

Linking GIS-based Modeling of Stormwater Best Management Practices to 3D Visualization

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Abstract

Compared to allied design professions, the diverse practice realm and spatial scales of landscape architecture pose challenges in the development of a single software package for parametric information modeling. Here we report progress in linking geographic, civil engineering, and visualization software together in the development of a comprehensive landscape model that will estimate the effectiveness of stormwater mitigation practices. Although the model is still under development and requires field calibration, a proof-of-concept prototype for data linking and interchange is demonstrated.

1 Introduction

Landscape Information Modeling (LIM), like the landscape architecture profession itself, is diverse in the types of projects, information, and scales that must be considered (AHMAD et al. 2012; NESSEL 2013). A useful LIM must integrate aspects of site planning (different contexts and scales), landform shaping, planting design, natural systems analysis, visual assessment, and many other activities. Counterparts in the Architecture, Engineering, and Construction (AEC) Industries, may be able to rely on a single information modeling system. The diverse scales and practice realms of landscape architecture will likely require reliance on several robust systems where interoperability and standardized data exchange are key components. As one example of integrated LIM, this paper relates progress being made to link geographic, civil engineering, and visualization software together. Data are interchanged between the programs to model, visualize, and predict the relative effectiveness of best management practices (BMPs) to control stormwater runoff.

2 A Single LIM Platform?

For the most part, information modeling systems are fairly mature for the architecture and civil engineering disciplines and rely upon a few mainstream software packages which are most akin to a parametric information structure. The end goal is typically construction documentation and implementation.

For the landscape architecture discipline, the situation is quite different, and a single, all-encompassing LIM environment may not be possible. For *site design and construction oriented tasks*, landscape architects can utilize the same information systems – particularly

those for civil engineers; but use of architecturally oriented Building Information Modeling (BIM) software is probably overkill for most landscape architectural design work since vast collections of architecture-specific features will not be utilized (Table 1). Over time, landscape architects focused on site design will transition away from 2D CAD to 3D BIM when more landscape “workspaces” or specialized site tools are offered.

For *planning, conceptual design, or environmental analysis*, geographic information systems (GIS) still offer to be the tool of choice. Instead of BIM structured around created “objects”, a LIM suitable for landscape architecture must incorporate both intelligent objects and an intelligent context, and process the complex interactions between the two. This is a particular challenge since the specific context could be located anywhere in the world, at any spatial scale, consider any particular feature, and extend to any depth of inquiry.

MICHAEL FLAXMAN (2010) highlighted some of the most promising strategies to overcome some of these challenges as GIS evolves to geodesign characterized by streamlined workflows and design informed by geographic context:

- *Sketch interface and auto-attribution*: Based on templates, users pick from a palette of symbols that carry semantic information (pre-loaded attributes) instead of merely graphical information, and the user interactively sketches the geospatial location and area.
- *Parameterized and Scalar Context*: Context is parameterized with environmental, social, and economic data including design / regulatory standards at various scales. Data is formatted to facilitate seamless compilation and interchange.
- *Distributed geospatial data creation and management*: Specific data is created, stored, and managed by dedicated sources, and streamed to multiple users.
- *Standardized Process Models*: Large libraries of simple models are developed on national or international standards. These models are geographically or technically distributed for assembly into more complex models.
- *Robust Scenario Manager*: Linked to scenarios, vast data files and analysis parameters are organized, distributed, and tracked across multiple options and timeframes.
- *Distributed Design Evaluation*: Scenario evaluation is distributed across multiple processors / servers which stream incremental results to support design-time feedback.

Perhaps the remaining part of the LIM component triad for landscape architects is the integration of advanced visualization of ecosystem and atmospheric elements. Progressing beyond just graphic representation (albeit sophisticated and detailed), these elements might be parameterized and function driven to control placement, growth, movement and timed events (e.g. stormwater runoff). Parameters would be dynamically passed from linked BIM or GIS programs. A rudimentary example of exchanging data and partially linking these systems together is the subject of this paper.

Table 1: Building/Landscape Information Modeling (BIM/LIM) features by discipline.

Architecture (BIM)	Civil Engineering (LIM)	Landscape Arch. (LIM)
Design Smart 3D components Auto-build / auto-assist tools Auto roof configurations Stair/railing configurations Auto-framing Auto pipe / duct routing Analysis Auto material tracking / takeoffs Structural analysis Clash detection Energy / water / carbon analysis Solar/shadow analysis Lighting analysis Visualization 3D architectural forms Construction 2D / 3D plans from model <i>Summary Conclusions</i> Parametric structure BIM is fairly mature Single software is sufficient “Object” oriented Construction is end goal	Design Smart 3D components Auto-build / auto-assist tools Road alignment / optimiz. Assisted grading / optimiz. Assisted lotting Utility pipe networks Analysis Auto material tracking / takeoffs Road geometric analysis Grading / earthwork analysis Hydrologic / hydraulic analysis Visualization 3D roads / utilities 3D landform / grading 3D civil related structures Construction 2D / 3D plans from model Field machine guidance <i>Summary Conclusions</i> Parametric structure LIM is fairly mature Single software is sufficient “Object” oriented Construction is end goal	Design Smart 3D components Auto-build / auto-assist tools Terrain sculpting Land planning tools Urban massing engines Deck auto-framing Planting auto-assist layout Irrigation auto-assist layout Lighting auto-assist layout Analysis Auto material tracking / takeoffs Civil eng. related analysis Planning scenario metrics Energy / water / carbon analysis Stormwater BMP analysis Irrigation pressure analysis Visibility mapping / analysis Time / growth analysis Visualization 3D site structures / furnishings 3D landform / grading 3D plants / associations 3D eco-environments Construction 2D / 3D plans from model <i>Summary Conclusions</i> Parametric structure & GIS LIM is immature Multiple software is needed “Object” & “Context” oriented Divergent end goals

3 Application Site

The integrated LIM was applied to the Timbercreek III subdivision near Manhattan, Kansas as a means to analyse local hydrology, estimate the relative effectiveness of proposed BMPs to control stormwater runoff, and visualize the results for public communications. This residential development consists of a 40.5-hectare site typical of suburban patterns and reflects typical BMP implementation in a retrofit situation. The subdivision is drained by Elbo Creek, a grading stream corridor with severe erosion problems caused by stream

bank destabilization spurred by increased flow volumes and velocities in the channel due to upper watershed land use changes (Fig. 1).



Fig. 1: Elbo Creek watershed and Timbercreek subdivision used to test the LIM model.

4 Methods

4.1 Hydrologic Modeling through ArcGIS and Civil 3D

Most of the processing power and organizational structure is being provided through Esri's ArcGIS Desktop 10.1 (ArcInfo) running the ArcHydro extension (MAIDMENT 2002). The extensive pre-processing phase, which went well beyond basic ArcHydro functionality, combined LiDAR derived topography, land cover, soil permeability, and infrastructure data. Autodesk Civil 3D (C3D) was used to model highly detailed street and gutter geometry to identify drainage catchment points. Source data was then processed to generate hydrologic surfaces at a raster resolution of 2m, supplemented with C3D curb definition, and prepare 23 variables used in subsequent calculations. The geodatabase was structured to support variable changes, maintain spatial relationships, and store temporal data related to multiple storm events.

A series of strategies were then proposed for reducing runoff by implementing various BMPs. Relative BMP effectiveness scores were input into the hydrologic model for processing eight scenario iterations. For each scenario, peak discharges for catchment points were calculated and compared against existing conditions to arrive at non-calibrated estimates of runoff reduction. These values were presented in tabular and graphed forms, which will be of most interest to engineers and planners once the model is fully completed.

4.2 Linking to Vue Infinite for Visualization

For non-technical audiences concerned with the appearance of BMP treatments, 3D plant simulations and a weather based animation were prepared. A successful proof-of-concept test exchanged GIS terrain data with the synthetic landscape generation program, Vue Infinite (E-on Software). Currently, we are working to also link GIS plant lists to Vue

through Python programming for plant auto-population based on plant density and topographic parameters (Fig. 2). Data exchange will eventually go far beyond just location.

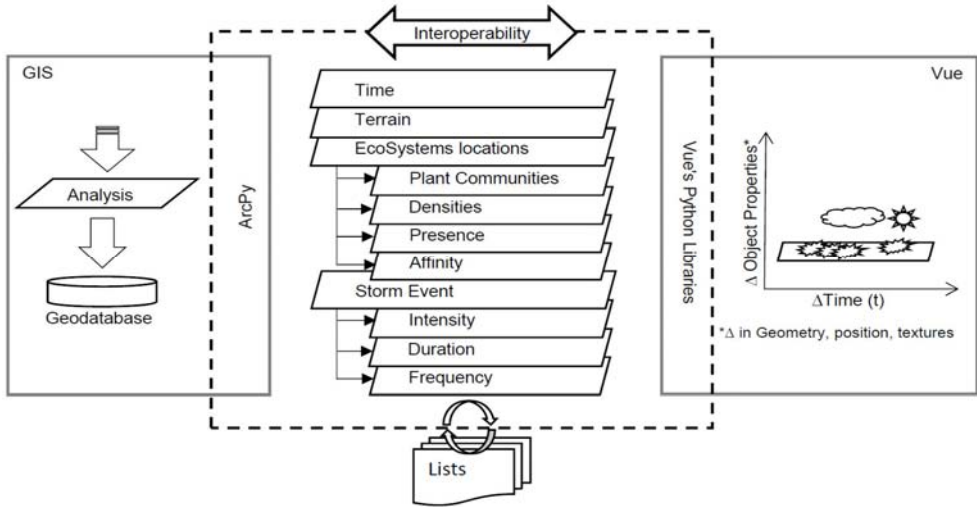


Fig. 2: Auto-plant selection and visualization strategy of LIM model.

5 Results

5.1 Hydrologic Modeling

At the scale of the Elbo Creek watershed and Timbercreek subdivision, the ArcHydro GIS-based system worked well for successfully generating variables to allow calculation of large area peak discharge. The dataset also allowed tracing precise runoff flowlines between built structures and along street gutters. Since the process was mostly automated, eight runoff scenarios for different BMP types were run aimed at optimization. In addition, a series of virtual BMP treatment chains were proposed which featured various flow resistance mechanisms to make water quality predictions (Fig. 3). Network Analyst (ArcGIS extension) was used to build the flow network and various nodes to record water quality, quantity, resistance, and flow conditions.

For the Timbercreek subdivision, uncalibrated results derived in a virtual implementation of BMPs indicate rain barrels reduce stormwater runoff by 18%, rain gardens / meadow lawns by 22%, and implementation of community level treatment chains in public right-of-ways by 40%. If all strategies are combined, runoff is reduced by 61%. If homeowners who live adjacent to Elbo Creek were the only ones to implement BMPs, stormwater runoff would

only be reduced by 20%. The BMP surface area coverage (disturbance to their lots) for rain gardens and bioswales for these residents would be significant.



Fig. 3: Stormwater runoff treatment chains (TC1-TC6) and various BMPs.

5.2 Visualization

Data from both ArcGIS and Civil 3D were imported into Vue for landscape visualization. Manually importing GIS data into synthetic landscape generation software for advanced visualization is not without precedent. 3D Nature's Visual Nature Studio (VNS) established limited data exchange through shapefiles in the early 2000s. Planting area outlines were transferred from GIS to VNS, but plants selections and all parameters were set in VNS, and plants were limited to 2D "billboard" representations (HAHN 2013, p. 584). An advanced landscape visualization program like e-on Software's Vue expands the possibilities in terms of 3D plant geometry and linked parametric control. The successful transfer of GIS terrain to Vue through Python programming demonstrates the potential for automation and more sophisticated data types than prior integration techniques. Now, we are actively working to also pass meadow and rain garden plant lists originating from GIS into Vue for populating a plant ecosystem like the simulation shown in Figure 4. Vue plants are true 3D geometry driven with a function editor, so it is possible to pass parameters from the GIS environmental model to control plant maturity, seasonal color, micro-placement, and other advanced features. Additionally, storm classifications in GIS databases could be passed to Vue to control cloud and weather parameters for visualization (Fig. 5).



Fig. 4: Vue simulation of BMP meadows and rain gardens from imported GIS and Civil 3D data. Dynamic links and parametric control from outside Vue is a future goal.



Fig. 5: Low-res video frame from a Vue simulated rain event where depth of gutter flow and water color (pollution) was approximated from GIS-based hydrology.

6 Conclusions and Future Research

A proof of concept has shown that ArcGIS, Civil 3D, and Vue can be used together in LIM for stormwater analysis, predicting BMP effectiveness, and advanced visualization. In totality, the comprehensive model integrated extensive variables and processing steps to arrive at virtualized, but un-calibrated results. Further work is being conducted to expand the range of runoff water calculation methods that can be used in the model, as well as improving general ease-of-use. Once fully automated, the model will enable multiple scenario evaluation in a short time. With calibration based on field measurements, it will be possible to optimize selection of BMP types and location, and more accurately predict performance for projects in which LEED or SSI certification is being sought.

In this project and other projects, we have successfully exchanged different types of terrain data represented as triangulated irregular networks (TINs), grid meshes, and raster height-fields between ArcGIS, Civil 3D, and Vue when spatial scales are similar. This was done through compatible import / export formats. With Python programming, we were also able to pass ArcGIS terrain into Vue which points to future automation and parametric linkages between the three programs. Each program is best targeted to specific scales. A significant future issue will be how to automatically coordinate, process, and exchange terrain data at vastly different scales and resolutions. We think that a GIS host environment and the Esri Terrain-Dataset structure (dynamic & multi-resolution) is probably the best option to pursue.

It was also shown that advanced visualization can be achieved by importing GIS data and Civil 3D geometry into Vue to support 3D planting representation. This is important because aesthetics are a public concern (EPA 2010), and directly linking model results with 3D visual simulation will enable the public to better visualize naturalistic BMP treatments prior to construction. In the future, plants lists and additional parameters will be dynamically passed from GIS into Vue via Python programming to control plant characteristics and weather conditions. Future use of this LIM tool by landscape architects, coupled with their specialized knowledge of plant material for BMP design, offers to expand their influence in this emerging practice realm.

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