially (for example, has it more than doubled)? If most bicycle parking in town is provided “incidentally” and at the motivation of a developer or property manager, then it would not be a substantial change (unless all developers are doing it) |
| Parks                       | Have new parks been built, remodeled, or removed? Where and when? Parks need to be larger than neighborhood pocket parks. Has there been significant remodelling of parks? If so, when and where? |
| Rail stations               | Have rail lines been extended or closed? New stations opened or old stations closed? Changes in service (later or earlier service, or weekend service cuts) would not be substantial changes. Extensions to others parts of town previously not served by rail would be considered a change of substantial degree |
| Rail routes                 | See rail stations                                          |
| City bus routes             | Was a line extended (or cut) by around 1 mile? Did the extended (or cut) route substantially change the connectivity of the network (this also includes changes to regional connectivity)? Service frequency was not considered as criteria |

on-road trails, rail stations, rail routes, city bus routes, parks, and off-road paved trails), followed by a 5-digit code indicating the specific feature (starting with 00001). For example, park #1 in Birmingham had a code of 2600001; bike lane #131 in Minneapolis had code 4200131. To the extent possible, we relied on written documentation about feature changes, such as city planning reports, physical maps, and GIS databases with changes in built environment over time. Local experts – individuals in the field with knowledge of the area and feature changes, such as city planning employees or members of advocacy organizations – were a key source of information when no written documentation existed. Auditors provided a qualitative indicator of the certainty of temporal estimate. Given the 25-year timespan of historic data collection, exact feature change dates could not always be confirmed, and auditors were asked to indicate whether time/date information was solid or based on an educated recollection of historic information. For all features, data fields comprised the dates of feature installations/openings/additions, remodeling, and closings, along with a dichotomous (0/1) temporal indicator of date certainty. Additional attributes varied by feature type (e.g.,
route extensions for trails and lanes, facility changes within parks, and numbers of bike racks at bike parking locations).

**Field Audit Data Verification with CIP, TIP, and PCIP**

An independent set of team members was selected based on experience and professional training in city/regional planning and/or transportation engineering to verify and expand on the on-the-ground audit. We approached the verification process of the field audit data using transportation improvement program (TIP) plans, capital improvement plans (CIP), and park capital improvement program (PCIP) plans for each of the cities obtained by contacting the city public works, metropolitan planning organization, and/or parks departments for each city. These plans helped to provide verification, including dates or timetable of investment, size or cost of investment, specific features modified during the investment, and programmed changes in features. CIPs and PCIPs provided data on recreational investments via short-range investment plans, usually 4–6 years, which identified capital projects and equipment purchases, a timetable and identified financing options, and a link between a municipality, school district, parks and recreation department and/or other local government entity, and a comprehensive and strategic plan and the entity’s annual budget (e.g., http://web.archive.org/web/20120308142650/http://www.metrocouncil.org/parks/CIP.pdf). The TIPs provided data on programmed changes for bike lanes, bike racks, off-road trails, and rail stations. TIPs are public documents, required by Federal Law, that summarize the proposed transportation investments for the following 5–7 years, categorized by type and source of funds. TIPs were updated annually in the 1990s and every 2 years post 1998. Although estimated completion dates are given for projects in the plan, it should be noted that the TIP is not a CIP. Unlike CIPs, TIPs represent an agency’s intent to construct or implement a specific project and the anticipated flow of federal funds and matching state or local contributions (57). In cases where CIP and TIP documents were not available, CIP and TIP documents from the year prior were used as appropriate. For example, Minneapolis did not have a 1988 CIP, but the 1987 CIP had information on projects for parks from 1988, thus providing verification details. In this case, 1987 CIP document is used to verify 1988 projects for parks. It is important to note that not all projects would be registered in TIP, CIP, or PCIPs. Those projects may be programmed and funded through other mechanisms, such as regular operating budgets, school budgets, and bond proceeds. For this reason, the verification was considered exploratory, in the sense that it provided information about the policy landscape in each location but limited the possibility of conducting a formal validation.

Several rules were applied for the verification process as follows: the project completion year was defined as the change/open year. If the completion year was unavailable, then the commencement year was used as the change/open year. Updates were restricted to projects valued at $1,000 or more and projects that affect physical accessibility to the feature. Thus, projects such as fencing or lighting in parks were not included. We also calculated the annual investment amount for the four cities based on CIPs and TIPs, using different approaches based on data available for each city. For Chicago, Minneapolis, and Oakland, annual investment amounts were calculated as the aggregate investment for each project. For Birmingham, the annual investment amount was obtained from the yearly total investment amount table provided in the TIP and CIP documents.
For bicycle lanes and off-road trails, a brief examination of the files and consultation with local planners enabled the research team to identify these features using different types/names (e.g., greenway, rail-trail way, and multi-use trails) and make decisions regarding whether the specific feature served as bike or off-road trails. Then, the researcher used Google Maps to locate the lanes based on the description of the start and the end points of the change in the GIS field audit file. For parks, researchers identified based on the description of the start and the end points of the trails. Then, the researcher used Google Maps to locate the lanes regarding whether the specific feature served as bike or off-road greenway, rail-trail way, and multi-use trails) and make decisions. The team to identify these features using different types/names (e.g., files and consultation with local planners enabled the research studied. This data harmonization process and preliminary data analysis occasionally revealed the need for additional data corrections. For example, the recreational trail and bike lane data were modified to address topological inconsistencies, such as unintended small gaps along linear segments. Finalized geospatial datasets were subsequently processed in ArcGIS by a spatial technician from the Spatial Analysis Unit of the Carolina Population Center at UNC to aggregate measures to higher geographic levels (e.g., neighborhoods, tract, and zip code) and integrate measures with CARDIA participant data from the clinic visits at each exam. Neighborhood features were compiled for each geographic level and every year (Table S1 in Supplementary Material) using a set of fixed neighborhood boundaries to isolate changes in features from simple boundary changes. Features and resources within 23-m (75-ft, determined by average road width) of a neighborhood were attributed to that neighborhood. Along a boundary shared between two neighborhoods, features within 23-m of each boundary were included in the data measures for both to reflect amenities that could be easily accessed by each neighborhood. This is because a bike lane, for example, serves both neighborhoods even if a street is between the neighborhood and the bike lane. Estimates of features and resources were linked to each individual CARDIA participant's geocoded address at every exam year. The geocoded residential location of a respondent is available for as many as six time points: circa 1985–1986, 1992–1993, 1995–1996, 2000–2001, 2005–2006, and 2010–2011 (corresponding to CARDIA exam years 0, 7, 10, 15, 20, and 25, respectively). For any exam period, a respondent's location may be within the four cities, outside the four cities, or unknown (e.g., absent from the study). Field audit data measures were assigned to individual respondents for each year that they lived in the four cities. Multi-year spans of audit data were assigned to each participant location by calculating the mid-point years between CARDIA exams and assuming that the participant remained in the same residence during that time (preceding inter-exam midpoint to succeeding inter-exam midpoint). Since 75% of participants remain in these cities, we have a rich longitudinal dataset of these individuals.

The proximity and accessibility of audited transportation infrastructure and recreational facilities relative to each participant's residential location were measured in multiple ways, as appropriate for each feature type (Table S1 in Supplementary Material). Distance to the nearest available feature was calculated in both Euclidean and network distance. Where relevant, other measures represent features within 250-m, 500-m, 1-km, 3-km, 5-km, and 8.05-km Euclidean and network buffers around the respondent’s geocoded residential location. For parks, we also calculated an inverse-distance weighted accessibility index to all parks in each city. Where a participant’s buffer extended beyond the boundaries of data, an indicator of the area within the city boundaries was created for use in analyses.

RESULTS

Not all CIP, TIP, and PCIP documents were available at all periods (see Table 4). Birmingham was especially challenging to gather data from, with no TIP until 1993 and no CIP or PCIP. In general, rail, trail, and park data were easier to gather from these documents than bicycle data. Bicycle parking, lanes, and recreation trails all increased dramatically between 1985 and 2011. Most notably, bicycle parking increased in Chicago, IL and Oakland, CA (USA) starting in 2000 (Figure 2). Similarly, tremendous growth occurred in bicycle lanes and recreational trails in all cities except Birmingham, AL, USA starting in the mid 1990s and continuing until the end of the retrospective audit (Figure 3). Minneapolis, MN, USA experienced the largest increase, followed by Chicago, IL, USA, and then by Oakland, CA, USA. During the duration of the retrospective audit, minimal changes occurred in bus service, rail lines and stations, and parks (Figures S6–S9 in Supplementary Material). However, bus service increased slightly in Birmingham, AL and Minneapolis, MN, USA). In addition, while Minneapolis, MN and Birmingham, AL (USA) did not have rail lines for the earlier part of the study, Minneapolis, MN, USA started a rail line in 2004 with 10 stations (adding 1 more station post-completion).

DISCUSSION

This protocol details methods to collect, verify, and process historic data on the built environment in the field audit component of the CARDIA four cities study. We developed and verified retrospective field audits in four cities [Birmingham, AL; Chicago, IL; Minneapolis, MN; and Oakland, CA (USA)] to capture introductions, renovations, and closures representing changes in recreation facilities (e.g., trails and parks) and transportation infrastructure.
TABLE 4 | Availability of CIP, PCIP, and TIP by year for verification of spatial elements and feature tables.

| Year | Chicago, IL, USA | Birmingham, AL, USA* | Oakland, CA, USA | Minneapolis, MN, USA |
|------|------------------|----------------------|-----------------|---------------------|
|      | CIP   | TIP   | PCIP  | TIP   | CIP   | TIP   | CIP   | TIP   |
| 1985 | R, R  | A     | P, T  | A     | T     | A     | T     | A     |
| 1986 | R, R  | A     | B, P, | T     | A     | B, P, | T     | A     |
| 1987 | R     | B     | A     | B, P, | A     | T     | A     | T     |
| 1988 | R, R  | P     | A     | A     | T     | A     | T     | A     |
| 1989 | A     | A     | A     | A     | A     | A     | A     | A     |
| 1990 | R     | A     | A     | A     | T     | A     | A     | A     |
| 1991 | A     | A     | A     | A     | A     | A     | A     | A     |
| 1992 | R     | A     | A     | A     | A     | A     | A     | A     |
| 1993 | R     | A     | A     | A     | P     | A     | P     | T     |
| 1994 | A     | A     | A     | A     | P     | T     | A     | T     |
| 1995 | A     | A     | A     | A     | P     | T     | A     | T     |
| 1996 | R     | P     | A     | P     | T     | T     | T     | T     |
| 1997 | A     | A     | A     | P     | T     | A     | T     | T     |
| 1998 | A     | R     | P     | T     | A     | T     | T     | T     |
| 1999 | A     | A     | A     | A     | A     | A     | A     | T     |
| 2000 | R, T  | P     | T     | P     | T     | T     | T     | T     |
| 2001 | R     | P     | B, P, | T     | T     | T     | T     | T     |
| 2002 | A     | T     | A     | T     | A     | T     | T     | T     |
| 2003 | R, T  | P     | A     | T     | A     | T     | T     | T     |
| 2004 | T     | P     | A     | B, T  | T     | T     | T     | T     |
| 2005 | T     | P     | B, T  | T     | B, T  | T     | B, T  | T     |
| 2006 | R     | A     | A     | B, T  | T     | T     | B, T  | B, T  |
| 2007 | R     | A     | P     | T     | B, T  | T     | B, T  | B, T  |
| 2008 | R, T  | P     | A     | T     | T     | T     | T     | T     |
| 2009 | P     | B, T  | T     | P     | B, T  | T     | B, T  | T     |
| 2010 | A     | A     | P     | B, T  | T     | B, T  | T     | T     |
| 2011 | A     | P     | A     | B, T  | T     | B, T  | T     | T     |
| 2012 | A     | A     | A     | A     | A     | A     | A     | T     |

*CIP was not available for Birmingham, AL, USA.
A: Data available, but no description regarding the spatial elements of interest.
B: Bike lanes available.
P: Parks available.
R: Rails available.
T: Trails available.

(e.g., bus, light rail, bike parking, and bike paths). These derived data were then linked to CARDIA sites’ respondents’ geographic locations over the 25-year study period to examine associations with health behaviors and outcomes. Our methodology can be used as a model for other studies seeking to generate detailed reporting of changes from various sources across cities. Additionally, this data collection was limited by a focus on infrastructure features (i.e., bicycle, trail, park, and transit). Thus, this protocol does not outline methods for capturing larger-scale built environment characteristics (e.g., density and land use mix).

Generally, cities are not collecting data for research, and it is the responsibility of researchers to forge partnerships that enable archiving of data for longitudinal and historic research. There was substantial variability in historic data and documentation by city. Some attributes were particularly challenging to document. Bicycle parking was one such feature due to the nature of reporting by local city governments, which was more focused on status quo rather than changes. In some cases, local officials and municipal employees overwrote or deleted data that they deemed “old” and replaced data with updated information. Additionally, verification was unequal across cities due to differences in availability of CIPs, TIPs, and PCIPs. This limitation might result in differential percentages of data verified by city or more accurate data for one city over another. Another contributing factor was unevenness in willingness to provide access to data. This is likely due to differences in the allocation of resources devoted to these issues or the internal structure of departments within cities. It is critical for researchers to create partnerships with local governments in order to archive data for future research.

Our choice to include auditors and verifiers with intimate knowledge of the cities was critical for decision-making around apparent inconsistencies in the data. While some auditors had knowledge of, and documented information about, specific people or sources of information, others had to rely solely on the information gleaned from the retrospective audit. For example, in several of our cities, we had names and information for key contacts, whereas in others, we only had the primary data source for each data element. Local, non-institutional community organizations also played a key role. For example, in Birmingham, we were able to meet a citizen who had collected all transit maps. Creating partnerships with local groups can also represent a bidirectional endeavor that can increase communication between researchers and communities; in Oakland, CA, USA, we worked with a group of city planners who were interested in seeing results and aggregated information after completion of data collection for their own purposes. Thus, there was clear benefit of our data collection for these local organizations.

Despite these complexities, our method provides a novel and valuable direction in the collection of retrospective neighborhood data for use in longitudinal analyses. Although the data produced have limitations that would not exist with prospectively collected data, they give insight into the way neighborhoods have changed over time. Our ability to link these data to the CARDIA clinical exam data allows researchers the potential for studies assessing the relationship between built environment changes and health behaviors. Additionally, the process of performing these field audits builds a network of informants...
within research cities that can help fuel new research questions, build evidence around appropriate model specifications, interpret research findings, and ultimately bridge the gap between research and cities to translate findings back into meaningful neighborhood policies. Given the importance of these data for research and the valuable direct application to resource allocation, future work should strive to build relationships with local governments around data collection and management.
CONCLUSION

This methodology details the innovative process of performing retrospective field audits of built environment data. Although the data produced have limitations that would not exist with prospectively collected data, they give insight into the way neighborhoods have changed over time. Specifically, we found large increases in bicycle infrastructure. Our methodology can be used as a model for other studies seeking to generate detailed data on historical changes in built environment features over a long period of time. Measures from this data compilation process can be combined with existing longitudinal cohort studies to examine critical questions of neighborhood resources’ influence on health behaviors and health outcomes.

AUTHOR NOTES

JH is a postdoctoral fellow in the Carolina Population Center at the University of North Carolina at Chapel Hill. She holds a PhD in Geographic Information Science and a Master of Science in Transportation from the Massachusetts Institute of Technology, and a Bachelor of Science from Fordham University. YS is a professor in the Department of City and Regional Planning at the University of North Carolina at Chapel Hill. She holds a PhD in City and Regional Planning from the University of Illinois at Urbana-Champaign. KP is a doctoral student in the Department of City and Regional Planning at the University of North Carolina at Chapel Hill. She holds a Master of Regional Planning from the University of South Carolina at Chapel Hill. PG-L is a Professor in the Department of Nutrition and the Carolina Population Center at the University of North Carolina at Chapel Hill. She holds a PhD and Master of Arts in Physical Anthropology from the University of Pennsylvania and a Bachelor of Arts in Anthropology and Experimental Psychology from Tulane University.

AUTHOR CONTRIBUTIONS

JH and KM drafted the study protocol manuscript. All authors reviewed and contributed to the final draft. PG-L, DR, MP, and YS were involved in data generation and analysis. JH, KP, and MP were involved in GIS processing. PG-L secured funding to perform the ancillary study.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at http://journal.frontiersin.org/article/10.3389/fpubh.2016.00065
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**Conflict of Interest Statement:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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