An Assessment of GIS-Enabled Walkability Audits

Marc Schlossberg, Asha Weinstein Agrawal, and Katja Irvin

Abstract: *Research on walking and the built environment is a fairly recent area of inquiry, accelerated over the past ten years by an increased interest in the relationship between urban form and public health. As the research has progressed, so has the interest in developing ways to collect data at a very fine scale—in essence, to be able to collect data at the streetscape level and link this data to transportation behavior. This paper discusses the development and implementation of a GIS-based pedestrian audit tool that allows users to collect data in electronic form using a handheld computer (i.e., a pocket PC or personal digital assistant (PDA)). While, such tools may be useful for better understanding the relationship between the built environment and pedestrian behavior, the tools may be unnecessarily complex and unfocused. Specifically, these walkability audit tools could be improved by: (1) applying unique sets of walkability measures to different types of walking environments; (2) perhaps focusing auditing activities on major streets and intersections only (e.g., do not audit neighborhood streets where possible); (3) including subjective as well as objective measures of the streetscape; (4) verify the accuracy of digital base maps before widespread implementation; and (5) continuously evaluating whether the simpler technology of pen and paper would be preferable alternatives. The authors conclude that appropriately applying GIS-enabled pedestrian audit tools can be an efficient way to collect and quickly analyze pedestrian infrastructure characteristics so that planners, practitioners, policy makers, and community members can make more effective decisions on behalf of walkability.*

INTRODUCTION

Research on walking and the built environment is a fairly recent area of inquiry, accelerated over the past ten years by an increased interest in the relationship between urban form and public health. As the research has progressed, so has the interest in developing ways to collect data at a very fine scale—in essence, to be able to collect data at the streetscape level and link this data to active transportation behavior (Schlossberg 2007). However, the lack of quick and cost-effective tools for collecting block-by-block data about the streetscape has prevented more widespread research and application of such tools. This paper discusses the development and implementation of a GIS-based pedestrian audit tool that allows users to collect data in electronic form using a handheld computer (i.e., a pocket PC or personal digital assistant (PDA)).

In a recent article on visualizing and measuring walkability, Schlossberg suggested looking forward to new technological approaches. In theory, tools that could allow for detailed, GIS-enabled data collection about pedestrian environments on handheld computers would allow planners to better understand the relationship between specific characteristics of the built environment and their relationship to either overall walking within an area or preferences for walking along one route or another. Once this relationship between the walking environment and walking behavior could be established, then specific recommendations to improve walking conditions could be made to policy makers, planners, transportation officials, and other decision makers could be made to improve conditions for walking.

This paper discusses the development and implementation of such a pedestrian audit tool and evaluates its promise for use in future projects. The larger project within which this tool was developed examined correlations between aspects of the built environment with the actual route choices that people make when walking from home to their nearest transit stations. The variables within this GIS-based audit tool were adapted from existing research literature and from other pedestrian audit tools, namely the Pedestrian Environment Data Scan (PEDS) developed by Dr. Kelly Clifton and Andrea Livi at the University of Maryland and Dr. Daniel Rodriguez at the University of North Carolina. This paper, however, will not focus on the types of data collected; rather, what follows is an evaluation of using this technology as a way to gather more detailed and nuanced data about walkable environments.

CONCEPTUAL BACKGROUND

As researchers, practitioners, and policy makers have become increasingly interested in the relationship between the built environment and physical activity, recognition of tools that appropriately measure urban form at a pedestrian scale has also increased. Perhaps the best-known and utilized tool in this area is an environmental audit instrument called SPACES, a comprehensive tool that helps inventory the characteristics of and along a roadway segment (Pikora, Giles-Corti et al. 2003). The authors categorize different factors of a walking environment into five classifications: (1) functional (physical attributes of the street), (2) safety (characteristics of a safe environment), (3) aesthetic (elements such as trees or gardens), (4) destination (relationship of neighborhood services to residences), and (5) subjective.

Moudon and Lee (2003) focused their work in a similar area, but dedicate more time to developing a conceptual framework for measuring walkability to help direct future research efforts. To develop their framework, they performed an exhaustive review of more than 30 published methodologies and inventorying tools that have been developed to assess walkability. They outlined a theoretical framework called the Behavioral Model of Environments (BME) that seeks to account for personal, physical, and internal responses factors that may explain the connection between individual pedestrians and their walking environments. In essence, they are attempting to lay the theoretical framework for focusing on the characteristics of place when considering the relationship between urban form and pedestrian behavior.

McMillan (2005) also provides a conceptual framework for others to follow when studying urban form and pedestrian accessibility. Through her focus on a child's trip to school, McMillan realized that urban form does not directly impact how a child gets to school, but rather a set of mediating and moderating factors do (McMillan 2005). Mediating factors include neighborhood and traffic safety, as well as household characteristics such as the availability of automobiles at home and the distance between home and school. Moderating factors include parental attitudes, social or cultural norms, and sociodemographic characteristics (McMillan 2005). The importance of this research is to illustrate that while urban form may have an important impact on pedestrian behavior, other nonbuilt environmental factors are also important. And in terms of our interest in audit tools themselves, McMillan's research shows that such tools may yield important data about the walking environment, but that such urban form data only represents one component of the overall decision-making process to walk or not.

Clifton and Livi (2005) developed the Pedestrian Environment Data Scan (PEDS) audit tool, which included 78 measures of streetscape characteristics that other research has shown to influence walkability. In addition to developing their tool, Clifton and Livi studied the inter-rater reliability of the instrument to understand the potential of such tools to be used in broad geographic areas with a diversity of audit administrators. Despite a wide range of street segment uses, conditions, and aesthetics, they found relatively high reliability scores for many of the questions contained within the audit instrument. Ewing (2006) utilized input from urban design professionals to develop operational definitions of the built environment relevant to pedestrians and translated those definitions into a field survey instrument (Ewing, Handy et al. 2006).

While the development of these conceptual and operational frameworks for assessing local walkability are important, researchers have been limited by the amount of time required to conduct block-by-block assessments of every street segment and intersection within a study area. As researchers identify more aspects of the built environment that may be important in creating walkable environments, the burden of applying those measures to each street segment grows. In their study of two pedestrian and bicycling environmental audit tools, Emery found it challenging to reliably evaluate road segments (Emery, Crump et al. 2003).

Recent technological innovations, however, have made it possible to create audit tools that work within a GIS environment on PDAs, enabling data collection that is relatively quick and instantly embedded into an electronic and GIS-ready data format for more prompt analysis. We used just such a tool in our study of pedestrian route choice, and the remainder of this paper will report on this method of data collection.

PROJECT AND AUDIT TOOL BACKGROUND

We developed the pedestrian audit tool as part of a larger research project designed to understand how far people walk to rail stations in the morning and what routes they take. Stages of the project included surveying people who walked to transit stations, asking them about their reasons for choosing the routes they do, mapping the routes they took to the station the day of the survey, and then auditing the physical environment to determine whether the built environment impacted the routes pedestrians took to access transit.[1] Our goal was to collect data about the built environment for every street segment and intersection within one mile of four transit stops. We used the PEDS tool as our starting point for developing the audit tool, but heavily modified the tool by adding and deleting variables to make the tool relevant to our particular study. Once we decided on the appropriate variables to use, we then created an interface to allow the tool to work with GIS software on a PDA.[2] We felt it was important to have different variables to audit the street segments and to evaluate intersections, so we created separate sets of variables to do just that. We field-tested the tool and made modifications before collecting data.

In all, our street segment audit consisted of six screen pages per street segment, constituting approximately 25 different sets of variables, depending on the presence or absence of certain features. The intersection audit consisted of two screen pages and six variables (see Figure 1 for sample screenshots of the tool).

We designed the audit tool to make it easy to use. In particular, we minimized the amount of screen "typing" and created data-entry forms that were efficient and intuitive for the auditor. To do so, we used a variety of methods for data input, including checkboxes, drop-down menus, and text fields where we could enter in observations that deviated from our predefined answer responses. In addition to these standard questions, we customized the data-input interface with more advanced features designed to make data collection more efficient. One feature was the use of skip sequences to make the flow through the tool more seamless, and another was the use of an on-the-fly field default-setting feature. In this default-setting feature, the user could save the answers entered for one particular street segment and then load them automatically for the next street segment, thus minimizing the data to be entered for the second segment. In general, street segments do not differ much from one block to the next, so this automatic field completion feature was a useful time-saving addition. It was still possible to alter answers to specific questions in the default setting as needed, when one or two features of a block segment were unique.

Collecting data with this tool essentially involved walking

The screenshots on the top row represent three of the six data entry screens for assessing street segments. To the right is one of the two screens for assessing intersections. To the far right is a screenshot of the GIS software loaded onto a PDA. The data entry screens appear on the PDA when a street segment or intersection is tapped by the user for data entry.

Figure 1. Examples of the walkability audit data-entry forms

along each street segment (or intersection) and visually scanning the environment as the audit questions were answered. At first this involved walking most of a street segment, pausing to look around, and then entering data while conducting additional visual scans if necessary. Over time, as the auditors became more familiar with the local environment and comfortable with the audit tool, the data-collection process became more efficient; essentially the auditors were able to walk, scan, and enter data simultaneously. Thus, in some environments there was little additional time needed for data collection other than the time it takes to walk along each street segment.[3] That said, there is an incentive to minimize the number of audit questions because the more questions for any particular segment, the greater the concentration needs for the auditor and the greater the likelihood of error. The default function mentioned previously helped significantly to achieve this efficiency without compromising quality.

To enter data, the PDA needs to be preloaded with a map of the local area as well as the database entry tool. In our case, we loaded the PDAs with edited TIGER street maps and intersection point maps that we created separately with GIS software. The auditor located the street segment on the PDA map where he or she was standing and simply tapped the street segment (or intersection) on the screen to call up the data-entry forms. Once the questions were answered, the data was automatically saved and associated with the street segment in the GIS file; thus, only one data-entry step is needed to both collect the audit data and prepare it for GIS analysis. This process was repeated until the audit of the study area was completed.

Overall completion time depended both on the size of the study area and the quantity of road segments in the study area. In our study, the areas audited in the Portland, Oregon, region had much higher densities of streets around transit stops than the areas around the other study areas in San Jose and Oakland, California. Budgeting time for conducting the audit, therefore, depends on the number of segments and intersections within a study area, and not just on the size of the study area itself. Total data-collection

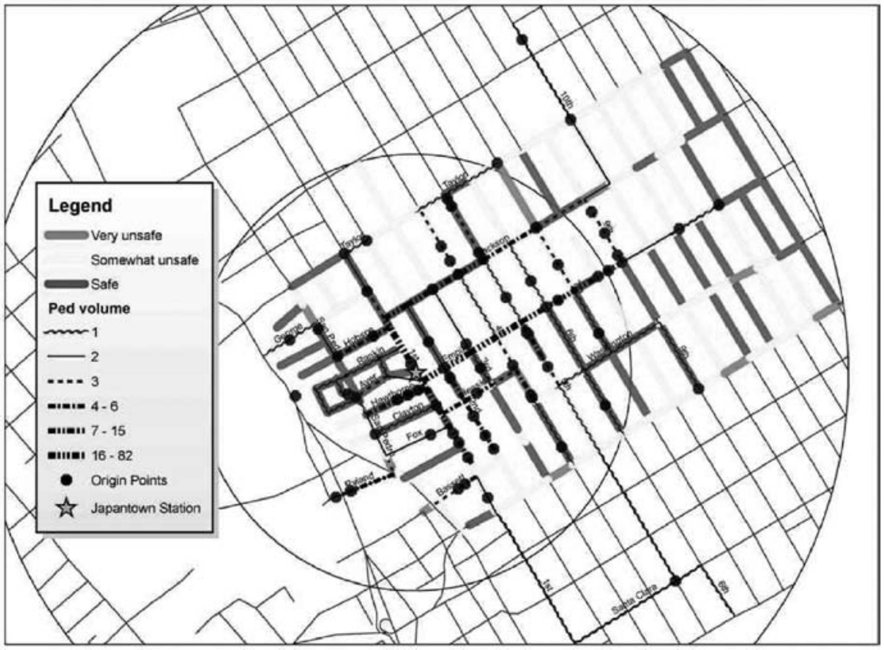

Figure 2. Map of safety overlaid with actual pedestrian routes to transit

time, thus, is a function of the average length of a street segment, the total number of street segments, the total data-entry questions per street segment, the total numbers of intersections, and the total number of audit questions for those intersections.

Once the data is collected, it can be mapped easily because the data was entered directly into a GIS format. Figure 2 shows an example of a map created by using a pedestrian audit tool.

REFLECTIONS AND MODIFICATIONS

Based on our experience in developing pedestrian audit instruments for classroom and research projects, and with the recent completion of a major study of transit access by pedestrians, we offer five general areas for consideration when developing pedestrian audit tools:

1. Verify the accuracy of the street base map before recording any data.
2. Develop data-gathering tools customized to street/path type.
3. Consider focusing data collection only on major streets.
4. Determine the relative importance of subjective versus objective measures.
5. Evaluate the utility of digital versus paper-and-pen technology for conducting audits.

GROUND TRUTH BASE MAPS

In our experience, with an accurate base map of streets (or sidewalks), collecting GIS-enabled data at a streetscape level was generally straightforward and provided the analysis with a rich dataset that would otherwise be impossible to derive. Before using the tool in the field, however, it is critical to ground truth the street base map that will form the core of the dataset. As mentioned previously, we utilized the TIGER street file as our base map and we did so because we wanted to use a freely accessible source of data that would be available to any community in the United States for free. As is often the case with TIGER data, some errors exist between the TIGER map and the actual presence or absence of streets around the transit stops. In some cases, the TIGER data included streets that did not exist, and in others streets existed that were not part of the TIGER data. And TIGER data is not particularly good at including off-street paths.

It is also important to check the address ranges of the streets within the TIGER data to ensure they are consistent with actual address ranges of the streets. We have experienced address ranges that were one block off, meaning we had to correct these errors in the map by hand before it was possible to accurately geocode our survey data. It is possible to add or delete street segments or adjust street ranges in the field on the PDA, but it is critically important that some basic ground truthing of the base GIS data be conducted prior to auditing the environment. Alternatively, one could use locally produced base map files that would presumably be more up-to-date and accurate for local conditions.

Customizing Data Collection by Street Type

Based on our experience, we have concluded that when auditing pedestrian environments, it would be useful to be able to differentiate between street type when collecting data and then collect data unique to each type of street or path. It became clear after collecting data that arterial and collector streets required a different set of attributes to collect compared to neighborhood streets. For example, street width, sidewalk buffers, on-street parking, and the number of high-volume driveways to cross were all much more important on arterials and collectors where the volume and speed of vehicles presents much more of a safety threat and level of discomfort compared to neighborhood streets. On neighborhood streets, at least in our study areas, aesthetic and street features seemed to be less influential for a pedestrian's ability to walk. For these streets, perhaps the most important feature would be the presence of sidewalks. Customizing data-entry variables for different types of streets would streamline the data-collection process and allow a greater range of streets to be surveyed in a shorter period of time. As mentioned previously, the tool we used had a built-in feature to save previous data-entry

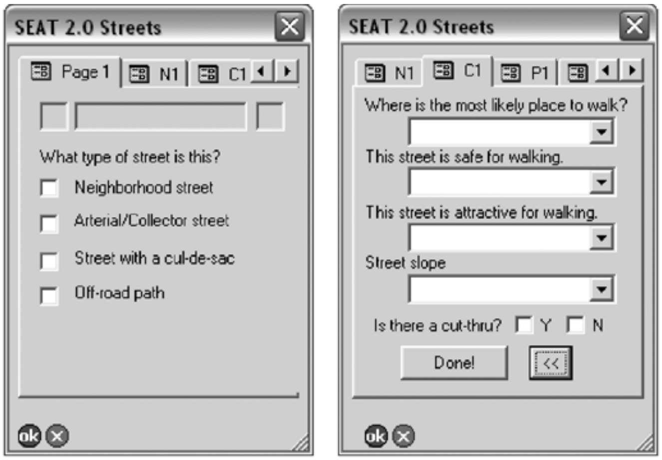

Figure 3. An example of an audit tool that is customized by street type

responses in a default mode so that they could be recalled for a subsequent street segment, but this feature required additional computer programming expertise that could well be avoided with a revised approach to data gathering that customizes the data fields by street type.

Figure 3 shows an example of a potential data-filtering system by street type. These are two screenshots from a new tool, the School Environment Assessment Tool (SEAT), being developed to audit walkability for safe routes to school. The image on the left is the initial data-entry page that appears, which provides an initial filter as to the street type being audited. Subsequent pages are customized based on which street type is selected. The image on the right is the data-entry screen that appears for a street segment that ends with a cul-de-sac. Most streets that end in cul-de-sacs are neighborhood roads with low volumes of cars and are most likely not severely impacted by different measures of walkability. Documenting whether a pedestrian can cut through the end of the cul-de-sac, however, is important and because it only pertains to segments ending in cul-de-sacs, this question only appears for streets selected as cul-de-sacs on the first data-entry page.

FOCUS ON ARTERIALS/ COLLECTORS

It was also apparent from our study sites that in some study areas, it was almost unnecessary to audit neighborhood streets and that focusing the audit on arterials, collectors, and their associated intersections may have been a better use of data-gathering time. In some neighborhoods, all neighborhood streets had sidewalks and were pleasant and safe enough to walk along. The real key, though, for evaluating the potential pedestrian friendliness of one's journey from home to transit (or other destination) were the attributes of the major roads and the intersections between neighborhood roads and major roads. In essence, the more focused question could be: What makes a major automobile road more or less pedestrian-friendly? In this approach, all neighborhood streets could be assumed to be generally walkable and the focus would concentrate on making the areas where high volumes and speeds of automobiles and higher volumes of pedestrians would intersect safer and more enjoyable for pedestrians to navigate. It is in these high-intersection places where interventions on behalf of walking might be best targeted. Comparing route choices and route avoidance by pedestrians along these more major streets would allow planners and policy makers to better focus resources and interventions where they would be most needed, and the audit data could point these decision makers into appropriate directions for their interventions. Of course, in study areas where sidewalks are not universally present, or where street widths in particular vary quite a bit, and are deemed important barriers for walking, then including neighborhood roads in the audit may be important.

Comparing Subjective to Objective Measures

An area for further investigation is to measure the relationship between broad subjective evaluations, such as "Is this street attractive and safe for walking?" with the objective measurements of individual streetscape traits. In other words, can a simple subjective question such as this be enough to evaluate streets and intersections on walkability principles, even with the eventual variation in subjective evaluations? Certain street segments in our audit evaluation felt like poor environments to walk along because of aesthetics, proximity to heavy traffic, and a general feeling of being uncomfortable places. It would be easy to imagine that pedestrians would simply choose parallel paths to walk along. Using the specific measures contained in the audit tool, however, the general feeling was not conveyed. For example, one of these uncomfortable walking streets had a buffer with trees between the sidewalk and the street, on-street parking, only two travel lanes in each direction, and properties that were decently maintained, among other attributes that would supposedly contribute to a safe and attractive walking environment. But by focusing on the individual, objectively measuring details of the streetscape, the larger feeling of the area could be missed without the inclusion of the subjective evaluations. Perhaps the individual objective measures we used were incomplete in this regard, or perhaps no matter how hard we try to measure every aspect of the built environment objectively, it is our subjective perception of a place that is the most insightful evaluation. This is the conclusion reached in a recent evaluation of audit tools where the authors conclude that "walking behavior is better explained by perceptions than sociodemographics or objective assessment of the environment" (Livi Smith and Clifton 2006). Of course, relying only on subjective evaluations does not provide decision makers with any guidance on how to design or retrofit good walkable locations; but for studies of pedestrian route preference, such questions may be enough to determine whether urban design has impact on route choices or not, or whether shortest routes is the predominant factor in influencing trip making.

Paper Versus PDA

This last area centers on the utility of an electronic and GIS-enabled approach to audit data gathering versus a more traditional approach of paper, pen, and clipboard. The obvious benefit of the handheld GIS computer approach is that by collecting data both in an electronic and a GIS format, there is no need for subsequent data entry once the audit is complete. When entering data collected by paper or data collected electronically with a handheld database program, there is additional risk of data-entry error when converting the data to a GIS environment. With handheld GIS technology, that risk is minimized because data can be collected in closed-ended questions directly within a GIS environment. In addition to potential error of additional data entry, there can be a significant amount of time involvement, especially with paper-based audit tools, in converting them to a usable digital format.

The handheld computer approach has the additional benefit of instant mapmaking, which may be important for community-based approaches to walkability assessments. For example, a group of community or elementary school volunteers may use the audit tool to assess streets and intersections within a mile of a target school. With the handheld GIS approach to conducting pedestrian audits, it would be possible for this group of volunteers to easily collect data in a few hours, gather together at the end of data collection, and synthesize the data from each PDA used into a single data file that can be mapped on the spot. Incorporating portable printer technology would allow each volunteer to leave the day's auditing with initial walkability maps based on data collected that day. For community-based approaches to walking issues, the ability to transform volunteer energy into a tangible map can be vital in sustaining community interest and catalyzing decision makers into taking appropriate action in regards to the needs of pedestrians.

Of course, the use of this advanced technology in assessing the walking environment can be limiting or carry risks. Perhaps the biggest limitation of handheld computer technology is taking field notes. When conducting a walkability audit, sometimes making field notes for specific audit questions is desirable, and unless specifically programmed to do so, such open-ended note taking can be more limiting on the handheld computers. Technologically, the built-in word-processing, voice-recording, or picture-taking capabilities of PDAs can be used, but writing observations or comments directly onto a survey form is probably still easier to do with pen and paper.

Another limitation of the digital approach is that audit questions are permanently preordered and auditors are forced to answer audit questions as they are written, not as they are observed. Paper versions of audits allow the auditor to answer questions in the most logical order for what is being observed, but electronic approaches make this approach too cumbersome to be useful.

Other technology issues are that the battery lives of PDAs can be short for all-day auditing, unless extended batteries are purchased. Also, in our experience, some people just find that PDAs are too cumbersome to use and that paper and pen are much simpler and easy to understand than using GIS software on a handheld computer. Good training and preparation can overcome this hurdle, however. Finally, carrying expensive computers while analyzing neighborhood streets and sidewalks can be unsafe in certain neighborhoods (or make auditors feel unsafe), especially if auditing teams are perceived as outsiders to that neighborhood. Making good community connections, as should be done with any project where a potential problem of outsider versus insider may exist, should be a prerequisite to conducting the auditing work.

CONCLUSION

An earlier study by Schlossbert (2007) found that "[Pedestrian audit tools] allow planners to begin to collect the more nuanced characteristics of an area that makes it more or less attractive for pedestrians. And instead of classifying streets based on automobile-oriented categories like minor, arterial, or collector road, with [instruments like these], streets can be classified with a pedestrian-orientation. GIS analysis can then distinguish between paths based on more relevant variables" (Schlossberg 2007). Indeed, walkability audit tools hold much promise to allow researchers and practitioners to better understand the relationship between elements of the built environment and pedestrian behavior. Most pedestrian trips are short, so it makes sense that tools are emerging that can be applied to small-area analyses. We have found that these audit tools, especially when used within a GIS environment, generally provide efficient ways for collecting data and provide researchers with data that can be more quickly analyzed with less error than similar data collected with pen and paper.

Because the increasing efficiency of these tools makes it tempting to collect more data, this urge should be resisted, or at least carefully considered. The appropriate use of this technology is important, and in conducting walkability audits, an appropriate application may be one that focuses on the real areas of pedestrian conflict, rather than on all streets and all elements of urban form. We believe that as these tools evolve, they can be used appropriately to understand how pedestrians interact with their local environment and that these audit instruments will be one means for enhancing the pedestrian infrastructure in such a way as to support increased rates of walking in our communities.

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About the Authors

Marc Schlossberg is an associate professor in the Planning, Public Policy, and Management Department at the University of Oregon, Eugene, an associate director of the Oregon Transportation Research and Education Consortium (OTREC), and a research associate of the Mineta Transportation Institute. He teaches and researches issues on participatory GIS, active modes of transportation, and urban form.

Corresponding Address:
Planning, Public Policy, and Management Department
University of Oregon
128 Hendricks Hall
Eugene, OR 97403
541-346-2046
Fax: 541-346-2040
schlossb@uoregon.edu

Asha Weinstein Agrawal is an assistant professor in the Department of Urban and Regional Planning at San José State University and a research associate of the Mineta Transportation Institute. She teaches and researches in the areas of transportation planning and finance, and the history of pedestrianism.

Katja Irvin is a planner with PMC in Rancho Cordova, Calfornia. She recently received an M.V.P. degree from San José State University, where she was a research assistant for the Mineta Transportation Institute.

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Footnotes

1 The research project was sponsored by the Mineta Transportation Institute, and the full project report will be available on its Web site at http://transweb.sjsu.edu/.

2 We used ArcPad GIS software created by ESRI on Dell Axim PDAs.

3 It is likely that one's pace is a bit slower when entering data compared to someone who would be walking the same street segment without a data-entry task to complete, but over time this tool does allow the auditor to essentially collect data without breaking a stride.