Information Technology for Building Documentation

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The adoption of technological tools may revolutionize the way in which architects and engineers collect, organize, and present information on renovation projects.

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Introduction

Few building owners or managers appreciate how crucial the initial discovery phase of a facade-renovation project is to the overall success and bottom-line cost. Too often, discovery is abbreviated in the misguided interest of time and cost. The results are often inflated construction bids, as contractors hedge against uncertainty during the bidding period, and expensive change orders that arise when surprises are encountered during the construction phase of work. Architects operating between the building administrators and the contractors have always regarded a thorough discovery process as a sound investment. This article describes a best-practices methodology for discovery-phase documentation that incorporates field annotation of AutoCAD drawings, management of digital photographs hyperlinked to the drawings, and quantification of condition amounts and severities.

Elements of a Successful Discovery Phase

The discovery phase of a facade-renovation project is an iterative process of research, investigation, and documentation whereby all available and relevant information about a building facade is collected. The primary goal of discovery in the design phase is to accurately determine the scope of the project at the outset, thereby minimizing contingencies and change orders during construction. By researching all existing design and maintenance documents and contract archives, the team gains an essential understanding of the original building design, construction process, and repair history. Compatibility between the renovation plan and the original construction is essential to the aesthetic and functional success and longevity of the designed repairs. On significant buildings, especially public buildings, a more in-depth search at the Library of Congress, HABS/HAER, or other archives may yield beneficial historic documentation, photographs, and correspondence. A single 80-year-old photograph taken during construction might provide an immediate answer to a vexing question about discrepancies between the construction documents and as-built details. The team must read available reports and must interview maintenance and management personnel to help complete the picture of the living history of a building. Finally, and crucially, an informed hands-on investigation of existing conditions should be performed.

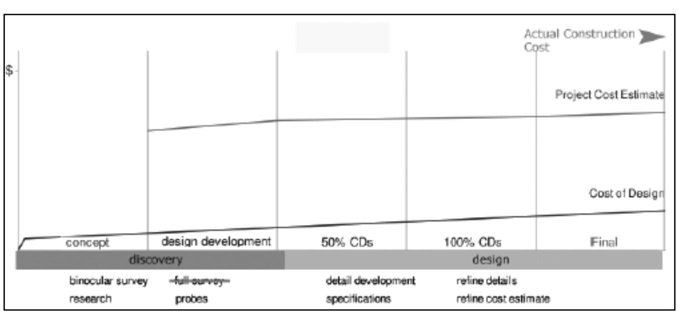

Fig. 1. Cost vs. time graph, when a full survey during discovery is eliminated. All images by the author, unless otherwise noted.

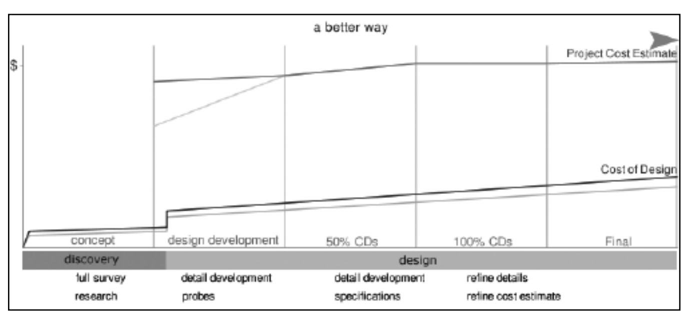

Fig. 2. Cost vs. time graph for a project for which a full survey is completed during discovery.

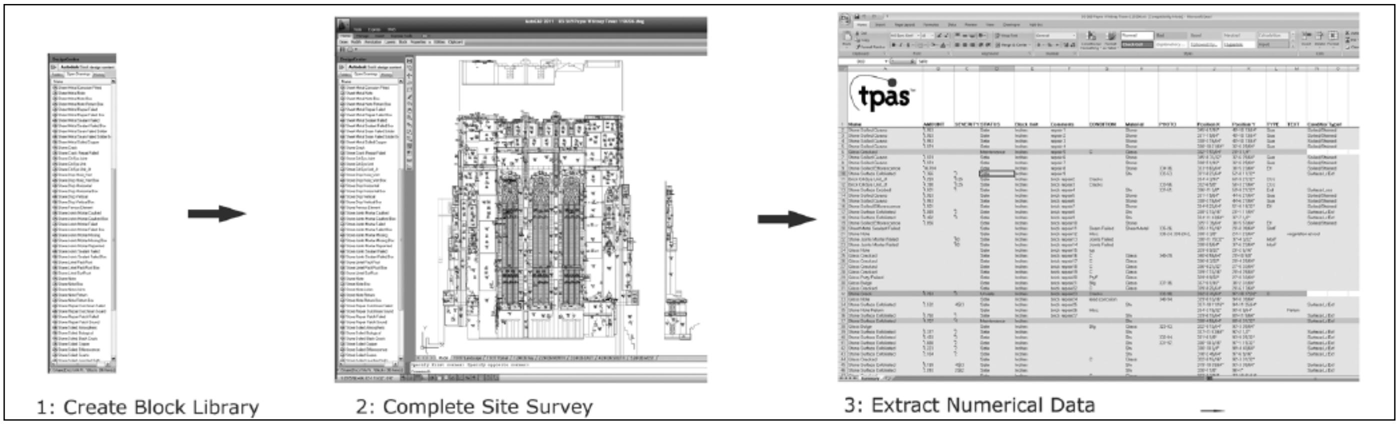

Fig. 3. The survey-data and information flow chart illustrates the how the conditions are recorded and can be searched.

While committed preservationists and enlightened building owners understand the importance of an efficient and accurate discovery process, it is not as well understood by budget-constrained building owners. The advocacy of the discovery process then becomes the burden of the professional team, who must design appropriate treatments based on discovery-phase results.

Analysis and design of thorough treatment details and specifications lead to a project that can be bid more accurately. The resulting confidence in a set of construction documents greatly reduces the number, type, and size of contingencies that contractors include in their bids. As the bid package improves, the risks for the contractor decrease, and bidding competition tightens, ultimately decreasing the total project cost for the building owner. In a recent project, the restoration of a circa-1933 large terra-cotta facade, the architect led an experienced team through a detailed, iterative discovery process to produce a well-developed set of documents and specifications. The cost to complete a series of full surveys during the concept phase was 0.76% of the final construction estimate and, ultimately, three bids were submitted; they were within 4% of each other on a project estimated at $54 million. The minimization of change orders and construction-phase discovery will likely result in a significant net savings for the entire project.

Figures 1 and 2 compare a hypothetical large facade-renovation project completed in two different ways. In Figure 1 a full hands-on survey is omitted in favor of a binocular survey, saving a small amount of money in the concept phase. The resultant project cost estimate is low. However, the actual project cost is much higher than anticipated. In Figure 2 a discovery process that includes a full survey is completed. This step adds a small amount to the concept-phase cost, but it is likely to result in a construction cost estimate that is much more realistic compared to the actual construction cost (defined as total construction cost after all change orders).

The most common error when undertaking condition-assessment surveys is the elimination of a vital front-end meeting among members of the project team to come to agreement on the goals of the survey. The participants in the meeting may include the owner, architect, structural engineer, conservator, and survey team. Too often, this meeting is abbreviated or omitted because the common misconception is that the evaluation of conditions and the design work begin after the survey is complete. This approach may result in the survey team, whether a consultant to the architect or engineer or staff of one of the project design firms, beginning field work without a clearly defined purpose. The initial meeting with the project team is essential to ensure that the scope of the survey is well defined and understood in the context of the overall project objective. From there, the team discusses the organization of the data and agrees on the methods for calibrating data among survey-team members and between the survey team and the full design team. The surveys that deliver the most value to architects and building owners are oriented toward the scope and objectives of the project: both the survey itself and the resulting documentation are based on the requirements of the subsequent phases. This end result requires preparation before, and precision during, the fieldwork.

The most successful projects are executed by a collaborative team of consultants who emerge from initial planning meetings with a common understanding of the goals of the project and well-defined individual scopes of work. Ideally, one result of this meeting is that the same base drawings that will be used for the final construction documents are used throughout the design phase, including the initial discovery survey.

Surveyors must then arrive at the building with scaled background drawings and a building-specific vocabulary of faults and pathologies. In nearly two decades of working on a variety of structures, Vertical Access has developed a master conditions library, organized by building material, that is used to annotate drawings. Site-specific library sets are then developed for each individual project, based upon its construction, materials, architecture, repair history, and project objectives.

The temptation may be to approach the survey with the entire library of condition codes so that every possible condition may be recorded. While this strategy may be appropriate in some cases, for most surveys, it is a cumbersome approach that makes calibration among surveyors more difficult and limits the value of the deliverable to the client. Valuable survey reports provide project-relevant information rather than bulk data alone, the difference being

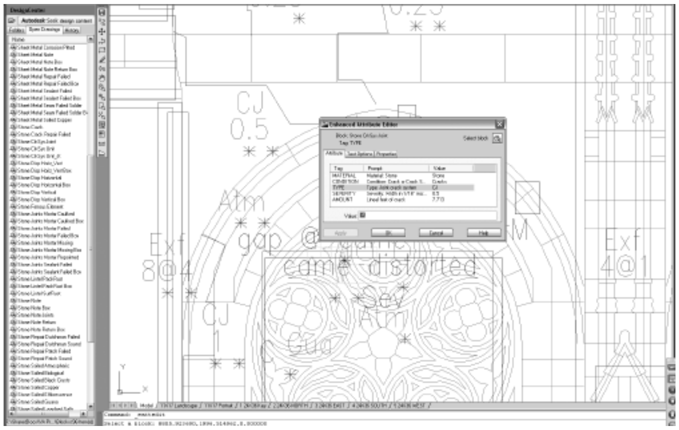

Fig. 4. An example of the type of information provided by TPAS.

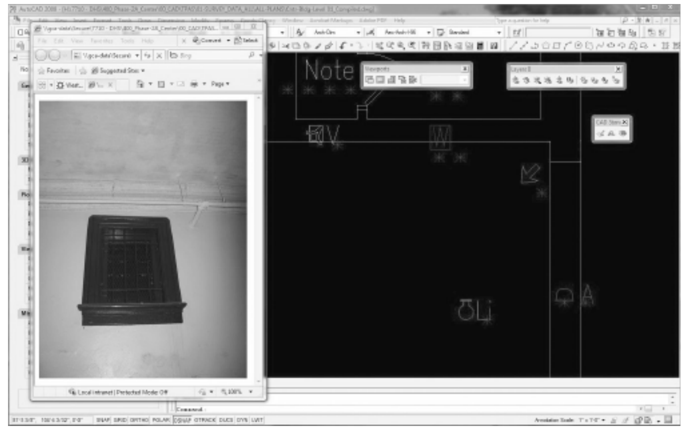

Fig. 5. An example of a window survey from St. Elizabeths. Courtesy of Goody Clancy.

that the information translates directly to an informed bidding process because of the way in which it has been condensed and presented. One illustrative example is a survey in which there may be three different types of crack repairs anticipated for a project. If the surveyors go into the field with three different condition codes calibrated to the different types of cracks, the survey results will be expressed in the same terms as those used by the design team in their construction documents and by the contractors in their bidding process. Ideally, a half day of investigative drops are completed so that sample conditions may be recorded. This investigation is then followed by some off-site work so that the conditions list can be customized and adjusted as necessary before the bulk of the survey work is completed. Of course, if the design team and the survey team are one and the same, specific repairs can be assigned at the time of the survey, streamlining the construction-document process.

In contrast, a rushed and imprecise survey produces poor results at higher cost because of a loss of efficiency. Such a survey may provide a vast amount of data, but much of it may never be used by the design team or owner. For example, prior to a large survey project, an ad-hoc conditions library was circulated on site, and background elevations from a laser scan were provided. The contractor hired for the laser scanning completed his work later than anticipated, so team did not have the necessary background for the survey completion. In addition, because there was not time to check the accuracy of the drawings prior to the survey, areas of the building that were not represented correctly in the base drawings had to be resurveyed once the background drawings were corrected. Later in the project, a significant portion of the survey was spent noting the quantity and type of various soiling conditions, although the design team had determined before the survey that all atmospheric soiling was to be cleaned in the same manner. A scoping meeting with the design team would have helped to better define the conditions for the survey and identified problems with the background drawings.

Technological Tools for Discovery

The development and incorporation of tools to streamline the discovery process on site and to organize and present the resulting information in a useful way has been slow, despite ever-changing technology relevant to survey work. Driving the incorporation of technology into the existing process is the promise of both efficiency and reporting quality. An exclusively electronic process eliminates two-phase data entry and associated redrafting errors, while also inherently driving notation consistency among surveyors. Electronic annotations from the field enable rapid extraction and summarization of survey conditions. This process is the translation of field data into the useful information the client requires, for example, a table of crack length by crack type or of spalls by material or size. Recording and storing individual conditions in a database record allows analysis to be completed both visually on the drawing and numerically by searching for commonalities in the database records (Fig. 3).

There are several obstacles to transitioning from pen-and-paper surveys to direct digital-annotation technology as part of the existing condition-assessment process. One factor is the fee structure used by design firms. Service companies who bill their expertise to clients by the hour may be reluctant to make significant capital investments in on-site hardware, especially when increased efficiency may translate to a reduction in billable hours. Also, the fear of the unknown can cause architectural-service companies to delay committing to a new process that is perceived to be a significant investment of hardware, software, and training. The concept can be very intimidating when the perceived benefit can be difficult to articulate.

Hardware. Another obstacle to incorporating new technology into the condition-assessment process is the rapid pace of technological advance, which increases the tendency to defer hardware purchases and postpone adoption of these new productivity tools. The latest computer with its brighter screen, longer battery life, and lighter weight is always just around the corner. While the idea of a tablet-based computer has been in development for decades (consider Kay's Dynabook concept of 1968 and Apple's 1993 Newton), the technology was not fully refined until 2001, when Microsoft unveiled the tablet edition of its Windows XP operating

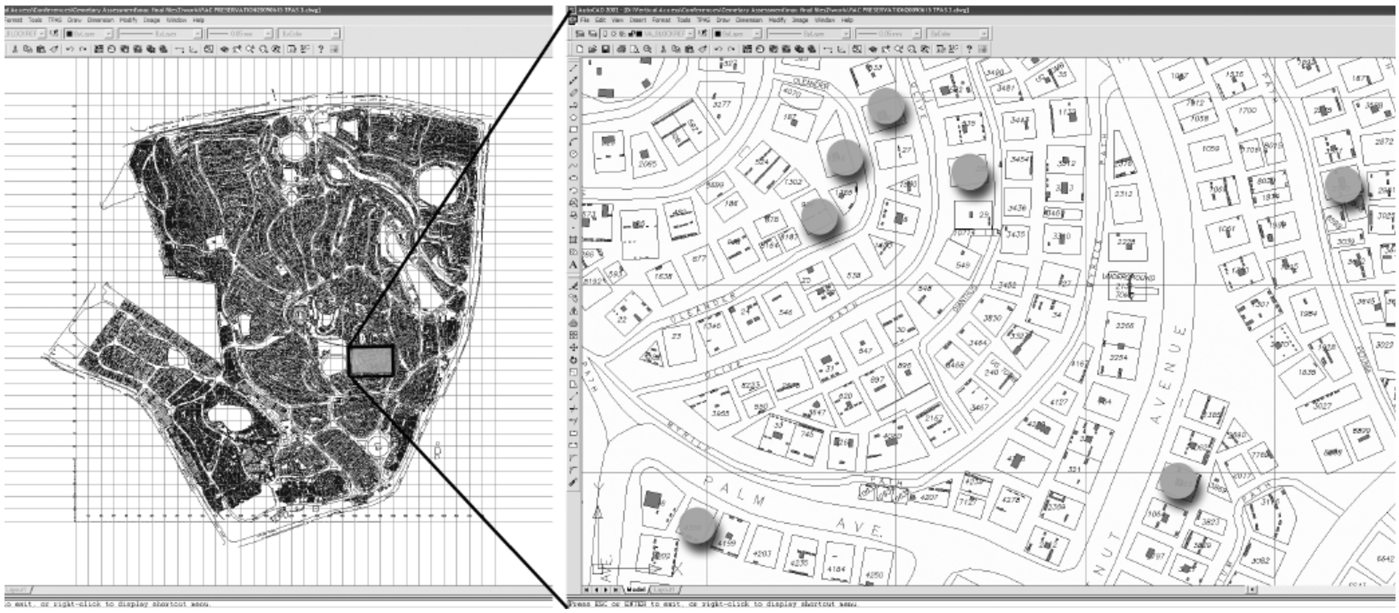

Fig. 6. Map of Mount Auburn, showing critical safety items.

system. There were few hardware vendors initially, but as the market has matured, the selection has grown significantly. A bifurcation of the market has also occurred: tablets are now designed to either serve the "industrial/professional" market or the "consumer" market. While products for the consumer market often are built for specific applications (e.g., digital book devices, such as the Amazon Kindle or Sony Reader), the "professional" versions are essentially Windows-based laptops in a tablet form, supporting a wide range of uses. The much-hyped introduction of the Apple iPad has altered the tablet market, but the iPad is targeted at the consumer, rather than the industrial or professional, market; it is based on a wireless web-application platform. It contains no hard drive and has limited memory and therefore is not suitable for documentation purposes.

New electronic surveying tools, such as project-management and construction field-reporting software packages, require on-site computing. The key goal when utilizing computers on site is to minimize the encumbrance to the technician. Some of the challenges are addressed by the simplified form of a tablet computer: instead of a keyboard and mouse, the stylus is used directly on the screen to type and interact with the application, simplifying its use. One of the greatest challenges has been protecting the fragile, expensive tablet computer under site conditions, but the use of protective "bump" cases and padded storage containers has effectively mitigated these concerns. A market niche of ruggedized industrial tablets has emerged for field work, but they come at a significant cost and weight penalty that often is not worth the protection provided. More aggressive battery-power requirements and screen-brightness issues for extended outdoor use must also be addressed. Increased battery life on newer tablets (up to eight hours) has eliminated this power-management concern in most situations. Expensive screen upgrades, available on several models of tablet computers, have mitigated outdoor usability issues by employing side-screen lighting as well as back lighting to improve visibility in various outdoor-light conditions. Also, tablet-computer performance and longevity can be greatly affected by elevated or lowered operating temperatures, resulting in slower processing time and responsiveness. The protective bump case reduces fan effectiveness, further exacerbating temperature issues.

Currently the most successful model for on-site computing runs the 32-bit Windows 7 Professional operating system. It has 2 GB of RAM with an 80 GB, 1.8" hard drive and uses a Core 2 Duo SU9400 1.4 GHz processor. The 12.1" screen can be ordered with a "transreflective" screen, and it can be operated with a high-capacity battery, both crucial upgrades for field-work applications.

Digital cameras are already ubiquitous field-inspection tools. The most significant issue with camera choice for direct digital-input field solutions has been a software, rather than a hardware, concern. Most low-price "point and shoot" cameras on the market today are conveniently compact and take high-resolution images. The remote-capture capabilities that surveyors are interested in, however, are difficult to find in an off-the-shelf product. The goal of remote capture is to save all image files directly to the hard drive of the computer, as opposed to the media of the camera. To date, most remote-capture software and capability were developed for the professional studio-photography market, combining digital-image capture with a computer, commonly called "tethered shooting." Finding a remote-capture system that allows for the use of the button on the camera to take the photo instead of having to use the keyboard or click a shutter release button on the computer screen has been challenging. This feature is significant for those doing condition surveys in the field because of the practical limitations on site: the user only has two hands. One is holding the tablet computer and the second is holding and pointing the camera. The index finger of the hand holding the camera must be able to execute the shutter (hence the term "point and shoot"). Also, in most tethered-shooting solutions, the camera zoom cannot be manipulated on the camera unit but only on the screen, which presents the same problem.

The refinement of tablets with onboard cameras has made it a possibility, in some cases, to run a complete data-acquisition system with one piece of hardware, but two issues remain: camera resolution and work flow. The camera resolution of these computers is not yet sufficient for many documentation purposes, where the digital image is often enlarged and carefully reviewed to identify faults and conditions not evident on a first pass. Second, the ability to place a hand-held camera out at arm's length allows photos with additional perspectives to be taken.

Software. Ever-evolving software packages challenge preservationists to keep pace with professionals in new construction. AutoCAD has long been the de facto standard in North America for architectural and structural representational drawing. In traditional architectural practice, AutoCAD has been deployed as a 2-D drawing tool with underdeveloped and seldom-used 3-D capabilities. In 2002 Autodesk bought Revit, which is a 3-D modeling tool incorporating building information modeling (BIM) capabilities. BIM typically uses a 3-D model of a building to record and manage all building data in order to increase productivity during design and construction. Whether in Revit or competing products, BIM has the potential to revolutionize how architects design, communicate, and create bid documents. AutoCAD users' adoption of Revit with its BIM capabilities has been slow but steady, as many architecture firms concurrently overhaul their design of new buildings in a BIM environment while still using two-dimensional notation for existing-condition assessments. The practical advantages of a BIM process are less obvious when applied to the renovation of existing buildings. Facade-preservation projects are inherently two-dimensional. Revit, which is so innovative for new-construction projects, has been used experimentally in facade-renovation projects of existing buildings by firms that can apply their BIM experience from their new-construction work. At this point, those experiments have been relatively limited because of the inherent difficulty in creating a 3-D model for an existing building. Without extensive probes or openings into the fabric of a building envelope, the actual construction of the walls and roof is seldom known prior to an investigation. More often than not, as-built drawings or even accurate design drawings showing wall constructions do not exist, and assumptions must be made about the third dimension of information required for a Revit model. Scoping a project based on a relatively few probe locations may lead to expensive mistakes when actual conditions deviate from assumed conditions.

Another platform for extensive collection and organization of survey data is the geographical information system, GIS. GIS is used primarily for site planning and development, with incidental uses in the preservation and conservation of large landscapes and cultural resources, such as botanical gardens, campuses, parks, cemeteries, and archeology projects. One powerful component of the system is its ability to assign geospatial coordinates to data points. In that way, the system basis is not very different from using AutoCAD in two dimensions to work on a building facade, with the "map" in plan view rather than in elevation. The ability of GIS to connect with a back-end database running in the background of the drawing makes the data accessible in both a visual and a numerical context. The biggest challenge to utilizing GIS as the basis for preservation projects is that the software currently used to create GIS maps, mainly ArcGIS, is expensive and not commonly used by architects, engineers, and building owners involved in preservation. Therefore, the incorporation of GIS into preservation projects typically requires an upfront capital expenditure for the software and personnel training for the new technology. In contrast many firms with a historic-preservation specialty have AutoCAD (and now Revit) software and in-house expertise. Other challenges include fundamental differences of scale and precision — miles in GIS versus inches in CAD.

Several software packages have been created and marketed for the architecture, engineering, and construction industry. Most have been designed for project management and punch-listing applications, which is a much larger market than that for facade preservation. Although there are components to these software systems that are useful and applicable to the collection and organization of facade-survey data, they tend to have a bloated interface, with many components that are not helpful or useful to the very specific needs of preservation professionals. One such software company, Latista, announced that it was incorporating Navisworks into its existing web-based field-reporting solutions.[1] Navisworks uses tablet PCs to update and share information on a single building model, allowing the user to update statuses, track commissioning and materials, and even incorporate a barcode scanner for materials tracking. The inclusion of Navisworks allows the Latista product to communicate with Revit and other BIM models. Their visual punch-list tool is an intriguing model that allows for standardized inspections using predefined deficiencies menus and the creation of a pdf report that is automatically sent to all stakeholders. It is likely that products such as Latista and their competitors, such as EZPunch[2] and Inspecttech[3], could be further standardized for the preservation market. However, they currently are not, and given limited size of the preservation market compared to that of new construction and infrastructure, it is unlikely that developing a lower-cost model for preservation will occur soon. This void leaves preservation professionals working "the old way," with pen and paper and a separate camera, instead of developing best practices now.

The Tablet PC Annotation System (TPAS)

Each preservation project is so different that a one-size-fits-all solution is nearly impossible. However, AutoCAD currently includes functions to export recorded conditions into a generic tab-delimited file, which can easily be imported into a spreadsheet or database program. Vertical Access has developed a tablet PC–based field solution using AutoCAD for both direct input of conditions and later exportation of the conditions database for summarization. The resulting project, TPAS[4], is an ever-evolving set of conditions libraries and annotation tools built on the widely known and widely understood platform of AutoCAD. TPAS also has the GIS-like ability to manipulate and view data in both a visual and numerical format. Organizational improvements, including automatic on-site renaming and hyperlinking of survey photos, increase its efficiency and usability on site and in the office. By leveraging the existing capabilities of AutoCAD along with extensive programming, customized input is created to match the needs of the project. It is an organizational tool for the numerical, graphical, and annotation data that increases consistency among surveyors, while helping organize thoughts, photos, graphs, and videos in a coherent way. While providing flexibility, it also allows for a focused survey, as the conditions library is coded in advance. The need to define the conditions library for the survey forces that initial pre-site meeting mentioned above, which is often either rushed or skipped altogether. The end deliverables provided from a TPAS survey require no special software to interpret other than AutoCAD and Excel (Fig. 4).

A community of development partners contributes field experience and project requirements that continue to evolve the TPAS system. In the past 12 months, several architecture companies have recently become development partners with TPAS, purchasing the hardware required to run the system on their own computer systems and licensing the TPAS software from TPAS LLC. A Development Partner portal allows the user to access a customized page that contains all of the support documents for TPAS, along with the master block libraries. Development partners can create project-specific libraries through a collaborative process in which they fill out a web-based form on the TPAS portal specifying the requested changes. Customized block libraries are created, and the TPAS code revised and then made available on the Development Partner portal.

Case Studies

Goody Clancy, a preservation firm that has incorporated TPAS into its work processes, used the program to complete facade-conditions surveys of 46 buildings on the campus of St. Elizabeths Hospital, in Washington, D.C., for the General Services Administration (GSA). Most surveys were completed using TPAS in conjunction with binocular surveys, as the majority of the buildings are two-to-four story, brick-and-stone masonry structures. TPAS is being refined for a second series of surveys so that the team can leave the site with completed construction documents. These refinements include automatic hatching of denoted areas and incorporation of dynamic leaders into construction treatment blocks. Instead of noting conditions, they will actually be creating CDs on site, so their block library will consist of actual repairs, making the export of TPAS data a vital component of the bid package. During the course of the investigation, Goody Clancy also created a block library to complete interior surveys, noting the presence of lighting fixtures, showers, etc. (Fig. 5).

On another TPAS development project, Vertical Access teamed with Mount Auburn Cemetery to investigate whether TPAS could be customized to enhance their ongoing monument-survey project. When the pilot project started, Mount Auburn's existing survey process was based on a well-designed and extremely thorough Microsoft Access–based database. Various database queries allowed for the simple analysis of large amounts of data. The missing component of the existing survey project, however, was the ability to see any of the information visually. TPAS teamed with Mount Auburn to perform a pilot study to customize the TPAS export function to allow both visual and numerical queries. One goal was the ability of the preservationist responsible for monument upkeep to view all safety violations on a map, as shown in Figure 6. She could then optimize crew time by geographically grouping projects on a given day. Prior to the TPAS map, she would have only a list of lot numbers, and a tedious process would ensue to determine the best work plan. TPAS was improved for use in cemeteries by allowing drop-down menus to increase annotation efficiency and accuracy in the repetitive survey process.

Conclusions

The evolution of TPAS through an ever-increasing community of development partners has allowed for the continual refinement of the software. By providing valuable feedback, the community informs the prioritization of the improvements to the system. TPAS development partners are encouraged to share their developed block libraries with the community. This model takes the focus away from reinventing documentation methods during the discovery process and allows more time to be spent on important design tasks that ultimately define the success or failure of a project. This collaborative approach also helps the field to develop and to learn from each other about specific conditions, materials, problems, and treatments.

KELLY STREETER is a structural engineer and partner at Vertical Access and TPAS. She speaks often about the role of technology in preservation at architecture and engineering consultancies, universities, and conferences. She manages TPAS, LLC, which helps firms incorporate the TPAS approach, customizing the system to meet their office-specific and project-specific requirements. She can be reached at Kelly@vertical-access.com.

Notes

1. http://www.latista.com/, accessed January-March 2010.

2. http://www.e-zpunch.com, accessed January-March 2010.

3. http://www.inspecttech.com/, accessed January- March 2010.

4. James V. Banta, Kent Diebolt, and Michael Gilbert, "The Development and Use of a Tablet PC Annotation System for Condition Surveys," *APT Bulletin* 37, no. 2-3 (2006): 39.