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Refining The Grain: Using Resident-Based Walkability Audits To Better Understand Walkable Urban Form

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Abstract

Researchers use measures of street connectivity to assess neighborhood walkability and many studies show a relationship between neighborhood design and walking activity. Yet, the core of those connectivity measures are based on constructs designed for analyzing automobile mobility – the street network - not pedestrian movement. This paper examines the effect of a finer grained characterization of street connectivity and illustrates the idea using parent ratings of street and intersection walkability for children throughout a suburban school district in Oregon. Several policy and practice recommendations are presented, including a discussion that extends Michael Southworth's (1993; 2005) foundational representation of streets and the walkable city using a refined, more pedestrian-centered approach to visualizing connectivity and walkable urban form.

Keywords

walkability; urban form; participatory GIS; active transportation; safe routes to school

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INTRODUCTION

Over the last seventy years, the American transportation system has been designed around the movement of automobiles, often at the expense of walking, and has produced cities and neighborhoods that have become unsafe and poorly designed for pedestrian use (Southworth and Owens 1993; Frank, Andresen et al. 2004; Rodríguez and Joo 2004; Southworth 2005; Sallis and Karen Glanz 2006; Ewing and Robert Cervero 2010; Bejleri, Steiner et al. 2012). Research has generally shown more people walk in neighborhoods that have connected sidewalks and provide shorter walking distances and more route choices to destinations (Krizek 2002; Frank, James F. Sallis et al. 2006; Krizek, Handy et al. 2009).

Perhaps more so than drivers, pedestrians are affected by the network of road and intersections that surround areas of home, work, and recreation. Pedestrian needs vary considerably, as do their feeling of what is comfortable and safe. For instance, parents of young children are especially aware of roads that feel unsafe. Children walking to school has dropped from 49% in 1969 to just 13% today (McDonald and Aalborg 2009). Children living in less connected neighborhoods are less likely to walk to school (Schlossberg, Greene et al. 2006), which leads to secondary impacts, such as decreased daily physical activity (Grafova 2008; Nelson, Foley et al. 2008; Franzini, Elliott et al. 2009; Nelson and Woods 2009). While children are notable examples (Schlossberg, Phillips et al. 2005; Schlossberg, Greene et al. 2006; Committee on Environmental Health 2009; Giles-Corti, Keltly et al. 2009; Villanueva, Giles-Corti et al. 2012), other groups are equally dependent on pedestrian infrastructure, including the elderly (Li, Harmer et al. 2008) and persons with disabilities (Clarke, Ailshire et al. 2009).

Southworth (1993; 2005) was one of the first researchers to show how pedestrian connectivity (i.e. walkability) could be systematically assessed based on the character of surrounding streets and intersections. Since walkability measures are typically derived from existing street networks, metrics can be applied across large geographic areas. This approach has formed the foundation for a large body of research in both metropolitan and urban-design analyses (e.g., school catchment areas, transit oriented development, etc.). The concept of connectivity has also been increasingly used by the general public. On-line tools, such as Walkscore®, are becoming a familiar way to understand the relationship between street connectivity and proximity to nearby destinations from any address in the United States

Yet street connectivity is not the same as sidewalk connectivity, and many walking paths require that people travel past areas that do not feel safe on foot. Common techniques for measuring connectivity may fall short of accurately capturing the pedestrian experience of since most street-level details are ignored (e.g., the condition of sidewalks, presence of street trees, or hundreds of other variables that differ from block to block). This may be especially true with regards to vulnerable groups, such as children.

This paper attempts to illustrate this gap by adding the pedestrian perspective to the visual approach pioneered by Southworth. One way to better understand the impact of elements of the neighborhood on different users is to directly involve them in observing and rating their

walking environment. For children, parents provide the key judgment on the safety and connectivity of pedestrian street networks, which is why they are the focus of this study. We draw from the Communities and Schools Together (CAST), a five-year community-based participatory research study focused on childhood obesity. One portion of the project engaged 55 parents of elementary-aged children in rating their perceived safety and comfort with school district intersections and streets safety for child walking. The results of this community-engaged process used in this paper illustrate how existing street data can be enhanced for planning pedestrian travel environments and that ‘regular’ residents can play a useful and critical role in assessing pedestrian safety of street networks for active travel mode decision-making for children.

BACKGROUND

There are two spatial scales to consider when trying understanding walkable urban form – the broad connectivity of the path network and the specific design characteristics that pedestrians experience firsthand. What many researchers and community professionals use to understand transportation networks at the more macro scale is based wholly on, enhanced from, or similarly constructed to TIGER data, a nationally maintained set of geographic street data that spatially depicts all streets in the country with a single line corresponding to the center of the street right-of-way. Few street characteristics tend to be included in the data beyond street type (i.e. highway, neighborhood road, alley, etc.), and the single geographical line segment generally does not capture differences between the left and right side of the street. While local enhancements or newly constructed street data may describe additional variables, they still tend to use the street centerline as its core structure.

Although this data lacks specific street characteristics, it has become very useful to both researchers and local planners to understand basic walkable urban form as defined by the street system. Visually, Southworth (1993; 2005) provides what is probably the most concise overview of how street patterns, and the differences in those patterns, relate to walkable neighborhoods. Figure 1 shows Southworth’s classic visual delineation of street connectivity over time, which illustrates how neighborhood designs changed with the increasing prevalence and planning for automobile-based transportation. Complementing the visual representation of differing neighborhood street patterns, Southworth identifies quantifiable metrics, such as intersection density and miles of linear road, that provide a more measurable method to differentiate between neighborhood designs.

Southworth (and others) argue that the “Gridiron” pattern on the left is the most walkable street pattern because of the high density of intersections and relatively short block lengths. These characteristics provide walkers direct travel and more route choices. In contrast, the “Lollipops on a Stick” street pattern provides little of either, directing all traffic, regardless of mode, from smaller roads with cul-de-sacs to neighborhood collector streets to larger arterials roads – a system clearly built for automobile mobility. The lack of connectivity from one cul-de-sac to another often transforms what could be a short trip (as the bird flies) to an exceedingly long one along the street network. The end effect is that walking trips are effectively designed out of the system regardless of whatever other type of pedestrian infrastructure might be present.

The use of street connectivity has since become a standard measurement by both researchers and practitioners when trying to understand the walkability of a community. Table 1 presents a 2004 overview by Jennifer Dill (2004) of some of the many measures being developed to understand walkability at an urban design scale based on measures derived by the street network. Since that time and with the advancement of Geographic Information Systems (GIS) and increased interest in understanding the relationships between street network connectivity and pedestrian travel, the number of studies that use variations of these types of measures has greatly expanded. Studies, often with very practitioner applied elements, include those focused on differing neighborhood types (Rodríguez and Joo 2004; Frank, et. al. 2010), transit oriented development (Schlossberg and Brown 2004), access to school (Schlossberg 2006; Sallis and Karen Glanz 2006), and much more. The use of intersection density to measure street connectivity as a core indicator of walkability has become ubiquitous.

These measures of connectivity have become accessible to the general public through on-line tools such as Walkscore®, which derives an overall assessment, or score, of neighborhood walkability using a combination of distance along the street network from a given location and the types of amenities available nearby, such as schools, parks, coffee shops, etc. The tool has become useful for many purposes, including for people searching for desired housing locations or for community planning purposes, but has also been applied to research. According to Weinberger and Sweet (2012), “Results suggest that walk scores may be used as a reasonable heuristic to assist with assessing trip impacts for individual projects. With the universal availability of such data, planners can establish a consistent, cost-effective tool for assessing walking behavior with robust and transferable results” (20). It has been shown to provide generally accurate assessments of walkability (Carr, et. al. 2011; Duncan, et. al. 2011).

At a more micro-scale of the streetscape and the pedestrian experience, an additional line of applied research has recently emerged in the development and application of pedestrian audit tools. These tools range in scale and scope, but are generally designed to capture a variety of objective, and sometimes subjective, characteristics of the pedestrian realm block by block in an effort to identify strengths and weaknesses in the walkable infrastructure. A useful overview of the range of pedestrian audit tools can be found on-line at walkinginfo.org (<http://www.walkinginfo.org/problems/audits-general.cfm>). Three of the most commonly known and referenced among these tools include Irvine Minnesota Inventory, the Systematic Pedestrian and Cycling Environmental S, and the Pedestrian Environmental Data Scan.

The Irvine Minnesota Inventory (Day, et. al 2005; 2006) is a wide ranging assessment tool that assesses 160 different variables in the local built environment about sidewalk quality, tree cover, architectural features, and street design. It is one of the most comprehensive collections of potential variables related to walkability and was designed to create a comprehensive set of indicators that could be tested as to their importance to actual pedestrian behavior.

The Systematic Pedestrian and Cycling Environmental Scan (SPACES) Instrument (Pikora, et. al 2006) was developed and applied in a study examining 2,000 kilometers of street network across a large area in and near Perth, Australia. SPACES includes thirty-seven variables related to the pedestrian environment, including path types and materials, street aesthetics including the presence of trees and lighting, measures of the road and parking, and more. The data collected using the tool are intended to add value to GIS-based street network information to help understand the layout of pedestrian infrastructure and identify neighborhoods or locations in need of improvement.

Clifton et al. (2006; 2007) has more recently developed and tested a comprehensive built environment audit tool called the Pedestrian Environmental Data Scan (PEDS). This instrument also allows for the evaluation of diverse built environmental features related to walkability. PEDS is a rigorously developed audit tool based on very controlled training of auditors. PEDS includes 36 variables similar in nature to the two preceding tools but also includes specific questions on intersections, degree of openness or enclosure of adjacent land use, and a series of subjective questions about attractiveness and perception of safety of street networks.

Given the proliferation of pedestrian audit tools, reviews have been conducted to summarize content and characteristics of instruments. Moudon and Lee (2003) reviewed all existing environmental audit inventories available for recreation or transport walking/bicycling. Their review synthesized instruments into the four categories of route quality assessment, area quality assessment, and assessments used to estimate latent demand for either walking or bicycling. Professional transportation engineers were the most frequently intended assessors (n=18) followed next by professionals (n=8), and finally researchers (n=3). Of the 31 audit instruments evaluated, only two used lay people or neighbors as the instrument informants.

As part of the development of PEDS, Clifton et al. (2006) reviewed audit instruments with a focus on pedestrian environmental analysis separately from bicycling. Maghelal and Capp (2011) added to this review with their own evaluation of 21 pedestrian environment assessment tools. They examined instruments across four dimensions of a pedestrian environment: 1) streetscape design (e.g., distance to destination, sidewalk, roads, intersection, vehicles, lateral separation), 2) population density, including demographic information, 3) diversity of land use, and 4) quality of the pedestrian path (e.g., safety and comfort/convenience). Five of the 21 audits assessed all features of the streetscape design with the exception of distance. Six instruments measured safety, yet only 3 of these five audits measured the quality of the pedestrian environment for safety/comfort or convenience.

While the development of these audit tools and larger spatial analysis of network connectivity have provided both researchers and practitioners new ways to understand the opportunity to walk and the quality of the pedestrian realm, gaps remain. At the urban design scale, street-centerline data typically do not include the types of objective pedestrian variables included in the pedestrian audit tools. TIGER-based or any locally modified walkability street data often fail to also include any qualitative measures of the walking environment as pedestrian experience (Schlossberg, Evers et al. 2012). In addition, few efforts draw on citizen-informed evaluations that also provide an emic perspective on the

safety and comfort of pedestrian environments. This is particularly important in evaluating street environments for child pedestrians and their parental gatekeepers who have strong concerns about safety (Carver et al., 2008, 2010; Kerr et al., 2006; Moore et al., 2010; Weir et al., 2006).

Including neighborhood residents directly in gathering spatial data is often referred to as public participation GIS (PPGIS) or Participatory GIS (PGIS). While PPGIS can refer to a wide range of ways that the public engages with spatial data (Schlossberg and Shuford 2005), in general it “pertains to the use of geographic information systems (GIS) to broaden public involvement in policymaking” (Sieber 2006). An important premise of PPGIS is that those impacted by decisions also be part of the data collection and evaluation process. Doing so produces spatial data that is meaningful to those impacted by decisions while also educating and organizing community members around specific issues of relevance to their daily lives. This participatory GIS approach to engaging parents to understand neighborhood walkability was a key component of this project’s methodology.

In sum, there are two research and practice worlds related to understanding design for pedestrian use: 1) connectivity analyses using street networks to characterize walkability; and 2) audit tools that document walkability from the pedestrian perspective. The former has the benefit of universal datasets and GIS-based methodologies that make it possible to compare places using street network connectivity as an important measure of basic urban design. The latter has the benefit of understanding pedestrian experience and urban design at the user scale, recognizing there is much more to walkability than a connected street network. The strengths of each, in general, are also the limitations of the other – universally accessible data vs. very locally derived data representing perhaps the most obvious trade-off between the two.

This project and paper focuses on what holds these two spatial scales together: the connectivity of the *pedestrian* network. Rather than relying on connectivity analysis using street centerline data as the sole basis for that connectivity, this project is also based on parental assessments of local walking conditions. The goal is to create a modified network connectivity analysis that better represents user experience, and ultimately help planners, urban designers, and policy makers better design walkable urban form.

METHODOLOGY

Since the goal of this paper is to find a common ground between the ubiquity and easy access of street centerline data available nationally with the addition of base measures of walkability to add more nuanced characteristics of street-level variables important to actual pedestrians. Our methods incorporated PPGIS approaches in measuring school neighborhood walking environments as part of a larger participatory research framework in the Community and Schools Together (CAST) study, a 5-year childhood obesity prevention project that used community-based participatory research methods to examine multiple environmental influences on the prevalence of childhood overweight or obesity in a sample of elementary aged children.

This study was focused on children and parental perception of the safety of features in local walking paths to and from school. The approach in this study was to: 1) utilize standard, TIGER-based street-centerline data; and 2) augment that data with both objective and subjective pedestrian attributes collected by parent residents of a school district in Eugene, Oregon, interested in better walking environments for their children.

All parents of K-5 students (n=2,508) from all 7 elementary schools in the district were invited to participate in the walkability assessment. Recruitment occurred through referrals from school counselors, principals, and staff using Parent Interest Nomination Forms, presentations at Parent-Teacher Organization meetings, responses to a flyer (in English and Spanish) on the school district's home page, and responses to notices sent home to parents in all K-5 student classroom envelopes. A total of 60 parents representing all the elementary schools expressed interest in participating in the street assessment study.

Geographically, Bethel is on the outskirts of the metropolitan area, adjacent to the urban growth boundary, and has a mixture of new neighborhood development and older development annexed into city limits over the years. The development pattern is largely suburban due to most areas being built during the age of the automobile, post-1950. There are also pockets of new urbanist styled development, built in greenfields at the urban edge. While the development pattern may be significantly different from the central areas of large cities, it has a typical feel of many suburban areas that surround big cities and a pattern that dominates many mid-sized cities across the country built during the automobile age.

Figure 2 shows the location of all the schools (black squares) in the study, with three singled out (labeled: a, b, c), which will be described in more detail later in this paper. Figure 3 shows four typical streets of this suburban, and generally lower socio-economic status area.

Walkability assessments took place over a 6-month period and were held at variable times (mornings and evenings during the summer, and Saturdays during the school year) to accommodate parent schedules at each school. The entire program of on-site training and assessment took four to six hours to complete, with in-classroom training taking 1–2 hours and field assessments 3–4 hours to finish. Each school area was divided into assessment zones for parent rating which were constructed so that a two-person team could assess them in 1 to 1.5 hours. Spatial data from the different teams were then synthesized into a new master data set of streets within the school district for further analysis. A brief training was provided at the beginning of every mapping day. The presentation included slides on the current state of obesity in the United States, the concurrent downward trend in students walking and biking to school, an overview of the Complete Streets Assessment Tool they were to use, and examples of different street and crossing designs from across the United States.

Street audits were conducted by parents in the district using the Complete Streets Assessment Tool (CSAT) (Schlossberg and Brehm 2009; U.S. Department of Transportation John A. Volpe National Transportation Systems Center 2011), a tool built on the PEDS audit tool previously described. The CSAT survey was conducted using a handheld computer that displayed maps of streets and intersections within an audit area, allowed users to select

geographic features (e.g. road segments, intersection points), and then record observations for that feature by answering a series of questions using buttons, checkboxes, radio buttons, drop down lists, and an onscreen keyboard. The software stored survey results as attributes of the assessed feature (see Figure 4).

For each street or intersection, the surveyor recorded various ‘objective’ observations of streetscape attributes (e.g. number of lanes, width of sidewalk, etc.) and two subjective questions that gauged auditors assessment of the safety of the comfort of the street segment or intersection. Subjective questions were asked both before and after the objective assessments so that auditors could give their unbiased “gut” feeling about the street before looking at features objectively and then give a second subjective assessments following the recording of objective variables.

Observations reported by parents were uploaded onto a laptop and data were synthesized into a master file. We summarized surveyed street characteristics by elementary school boundaries and by the 0.25 mi area surrounding each school, filtered the streets based on differing attributes identified by parents as feeling unsafe, then used and augmented Southworth’s original metrics to illustrate the impacts on connectivity around schools in the audit area after each parental-based filter was applied.

RESULTS

Parents assessed the vast majority of street segments and intersections within the school district and felt that most vast streets (82%) and intersections (83%) were acceptable or good places to walk for children (see Table 2). Nevertheless, 32% of the assessed streets had no sidewalk and children would need to walk in the road. Taken as a whole, this would seem to suggest that parents felt reasonably comfortable with the street network and considered very low volume neighborhood roads without sidewalks safe enough for their children to walk.

While the overall figure of safe streets could be considered encouraging, the real importance of safe streets is their spatial location and connectivity. If unsafe street segments or intersections are located in areas between schools and neighborhoods and if they create a break in the walking network, then that network would be potentially inaccessible to pedestrians. Figure 5 shows one school (white square) and its surrounding street and intersection network under different conditions. In the leftmost image all streets are shown, showing a fairly well connected network. In the second image, only streets with sidewalks are shown (in bright white), immediately altering the conception of a pedestrian network by showing the difference between a street network and a pedestrian network. In the third image, streets are shown that parents found to be safe. It is interesting to note that this image has much more of the network present than the previous image. Nonetheless, the network is still disconnected due to the absence of some importantly located safe street segments. The fourth image “removes” intersections that parents felt to be unsafe for their walking children. When removing these intersections from the pedestrian network, it becomes visually clear that this school is almost inaccessible by foot in a way that makes parents feel comfortable.

What is most clear from looking at the community-based assessments of local walking areas was the significant disconnect between street centerline data as indicators of a walkable network of streets and first-hand, user characterization of that same street network. Specifically, the sidewalk network was much less robust than the street network, parents qualitatively indicated a significant number of streets that felt unsafe, and parents also identified intersections that acted as barriers to continuity of the pedestrian/street network.

Thus, adapting Southworth's visual representations of walkable communities based on the input from the parent-based evaluation of the walking journey to school, can provide a finer grain of understanding of the adequacy, completeness, and connectivity of pedestrian networks. Figure 6 more fully extends Southworth's basic figure-ground map shown in Figure 5 and adds the three additional pedestrian refinements (rows) using three different Bethel elementary schools areas (columns) as examples¹. The first row shows the entire street network and is similar to Southworth and the common universe of streets often used in walkable urban form network analyses. The second row shows maps after 'removing' streets without sidewalks (streets with sidewalks in white). The third row shifts the assessment lens by showing parent responses to the questions "this street segment (or intersection) feels safe (unsafe vs. safe/neutral)" and shows maps 'removing' streets and intersections identified as unsafe by parents. The associated quantifiable metrics are presented in Table 3.

When considering these basic pedestrian-oriented attributes, a well-connected network for cars becomes much less so when considering the infrastructure available for pedestrians. In some of these areas, pedestrian infrastructure looks like a series of disconnected projects rather than a network. If sidewalks are often a precondition for walking, then it is clear that there are serious barriers for children to walk to school more often. And while overall statistics seemed to indicate that many of these streets were thought acceptable for walking by parents, the Southworth illustrations make clear this was not universally true (row three).

In addition, most research on street connectivity does not make any distinctions as to the nature of an intersection. Yet street crossings may be more important for walking than the path in between intersections due to the explicit action of crossing paths of moving vehicles. Unsafe crossings act as barriers to pedestrian movement and further disconnect the street network. Thus, the final row in Figure 6 arguably illustrates the true connectivity of the pedestrian network from a user's point of view (or in this case, the gatekeepers (parents) of user (children) behavior).

In looking from row one to row three, then, it becomes clear just how different the actual street network and the pedestrian-acceptable network are. Street centerlines may be able to show a development pattern more or less conducive to walking by its basic layout and connectivity, but may over-represent true opportunities for pedestrians - especially child pedestrians - to navigate to school or other local destinations by foot.

¹The three schools represented in Figure 2 were chosen to represent different neighborhood typologies and development patterns. Patterns from the other four schools were similar, and in all cases there were large concentrations of students living in close proximity to each school.

Interestingly, the Walkscores® for each school indicate a different reality. Out of a ‘perfect’ walkability score of 100, school A and C were classified as “car dependent” (38 and 37 respectively), while school B was considered “somewhat walkable” (54). This assessment runs somewhat counter to the report of community members, who described schools A and C as surrounded by a much more complete network than school B, once unsafe streets and intersections were “removed”. Part of the problem is that tools such as Walkscore® conflate three separate aspects of walkability into a single measure: 1) general street connectivity independent of specific destinations; 2) the value of specific pedestrian-oriented destinations in close proximity to a given location; and 3) some indication of the actual pedestrian environment. So while existing street centerline-based walkability analyses and research often provide a useful general assessment of access to amenities within a certain distance along a street network, the reality of actual pedestrians can differ because of very local conditions.

RECOMMENDATIONS

This project differed from most walkability network assessments by including neighborhood residents in the evaluation of their own neighborhood pedestrian environment. Moreover, the data collection tool and data gathering approach explicitly included subjective assessments of perceived comfort/safety. Parent concerns over traffic safety illustrate the importance of this understanding, since getting approval from a parent to walk to school is based, in part, on the perceived safety of a child’s walking to school.

Conventional analysis of walkable networks often relies on quantifying aspects of a street network, such as its connectivity. Measures of intersection and dead-end density can be useful assessments at multiple scales, from regions to neighborhoods to areas around a school. Given that such measures normally rely on existing street centerline GIS data for the entire country, there is much to appreciate in this type of quantitative, spatial, and objective analysis of walkable environments.

What such analysis fails to describe, however, is the quality of the pedestrian experience or the perception of potential pedestrian users - a finer grain of understanding that could inform design, planning, and activity. Yet, efforts to get personalized assessments of all streets and intersections throughout the country would be a time-consuming and uneven process, with much debate as to what streetscape variables to collect given the wide number of possibilities as identified in many existing pedestrian audit tools.

With an emphasis on the pedestrian network, several recommendations naturally flow from this project and analysis, including: 1) augmenting current walkability analyses with measures that better assess the quality of pedestrian environments; and 2) developing a national database of pedestrian-relevant infrastructure just as has been created for driving.

Augmenting conventional walkability analyses with measures of quality

In both its visual and quantitative approach, we recommend augmenting Southworth’s work with variables that capture the quality of pedestrian space in addition to the basic connectivity of existing street networks. Specifically, we propose adding the following two

refinements to Southworth's work and to future quantitative analysis of walkable urban form:

1. Streets with sidewalks. This is the most straightforward and most important measure and would get to the basic infrastructure provision for pedestrians: the sidewalk. While it is entirely possible for pedestrians to walk in the street on low volume roads, which in some instances neighborhood residents validated, such comfort is not universal. On the other hand, sidewalks guarantee a protected, exclusive space for pedestrian movement.
2. Integrating intersections. We recommend integrating unsafe intersections into the imagery of street network connectivity, rather than considering all intersections of equal value in a neighborhood intersection density calculation. When intersections become unwalkable, they further disconnect the street network and isolate people from the places they may want to go on foot. As a somewhat crude, but recommended starting point, unsafe intersections can be any that include at least one major arterial street. While this may be an oversimplification, it does alter the default analysis condition from one where all intersections are considered safe for pedestrian connectivity unless otherwise proven so, to one where crossing major streets are considered unsafe unless proven otherwise.

Not only would these variables add some aspect of the quality of the pedestrian environment, they would allow both intra- and inter-neighborhood comparisons. The power of the original Southworth guide is to illustrate the relationship between neighborhood structure and walkable design. Adding these variables would refine the grain of analysis by allowing an intra-neighborhood comparison between the basic transportation pattern formed by existing streets and the quality of those streets for pedestrian use. In this way, a well-connected area (i.e. the Gridiron pattern per Southworth's measures) may *feel* as disconnected to a pedestrian as a physical street pattern with low connectivity (i.e. Loops and Lollipops) because of the low quality of the pedestrian realm.

Develop national database of pedestrian-relevant infrastructure

Existing national street databases can only go so far in representing qualities of the walking environment. There is an obvious limit to how much information can be captured within street centerline files. Creating a standardized, comprehensive dataset on the pedestrian infrastructure is important to addressing obesity, climate change, and the higher costs of sprawl-type development. It is time that national priority is given to creating a robust pedestrian network database for the entire nation in the same way that has been done for automobile and train transportation. From there, the network connectivity analyses frequently used in research and practice could be done separately based on street network connectivity and pedestrian network connectivity, with the resulting interventions appropriately pursued.

There would undoubtedly be a debate about how much basic information to include in such a national pedestrian network database, but the following could be considered as basic building blocks:

1. *Left and right-side pedestrian data, not augmented street centerline data.* The presence and quality of sidewalks often differs from one side of a street to the next, and for a comprehensive dataset to be useful, the “mapping” of a street should not be done by a centerline, but by where pedestrians would actually walk – on either adjacent side of the street.
2. *Intersection crossings.* In addition to the pedestrian paths adjacent to streets, it is critical that intersection crossings be included, whether or not pedestrian facilities like crosswalks exist. Including data for crossing allows for connectivity modeling and allows for descriptive characteristics about the nature of the crossing.
3. *Pedestrian paths not adjacent to streets.* Not all pedestrian paths are adjacent to streets, yet are “officially” part of a city’s transportation network. One example would be a pedestrian path at the end of a cul-de-sac that allows through movement by foot, but not by car. While often short in distance, these paths often significantly enhance the connectivity for pedestrians, and because they are linked to cul-de-sacs, they exist in low-volume automobile roads, enhancing one potential aspect of pedestrian quality. Other pedestrian paths that could be included are off-street, multi-use paths and pedestrian paths that connect sidewalks to commercial buildings.
4. *Some basic sidewalk qualities.* Some basic qualities beyond just the presence of sidewalks should be part of this database. Examples could include width, adjacency to street, type of crossing support, etc.

Developing a national database of the pedestrian environment would entail a substantial effort and would require constant updates. However, the same could be said about developing a national dataset for streets, which has matched federal resources with local capacity to update data. With more cities using GIS and on-line map editing tools, connecting local and federal efforts to maintain pedestrian walking networks may be easier to do than ever before. For instance, bike lanes are now being added to tools like Google Maps via partnerships with Google.

METHODOLOGICAL LESSONS LEARNED AND FUTURE RESEARCH

Parents ultimately decide how their children get to school (McMillan 2005), yet their perspectives on what feels safe or unsafe for their children are rarely considered in transportation planning or in the application of pedestrian audit tools. The integration of parent volunteers in collecting street and intersection data proved to be pleasantly rewarding and controversy-free. Several elements were crucial to this methodological success. In terms of volunteer recruitment, this project heavily utilized existing organizations and institutions to build interest and recruit volunteers in the walkability audit. This process required

significant effort, but given that this walkability assessment was explicitly part of a larger, five-year community-based participatory research effort, there were multiple reasons to deliberately build this community investment in the work. In terms of having community volunteers use somewhat sophisticated audit instruments and help them understand how to look at streets and intersections, a substantial effort was undertaken behind the scenes to make the audit tool simple to use. Although users were in fact entering data in a GIS on a handheld computer, the interface only required straightforward point and tap actions and training that could be done in under an hour.

Packaging tool training, street feature training, and street/intersection assessment on the same day also proved useful. Parent volunteers would typically gather in the morning for the training, then go out in teams of two to do the assessments, and return together to upload the data and discuss what they saw during their audit. This packaged approach created great discussions about streets and walking and also created new community connections among participants. Each of these activities was facilitated by several CAST staff and many support mechanisms were in place to make it easy for residents to participate, including providing tools and training in both English and Spanish, provision of childcare, and provision of food for all throughout the day. Making it easy for people to participate was key to their participation.

As a tenant of community based participatory research, the process of data collection can also be an intervention to make local conditions better. Of course, altering the walkable environment is a long process that requires both money and political will. Involving the community in the process of identifying gaps in the pedestrian network *also* nurtures a new and educated lay leadership that understands walkability in a new way. Most people know little about street design or how street re-design can happen; in this school district there is now a new group of adults that likely cannot help but continue to evaluate every street they encounter. Tracking the changes of the infrastructure over time and the role of these parental auditors in that change will be an interesting longitudinal research effort. Concurrently tracking any changes in both the walk to school rates and the physical health of youth should be part of the evaluation research effort.

CONCLUSION

Michael Southworth's foundational work on the walkable city has provided both a visual exploration of changing neighborhood designs and their implication for walkability, as well as a foundational approach to spatial quantification of walkability based on street connectivity. But it also presents a somewhat impersonal interpretation of the walkable character of a neighborhood. Most network analyses of walkability utilize street-centerline data that yield little differentiation between the motorized and non-motorized qualities of the streets and thus, use of the street network to assess walkable urban form can be an excessively crude measure. On the other hand, use of pedestrian audit tools to assess every street and intersection individually, while helpful in gathering a robust set of qualities of the pedestrian realm, are extremely time consuming and uneven across place.

For part of this five-year study focusing on a broad range of childhood health issues, fifty-five parent volunteers assessed almost every street and intersection across seven elementary schools throughout a school district to determine their safety. The result of this community-based assessment was to refine the characterization of streets as a parent perceives them when thinking about their children's walking journey to school. Based on this input, several additional refinements can be made to Southworth's basic typology of street patterns to better reflect a pedestrian perspective, and can be part of the growing set of research and analysis on the connection between street patterns, urban form, walkable environments, health, and climate change. In particular, the basic inclusion of sidewalk data is critical to understand how robust a pedestrian network exists given that there is no national database of pedestrian infrastructure. Beyond the basics of including sidewalk data, including aspects of intersection crossings can fundamentally improve our understanding of walkable urban form and make retrofitting existing built areas, as well as the planning of new developments, better able to create more walkable urban form.

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	Gridiron (c. 1900)	Fragmented Parallel (c. 1950)	Warped Parallel (c. 1960)	Loops and Lollipops (c. 1970)	Lollipops on a Stick (c. 1980)
Street Patterns
Intersections
Lineal Feet of Streets	20,800	19,000	16,500	15,300	15,600
# of Blocks	28	19	14	12	8
# of Intersections	26	22	14	12	8
# of Access Points	19	10	7	6	4
# of Loops & Cul-de-Sacs	0	1	2	8	24

Figure 1.
Visual and Quantitative Representation of Different Urban Forms

Figure 2.
Map Showing Resident-Based Walkability Assessments and School Focal Areas

Figure 3. Typical streets and developments in Bethel School District

3a) Barger Road: Minor arterial road with bike lanes and sidewalks

3b) Candlelight Drive: Residential street adjacent to school

3c) North Terry Street: Arterial with adjacent uses oriented away from street

3d) Hollow Way: Newer residential area with skinny street. Source: Google Streetview

Figure 4.
Screenshots of the CSAT tool

Figure 5.
Street Connectivity Based on Parent Perception of Safety

Figure 6.
Refined Visualization of Walkable Urban Form

Table 1

Measures of Connectivity used in Research Literature from Dill (2004)

Measure	Literature
Block length (mean)	Cervero and Kockelman (1997)
Block size (mean area)	Hess et al. (1999) Reilly (2002)
Block size (median perimeter)	Song (2003)
Block density	Cervero and Kockelman (1997) Cervero and Radisch (1995) Frank et al. (2000) (census block density)
Intersection density	Cervero and Radisch (1995) Cervero and Kockelman (1997) (# dead ends and cul-de-sacs per developed acre) Reilly (2002)
Percent four-way intersections	Cervero and Kockelman (1997) Boarnet and Sarmiento (1998) Street density Handy (1996) Mately et al. (2001)
Connected Intersection	Ratio Allen (1997) Song (2003)
Link-Node Ratio	Ewing (1996)
Percent Grid	Boarnet and Crane (2001) Greenwald and Boarnet (2001)
Grid dummy variables	Crane and Crepeau (1998) Messenger and Ewing (1996)
Percent quadrilateral blocks	Cervero and Kockelman (1997)
Pedestrian Route Directness	Hess (1997) Randall and Baetz (2001)
Walking distance	Aultman-Hall et al. (1997) (mean, maximum, percent of homes meeting minimum standard)

Table 2

Presence of Sidewalks and Parental Perception of Safety

Street/intersection attribute	N	%
1. Feel safe child walking		
- Disagree	294	18%
- Neutral/agree	1347	82%
2. Most likely place to walk		
- Sidewalk	1116	68%
- Side of road	518	32%
3. Feel safe child crossing		
- Disagree	191	16%
- Neutral/agree	988	83%

Table 3**Metrics of Walkable Urban Form**

	<u>School A</u>	<u>School B</u>	<u>School C</u>
1. Street network surrounding three elementary schools			
– Linear feet of streets	41,930	34,450	37,400
– # of blocks	28	25	26
– # of intersections	45	38	57
– # of loops & cul-de-sacs	13	11	22
2. Street network after streets without sidewalks are removed			
– Linear feet of streets	30,355	10,092	14,635
– # of blocks	11	6	12
– # of intersections	22	8	21
– # of loops & cul-de-sacs	14	5	16
3. Street network after streets and intersections that felt unsafe to parents are removed			
– Linear feet of streets	36,975	19,574	23,559
– # of blocks	16	12	14
– # of intersections	32	11	30
– # of loops & cul-de-sacs	26	36	33