Preservation can be an important component of urban design, particularly within older neighborhoods, districts, and cultural landscapes. Character-defining features and systems, including architectural elements, trees, signage, and other elements of the landscape, influence how one experiences both individual landmarks and the district as a whole. To plan for an entire district or landscape, urban design must be holistic and operate across scales from individual building elements to broader geographical regions. Just as importantly, preservation also operates across time, requiring the documentation of information from the past and present and proposing planning and design interventions for the future. The digital tools used by preservation professionals, therefore, should ideally not only incorporate the ability to visualize and analyze sites in three dimensions at various scales but also provide a window into the additional dimension of time (Fig. 1).

Architects commonly utilize 3D modeling in building design, as do urban designers when visualizing the massing, scale, and other aspects of streetscapes and public spaces. Local planning departments and historic-preservation offices often use GIS in the form of municipal-enterprise, desktop, and web-based GIS systems to maintain property information, share data, and make decisions. The number and diversity of 3D and GIS tools continues to grow, leading not only to opportunities for new ways of visualizing and analyzing the built environment but also to complexities as professionals attempt to use an ever-evolving set of tools. On a single project professionals with backgrounds from different disciplines often employ very different tools.
Much of the preservation literature on 3D modeling has focused on 3D terrestrial (ground-based) laser scanning used for "as built" documentation.\textsuperscript{1} This documentation is valuable and can be used in many ways. However, there are only a few examples of systematic research on 3D modeling beyond laser scanning. This article evaluates the use of various 3D-modeling tools to visualize change to a cultural landscape over time, to explore alternative reuse or redevelopment scenarios, and to bridge between the scale of the individual building and the broader geographic scales of district, landscape, and community.

Drawing from research funded by the National Center for Preservation Technology and Training, this article examines 3D GIS as a tool for uniting architectural and geographic knowledge in planning for cultural landscapes and historic districts. Two case studies examine the use of CityEngine, a 3D GIS platform. Also discussed are other 3D-modeling technologies that either were used in conjunction with CityEngine or are compared to it. The case studies are Flushing Meadows Corona Park in New York City, where 3D GIS is being tested as a design tool, and Portsmouth, New Hampshire, where it is used in downtown design review.

The potential exists to unite multiple disciplines, scales, and time frames with available 3D-modeling tools to achieve a 4D planning and design tool. Both case studies below, however, demonstrate that considerable development of the current 3D GIS software is needed in order to support a seamless union of architectural and geographic information. In particular, further development of crossover technologies that unite architectural modeling tools, such as sophisticated Building Information Modeling (BIM) software, should be more robustly accommodated. In addition, the database, querying, and spatial analysis functions that are a strength of 2D GIS need to be better represented within 3D GIS. Finally, the case studies demonstrate the importance of two other sets of concerns: the compatibility of software used for bringing information into and out of CityEngine and the diverse, situation-specific expectations and needs of users of 3D-modeling software. Since the element of time is introduced to these tools by the user and is not yet an inherent attribute of the software, the remainder of the article will refer to these programs as 3D.

Bridging Innovations in 3D Modeling and GIS

Several 3D-modeling packages, such as AutoCAD, Revit, and Rhino, are used by architectural firms for design. The
film industry and other creative industries also utilize 3D-modeling packages to generate realistic-looking city scenes for movies and games. In addition to desktop 3D applications aimed at professionals, the free availability of Google Earth Pro and 3D Warehouse, an online website for sharing 3D models at no cost, is supporting a growing and global network of users who generate and share buildings and structures.

Several decades of advances in laser scanning and computing have enabled the production of increasingly faster and more detailed 3D building models of cultural resources. Laser scanning can save time and reduce errors (and hence costs) compared to manual documentation. The point clouds generated through 3D laser scanning can be used to create “a rendered model, animated fly-throughs, and measured drawings,” as well as “contour maps, visual analysis, environmental assessments, documentation reports, and mitigation surveys.” Models are converted to construction documents and finished 3D models using specialized 3D-modeling software.

Meanwhile, local governments are increasingly using geographic information systems (GIS) for preservation purposes, such as storing data from tax assessors about parcels and improvements. New desktop- and web-based GIS tools have also supported advances in analytical and predictive techniques for surveying cultural resources, as well as for engaging the public via websites that allow anyone with Internet access to contribute information to historic-resource surveys online.

These areas of technological innovation are producing a dynamic environment for the use of technology for preservation-planning purposes. However, advancements in 3D modeling and GIS typically remain separate worlds of innovation. The use of 3D modeling within preservation is more commonly oriented toward documentation and is not typically incorporated into GIS systems that have the ability to query and analyze data. While readily available tools such as Google Earth Pro tout the ability for its users to “measure view-sheds from a new residential high-rise to the nearest park, or the line-of-sight to the ocean,” in fact these GIS tools are rudimentary compared to some of the spatial analysis tools available in 2D and 3D GIS platforms developed by ESRI or open-source tools such as QGIS. Perhaps Google Earth Pro could be better integrated into preservation practice, but for now it and other similar 3D tools remain largely disconnected from the municipal-enterprise GIS systems that are both a source of publicly available data for preservation planning and a primary means for public agencies to manage geographic information.

For this study the research team tested ESRI’s CityEngine, a software application selected because it is a 3D GIS system. CityEngine is described as a procedural modeling tool. It allows users to generate city models using “rules.” These rules are created using a “CGA shape grammar,” a specialized computer-programming language (referred to throughout this article as CGA). The rules are powerful. For instance, they can be scripted and applied to specify how far buildings are set back from the street on a single parcel, a set of parcels, or in an entire model city. Rules can also specify the types of windows, building facades, or building materials associated with certain building types and then they can be applied to individual parcels to generate a specific building or randomly across a district to simulate variations in future developments or past cities. For example, CGA rules have even been used to “recreate” ancient Roman cities by generating likely column and roof types on buildings whose actual historic form and construction are unknown. CGA rules can also be made interactive: buildings that are set up as “dynamic” allow a city designer to create a graphical interface of sliders, toggles, and text entry areas so that users can make changes to the building height, mass, or architectural features on the fly.

The following case study provides insights into the extent to which CityEngine can serve as a bridge between 3D modeling and GIS, as a platform for the integration of 3D models from multiple sources, and as a tool for cultural-landscape analysis and urban design.

Flushing Meadows Corona Park, New York City

Flushing Meadows Corona Park is an 897-acre park in the Borough of Queens. Robert Moses, New York’s notorious city-shaper, strove for decades to turn this area from an ash dump into a municipal park. Integral to achieving that dream was constructing the 1939 and 1964 World’s Fairs at the site (Figs. 2 and 3). Construction of the fairs spurred improvements in infrastructure and landscaping that paved the way for today’s municipal park.

Since 1965 the neighborhoods adjoining the park have developed into some of the most ethnically diverse in the world. Where fair pavilions once stood, residents from nearby areas now play soccer and other sports, and the park is a popular location for weddings, as well as many informal activities. Also in the park are the UTSA Billie Jean King National Center and Citifield, the home of Major League Baseball’s New York Mets. Several cultural institutions are located in Flushing Meadows, including the Queens Museum. Originally a pavilion constructed for the 1939 World’s Fair and adapted as the New York City Pavilion for the 1964 World’s Fair, the Queens Museum also served as a temporary location for the United Nations. Today it houses a famous panoramic physical model of the city along with art exhibits. The nearby New York Hall of Science was designed for the 1964 World’s Fair and remains a museum with interactive science exhibits.

The New York State Pavilion, designed by Philip Johnson for the 1964 World’s Fair, also remains on site (Fig. 4). After suffering from years of neglect, the pavilion was named a “national treasure” by the National Trust for Historic Preservation, the outcome of advocacy campaigns by the local nonprofit People for the Pavilion. The Port Authority building is another pavilion left over from the 1964 World’s Fair, and although it too needs rehabilitation, the building remains a public-events venue called Terrace on the Park.
Many landscape features from the two world’s fairs survive as well. The most visible is a network of pathways constructed for the first fair and reused for the 1964 fair (Fig. 5). Large formal fountains are oriented along the paths, only one of which is still operational. The fountain is located at the site of the Unisphere, a 140-foot-tall globe depicting the world. The Unisphere was the centerpiece of the 1964 fair landscape and remains today a central feature of Flushing Meadows Corona Park (Fig. 6). The park also has sculptures and more than 600 benches, many left from the world’s fairs.

In recent years there have been ambitious ideas for improving the park. Former Mayor Michael Bloomberg’s administration proposed a soccer stadium, the construction of which would have destroyed some of the fairs’ pathways and fountains. Separately, a 2008 strategic-framework plan described the pathways as being too wide and urged freeing the Flushing River from its culvert. Neither of the two plans considered the remaining fountains or pathways from the fair as “historic” and little consideration was given to options that would preserve them as integral to the landscape. Those plans were...
eventually scuttled due to public opposition and a lack of resources. Since then, there has been interest in preservation interventions, including repainting and eventually rehabilitating the New York State Pavilion. However, no plans considered the park landscape holistically from a preservation standpoint.

In the fall of 2014 a Cornell University urban-design workshop led by Jennifer Minner analyzed Flushing Meadows Corona Park. Students proposed design interventions aimed at preserving historic resources (such as the fountains and pathways) and interpreting the history of the landscape, while adapting the park to current needs and future opportunities. Based on the findings from that workshop, as well as information collected from community partners, the Cornell research team developed “use cases” for preservation and design interventions for the park that could serve as criteria or as a wish list for any 3D-modeling GIS software. These use cases or areas of concern were broken down into six categories: cultural landscape preservation, land use and development alternatives, planning for sustainability and climate change, architectural documentation, wayfinding, and interpretation and education.

The 3D-modeling use cases included developing models of various landscape elements in the park at different key points in time, such as the fountains, walkways, and vegetation; modeling the restoration of ecological features at the site, such as the Flushing River; modeling land use and developments in the communities neighboring the park; and creating mobile apps for various types of park users. For each of these use cases, there were expectations that the 3D model would be both accurate and able to convey in a meaningful manner the quality and experience of the features being described. The use cases envisioned both modifying and capturing very detailed information in the desktop version of CityEngine and also providing interactive 3D models via web scenes, which stakeholders and the public could explore on the web without having to install specialized software. There were also expectations by the research team for the ability to capture and query character-defining features and other data typically associated with historic sites at a district or landscape scale, functions commonly found in GIS.

The exploration of use cases led to the construction of three digital models of the park from different points in time: 1964, during the World’s Fair; existing conditions in 2016; and a proposed design intervention to be built in the near future. Producing a detailed model of the 1939 World’s Fair was too time-and information-intensive to be a primary goal in this phase of the project. In the future the research team hopes to either initiate or support efforts to model the 1939 World’s Fair and continue to improve the 1964 model.

Since the aim of this research was supporting preservation and design and not producing immersive 3D environments, the research team did not create highly detailed models for visualization of past fair landscapes (as is evident in Figure 1). The surviving fair pavilions received the most detailed attention in the historical model. In addition, a few pavilions available on 3D Warehouse were incorporated into the historical model, and graduate students contributed some models of historical pavilions that piqued their interests. Over time, the historical model of the fair can be improved through cumulative contributions via 3D Warehouse and other sources, with individuals generating more detailed models of pavilions of personal interest.

The New York City Parks Department supplied the team with a GIS database of locations of former pavilions, created for the 2008 strategic-framework plan. It was used as the initial source of building footprints and then extruded to show the location and rough massing of pavilions no longer on the site. The research team then observed that the shapefile was overly generalized and had inaccurate footprints for some pavilions. To fix this, a detailed site plan from the 1964 fair was located, and a research assistant traced landscape features, pavilions, and roadways from the site plan. The site plan was double-checked against a historic aerial photograph of the 1964 World’s Fair and found to be much more accurate than the building footprint shapefile from the GIS database. Detailed outlines of the building footprints were completed in AutoCAD and ArcGIS and then brought into a CityEngine environment. A geo-
the other pavilions modeled by students could be draped onto the ground plane. Some fair pavilions were simply extruded from the new footprints. The detailed digital models of pavilions available from 3D Warehouse were then brought into the environment, as were the other pavilions modeled by students in a combination of Revit and AutoCAD. The team also imported models of the Unisphere and the New York State Pavilion that had been generated by a team at the University of Central Florida. These models had been created in Autodesk’s Maya, a 3D animation and modeling software that can be used to create immersive scenes for games and movies.11 The results were then exported into a web scene in which the historical model could be compared to existing conditions using a time slider (Fig. 1).

The development of the 2016 existing-conditions model followed a similar process. GIS data for building footprints were downloaded from PLUTO, New York City’s detailed database containing tax-lot, land, and building information. Relevant buildings were brought into CityEngine and extruded to show rough massing for the surrounding neighborhood and for some park buildings. Prominent buildings in the park were incorporated into the scene using 3D models found online or produced by the research team.

Using the plans for the never-built soccer stadium, the research team created a future scenario that dramatically portrayed the negative impacts that such an ill-considered design intervention could have had on the remaining historical features of the park. The team is also continuing to work on future scenarios, such as daylighting the Flushing River in a way that is sensitive to the historic fabric of the site. (Daylighting is the process of exposing buried waterways and restoring habitats and ecological functions lost when a stream or river is piped underground.)

The research team is also experimenting with methods for displaying continuous change. Figure 7 illustrates how all known building footprints, including those from the 1939 and 1964 World’s Fairs and from 2016, were merged into a single file. The file also includes data for the construction and demolition dates associated with each building footprint, allowing a user to display the site as it existed in a specific year (any year is possible). CGA script generates a 3D building model in place, if one has been created; or if not, it extrudes a footprint associated with the appropriate display year. The footprints of all structures built in the park and surrounding area are always present, but only extruded or generated only if they were present in the display year. Another setting allows the user to specify whether to extrude the buildings in the immediate vicinity of the park (in the bottom panel of Figure 7, the user has elected to extrude the buildings in the surrounding neighborhood context). The research team is experimenting with applying this same method to light standards, trees, benches, and other landscape features so that they too can change according to the display year and underlying attributes. CityEngine’s web viewer can only compare only two points in time. Therefore, the research team will likely move the desktop CityEngine model with more sophisticated representations of time into a different platform for online viewing (such as ArcGIS Pro).

The process of creating models in CityEngine proved to be complicated and frustrating at times. The research team found the available documentation and overall user-friendliness of CityEngine to be deficient. Using CityEngine requires knowledge of ArcGIS in order to prepare and import available geographic data. However, proficiency in the use of GIS is not enough; one must also develop what are likely to be new skills. Adding a new piece of information to a building model, such as building materials or the source of the model, requires CGA scripting. This contrasts with ArcGIS and other GIS tools in which adding new types of information to underlying shapefiles or geodatabases can be accomplished with relative ease by simply adding a new attribute field. As an example, a CGA script can be used to generate 3D models of benches according to type. There are benches at Flushing Meadows that date from both world’s fairs, as well as from other periods. Scripting enables generation of the correct bench type in the scene.

Some of the use cases for 3D modeling assumed the ability to store information about a building or landscape element’s status (contributing or not) in a potential historic district and its character-defining features. Storing this information requires creation of an attribute field identifying character-defining features of individual buildings and the landscape, so that they could be easily queried and displayed throughout a scene. However, as noted above, in order to query information in CityEngine or to aggregate and summarize underlying data in the models, CGA scripting is required to make selections and generate reports.

Another sorely-missed feature in CityEngine, but found in tools such as Google Earth Pro, is the ability to measure buildings and other elements in 3D space. Dimensions are key to planning and design decisions, so the lack of a measurement tool was frustrating. As a work-around, a research assistant created a height attribute in feet for buildings in the scene using CGA scripting. This enabled the calibration of building models using data entry of building height in feet. For heights of buildings in the surrounding neighborhood, the team developed estimates based on underlying tax-assessor data on the number of floors. There were also substantial complications in importing models. For instance, texturing was lost when importing the detailed models of the Unisphere and the New York State Pavilion that had been created in Maya by the Florida researchers. In addition, positions of models could be lost during import and many models had to be manually repositioned in the correct locations or oriented in the correct direction.

The research team’s experimentation with 3D modeling in CityEngine complements other 3D-modeling efforts for
the park. Dr. Lori Walters, a professor from the University of Central Florida, has focused on two additional types of 3D modeling. One is the creation of a highly detailed model of the New York State Pavilion through laser scanning. In the future, the results of that effort might be incorporated into 3D GIS, although the size of the model is likely to cause errors in CityEngine. The second type of modeling is the use of software applications Maya and Unity (a game-development platform used to create 2D and 3D games) to design computer games for middle-school students based on a world’s fair theme. The Cornell research team imported two of the models developed for these games. However, other details of the immersive game environment were not shared between the two research projects.

Dr. Walters’s Maya and Unity-based 3D-modeling efforts have been turned into a game-like display in which museum-goers can step on a mat with a map of the 1964 World’s Fair site and see a 3D image of a corresponding pavilion on a TV screen. The game environment allows users to see the fair landscape; however, it is not a geographic information system. There is no way to add underlying information to individual features or to query, as there is in GIS. This difference highlights an additional divide between curated public history and educational aspects of immersive environments versus the design-oriented software in CityEngine.

Downtown Portsmouth, New Hampshire

A case study in Portsmouth, New Hampshire, illustrates the use of CityEngine in a downtown historic district. With a population of just over 21,000, it may seem surprising that 3D modeling has been a major initiative for the city. However, as explained by Nicholas Cracknell, the city’s principal planner, the city has pursued 3D modeling as a means of improving the development-review process to better preserve the historic character of downtown. Heritage tourism contributes substantially to the local economy, and many residents value the historic fabric of the town. A new set of 3D models and a new process of incorporating the models into development review enables interested parties to participate in deliberations about development proposals.

The city contracted with Tangram 3DS, a private firm located nearby in southern Maine, to model the historic downtown area. Initially, the city’s geographic information systems department provided the consultant with GIS-based building footprints and data on building height, which the consultants then used to produce untextured volumes representing existing buildings. The consultants then took more than 6,000 photographs to capture building facades in color and details such as doors and...
windows, in order to texture a subset of approximately 600 buildings. Models of downtown Portsmouth are now available on a web portal created using 3DS Max. From there, users are able to download individual buildings or entire sections of downtown as DWG (associated with AutoCAD), 3DS Max, Obj, or Sketchup files (Fig. 8).

However, the integration of 3D modeling into the development process did not stop with a point-in-time model on a static website. When the cost of a proposed project exceeds $50,000, whether it be an infill or exterior renovation, developers are required to submit 3D models to the city. These are typically generated in Sketchup, Revit, or 3DS Max. The city’s GIS department, which maintains a model of the entire city in CityEngine, then places the developer’s proposal into a 3D model of the entire historic district. Prior to a public meeting on a proposed development, the model and a portion of its surrounding context, usually everything within a 300-foot radius of the proposed development, are exported into a “web scene,” which is made available to the public via a link. As mentioned previously, unlike the full models viewed in the desktop version of CityEngine, exported web scenes can be viewed online and do not require users to have access to CityEngine. While the viewer on the city’s geoportal has limitations in terms of navigation, the CityEngine-generated web scene allows users to zoom in quite close and navigate freely around the scene.

While the use of CityEngine allows for the collection of files from multiple sources and applications, city staff have found that maintaining the 3D models is labor-intensive. Keeping the model up-to-date takes substantial time, given complications in importing 3D models, placing and orienting the models, and exporting portions of the entire downtown model into web scenes (differences in the way that 3D models are produced are one source of errors). New 3D models also need to be reoriented to the correct location and scaled upon import (these problems with the 3D-modeling platform were also observed in the Flushing Meadows case study). In addition, there are memory limitations on what can be exported into web scenes. When memory limitations are exceeded, errors are generated, and the web scene cannot be exported for viewing online. Often the software simply times out and offers no indication of what the problem might be. Therefore, a very large district with highly detailed models may be difficult or impossible to export into a web scene. City staff have expressed interest in developing clear specifications for models to ensure that the models submitted with development proposals can be imported more seamlessly into and exported from CityEngine.

Despite some of the complications experienced by city staff, architects, and developers have not protested the new requirement to submit 3D models. Cracknell attributes this to the regular use of 3D modeling among architects designing projects in Portsmouth and to the established practice of using 3D Revit or Sketchup models in public presentations. In fact, designers have applauded the ability to download 3D models from the city’s website, since it saves time in generating 3D scenes that show a specific development proposal in context.

Although a consultant created the initial downtown 3D building models and the online geoportal in 3DS Max, the city’s GIS department maintains the model in CityEngine. One staff person has expertise in both ESRI ArcGIS and CityEngine and is able to perform these duties in-house. Because the web portal is a different proprietary system, staff must work with a consultant to update the 3D models available online to keep them up-to-date and downloadable from the web portal. This means that there are additional long-term costs associated with maintaining public access to 3D models via CityEngine web scenes, keeping 3D models available to developers and design professionals via the web portal, and maintaining a complete model of the entire downtown in a desktop version of CityEngine.

While developers are required to present both before-and-after models as part of applications, the city does not yet have a clear plan for archiving models of demolished or pre-remodeled buildings. The maintenance strategy for the CityEngine model appears to be continual replacement of older, less-detailed or since-modified building models with their newer counterparts. Therefore, there does not appear to be an easy way to step back in time to visualize the impacts of cumulative changes to the historic district. This is an important, unresolved issue in visualizing landscape change that has largely been unresolved in many 2D and 3D GIS projects. Valuable information about landscapes and districts is often discarded instead of being archived in a format that can be analyzed over time.

Portsmouth is now embarking on a climate-change project to visualize the potential impacts to cultural resources as part of a federally-funded project looking at coastal communities in New Hampshire. City staff anticipate that the 3D model will aid in visualizing the potential impacts of sea-level rise. Hence, the ability to visualize climate-change scenarios—in terms of potential design interventions and impacts and of addressing vulnerabilities in the context of cultural resources—appears to be an important direction for the use of 3D modeling.

Conclusions

In the early 1970s the environmental-simulation laboratory in the College of Environmental Design at University of California, Berkeley, under the direction of Donald Appleyard, constructed a 40-foot-wide physical model of San Francisco and developed a new computer-driven mobile camera system that allowed researchers, designers, and public officials to experience the city and alternative urban-design scenarios in 3D, as if they were traveling in a car at scale through the model.19

Forty years later CityEngine represents one more step in this attempt to create an experience that either mimics what exists or takes us to an alternate universe, with the goal of using that experience as the basis for acting in the world. In CityEngine it is much easier to build a model of a large city constructed...
of many Miesian buildings than it is to document a single building by Ludwig Mies van der Rohe, because the rules-based architecture makes it relatively easy to generate a wide swath of repeating geometries and architectural features. However, CityEngine is weak in giving the user the ability to model data associated with distinct architectural features. The more one attempts to add underlying information or ground the building to an actual site and time, the more CGA scripting is required, and the complexities quickly increase.

The bridge between design (and its 3D representations) and geographic information systems (and their arrays of attributes and data) is still relatively new, and so the functional flaws show. The next versions of such a 3D GIS hybrid need to be more user-friendly and have additional functionalities. Ideally, new versions should facilitate the storage of rich forms of documentation about historic fabric. New hybrid tools should be capable of the rapid generation of design alternatives on the fly at design charrettes, a functionality presently limited by the complexity of operating CityEngine.

In the interest of better understanding historic districts, future versions could unite methods from other disciplines, such as engineering or archaeology, in addition to architecture and geography. For example, a true 4D GIS could embed life-cycle analyses into procedural modeling. Imagine if users could visualize the flow of materials and energy in and out of a historic district, through different preservation, demolition, and redevelopment scenarios. This goal might be accomplished by combining CityEngine's strength in modeling urban fabric according to rules with the addition of built-in life-cycle analyses that are a strength in building information modeling.

For cultural landscapes such as parks, the ability to bring together detailed hydrological information in GIS with detailed architectural information could be quite valuable. This is of particular interest for models of Flushing Meadows Corona Park, where the daylighting of the Flushing River is a design scenario that needs further visualization and analysis in relation to the historic fountains, pathways, and pavilions from the world's fairs.

Observations of the two case studies in this article suggest that integration of 3D GIS modeling and BIM is a particularly promising area for further technological development. While engineers, architects, and facilities managers may be moving toward greater use of BIM, which enables detailed analysis related to life cycle and energy usage, planners and geographers benefit from the greater scalability of GIS to analyze geographic data. Heritage practice at the scale of district, city, and region is likely to benefit when the detailed architectural scale of BIM is united with the sophisticated querying and spatial-analysis capabilities of GIS, enabling new bridges between technologies linked to distinct but related disciplines.

Currently CityEngine, like most other platforms, is limited in the ability to both visualize and analyze landscape change through time. CGA scripting can be used to create continuous modeling of time in the desktop version of CityEngine, but the full models cannot be shared easily. One can create separate models for different points in time and export them to web scenes in order to compare two specific snapshots in time with a time slider. However, CityEngine-generated web scenes do not yet have the continuous time slider available in ArcGIS or in Google Earth Pro. A workaround is to make video scenes of the desktop version showing incremental and continuous change, but this approach does not give the public an interactive version of a multi-dimensional model—only a movie to watch passively from beginning to end.

In order to fully support the needs of preservation practice, the tools of the trade must more robustly support the integration of knowledge about historic buildings, sites, and communities through both multiple scales and over time. In some cases, this goal may mean more effectively and creatively using the existing tools and adapting them to heritage uses, perhaps by including greater adoption of user-friendly tools such as Sketchup and Google Earth Pro. However, these freely available tools may not have all of the capabilities needed to document character-defining features. They also do not have the advanced querying and spatial-analysis capabilities of full GIS. Heritage professionals could benefit from the development of new, advanced tools, such as the integration of building information modeling and 3D GIS tools that may provide much greater capabilities not only for visualization but also for multiscalar and temporal analysis. If this integration of technologies is achieved, it could result in new windows into time and place and new methods of analysis and design.

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Notes
7. The two world’s fairs both ran for two seasons, 1939-1940 and 1964-1965. In this article they are referred to as the 1939 and 1964 World’s Fairs.
13. The research team created an initial visualization of the 1939 World’s Fair time period using building footprints. However, the model is very imprecise and would need additional work to be considered accurate and complete.
14. It is still conceivable, however, that the re-creation of the historical context, including the depiction of demolished buildings in detail, would still be useful in planning appropriate new development and also for interpretive and educational purposes.
17. Unity is also used by some architectural and planning teams to create interactive 3D renderings of plans and development proposals. Eric Brady of Bergmann Associates, a planning firm, described the use of Unity for architectural and planning uses in an April 15, 2015, lecture for course CRP 5850: Cities Place Technology at Cornell University.
18. It is not known how committed the city is to maintaining the separate web portal, whether fees associated with new development will cover the long-term costs of accepting 3D models, and how sustainable the long-terms costs of 3D modeling might be.
19. One of the researchers, John Dykstra, went to work for George Lucas and used the same technology to provide a similar viewer experience of the Death Star in the movie Star Wars.

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