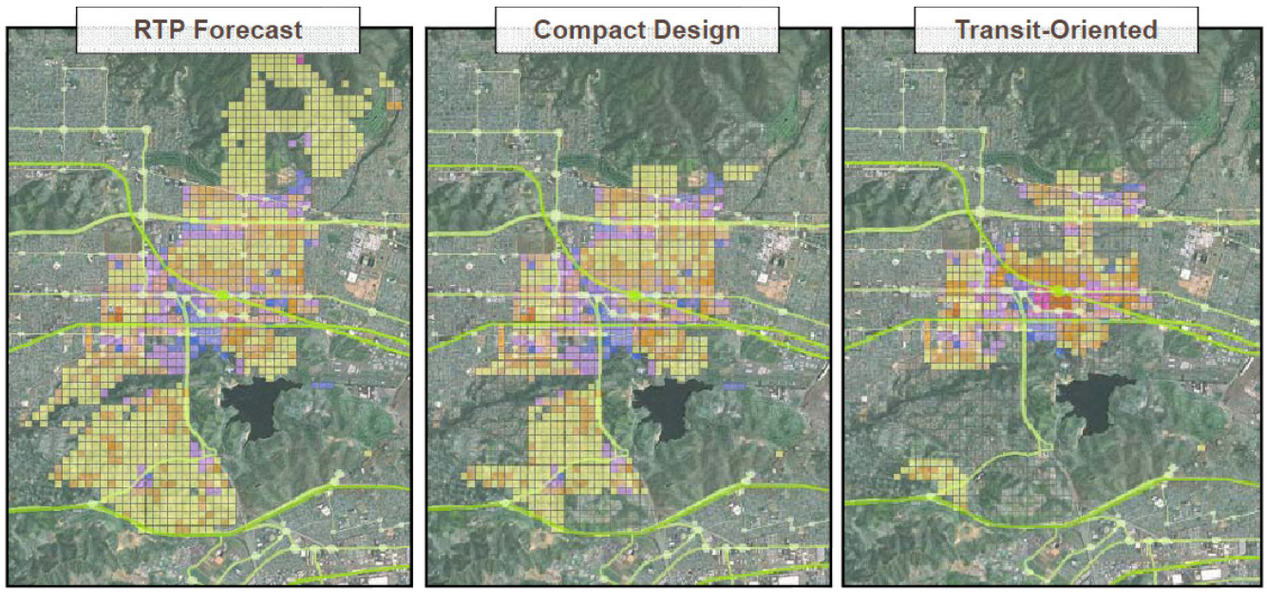
COMMUNICATING CLIMATE-SMART SCENARIOS WITH DATA-DRIVEN ILLUSTRATIONS

Nancy Yen-wen Cheng
University of Oregon

Brian Lockyear
Parametric Design Solutions



1 Fregonese Associates' Envision Tomorrow allows planners to paint DevTypes onto map gridcells.

Abstract

To communicate how planning investment scenarios might look on the ground, a new graphics workflow generates streetscape perspectives from planning scenario maps. The workflow connects planning forecasts (incorporating economic, transportation and land development data) to a parametric urban modeler to efficiently generate visual representations according to evolving forecasts.

This paper explains the decision-making context, how regional to pedestrian-scale information is integrated, and the necessity of diverse expertise in creating the workflow. It compares custom programming in *ArcGIS*, *Python* and *CityEngine* for urban infill tasks, and describes approaches for connecting the specialized software to a broader palette of tools.

To generate future urban massing, undervalued lots with high development potential are first identified. The lots are then matched to grid cells in the associated GIS planning scenario map. The cell's assigned Development Type is used to select possible building types and heights to model on the lot. The undervalued properties are iteratively "redeveloped" until target numbers are met (for example number of jobs linked to commercial properties and the number of housing units satisfy development forecasts).

The project explored procedures for refining the model graphics, including developing a streetscape model toolkit, so that different designers could generate consistent and compelling perspectives.

04_ACADIA_Template_LP_F39.indd 1 8/18/14 1:15 PM

COMMUNICATION CHALLENGE

City governments can reduce greenhouse gas emissions by investing in ways that attract private development of pedestrian and bicycling-friendly communities. They must first convince stakeholders of the importance of investments such as providing convenient services and shopping, expanding transit service, managing parking and providing safer pedestrian and bicycling routes. To involve stakeholders in these decisions requires visual communication that makes the options feel local, relevant and urgent (Carlson 2011). The way a story is told is crucial because imagery and language carry connotations: for example, Portland planners coined the phrase "Twenty-minute neighborhood" to avoid using the dreaded term "Density".

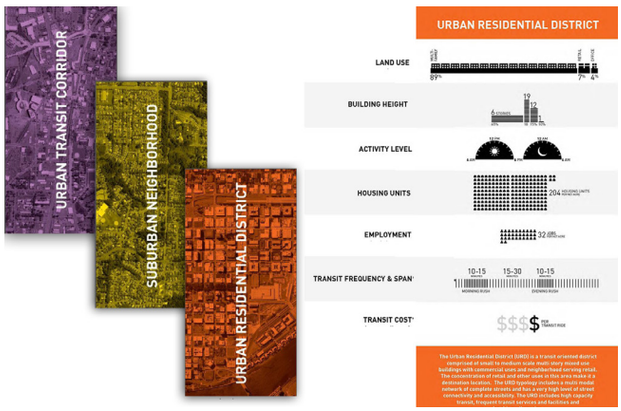
Metro, Portland's regional government, initiated the Climate Smart Communities (CSC) Scenarios Project (Metro 2014) to develop a legislature-mandated strategy to reduce greenhouse gas emissions from cars and small trucks by 2035. The CSC Scenarios project seeks to bring local leaders into consensus about how to reduce greenhouse gas emissions while supporting community development visions. Metro evaluated three scenarios for investing in land-use and transportation plans and policies, and evaluated the impact of those investments on regional growth over the next twenty-five years. Informative graphics were needed to communicate the tradeoffs and benefits of alternative investment scenarios to policymakers and the public.

This research project focused on developing accessible illustrations of potential on-the-ground impacts of these scenarios. The project team researched processes to create visualizations that can be updated to reflect forecasted growth. The workflow uses city and regional growth distribution forecasts to generate possible urban development massing and views refined with 3D and 2D graphic procedures. Our goal was to streamline the creation of visuals to communicate urban form and street design at different levels of investment. We prototyped a workflow that allows different designers to create illustrations with a consistent graphic style. This report describes our task, the graphic workflow, and identifies challenges and questions for further work.

PLANNING BACKGROUND

The Metro CSC team worked with regional advisory committees, community and business leaders, and other stakeholders to develop three scenarios for regional growth through 2035:

Scenario A–Recent trends with Existing revenues and policies.



2 Each DevType describes building types, building heights, number of housing units and jobs, and transit activity. Graphics by Ryan Sullivan .

Scenario B–Adopted Plans for increased investment (2035 Regional Transportation Plan).

Scenario C–New Plans and Policies for deep investment throughout the region

For each scenario, state-of-the-art models calculate greenhouse gas emissions, regional travel, and the growth and distribution of households and jobs. Scenario B has been calibrated to adopted land-use plans and a regionally developed, local-government-reviewed household and employment forecast adopted by the Metro Council in November 2012.

Data for Scenarios B and C was translated into color-coded maps using Fregonese Associates' Envision Tomorrow *ArcGIS*-based Scenario Builder, an urban and regional planning tool for developing and evaluating land-use growth scenarios, seen in Figure 1. A set of Land-use Development Types (*DevTypes*) was defined as percentages of building types (such as office, industrial, multifamily residential) and typical building heights (Figure 2). *DevTypes* were assigned to 264x264 foot grid cells based upon consequences of transportation and land-use policy directives. Envision Tomorrow calculates each cell's capacity for housing units and jobs, whichallows planners to more accurately forecast their growth distribution.

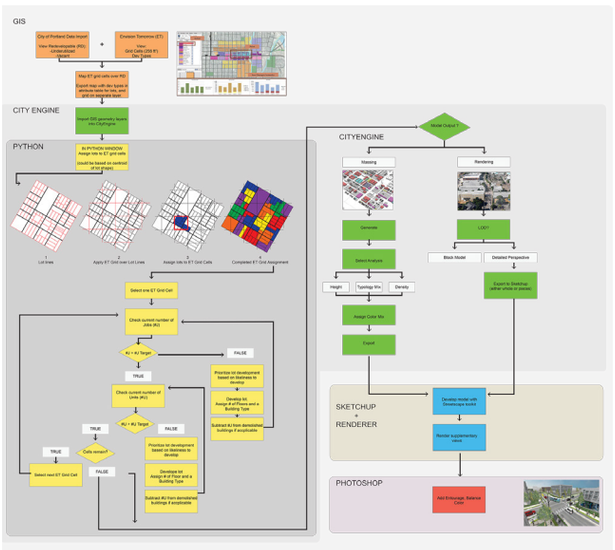
The development capacity of the scenarios was subsequently reviewed by city and county staff and then modeled using MetroScope (Metro 2014). MetroScope is a planning tool developed by Metro's Data Resource Center that forecasts growth distributions through the interplay of market forces with land-use policies and transportation. It takes into account economic factors, demographic trends, local zoning, buildable land, real estate prices, and other development factors to estimate future household and employment growth distribution.

04_ACADIA_Template_LP_F39.indd 2 8/18/14 1:15 PM

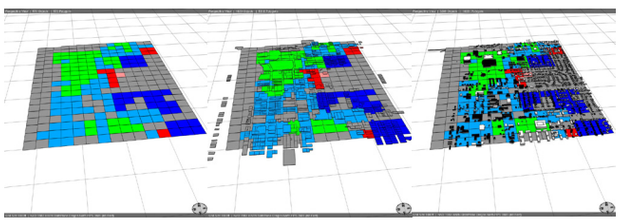
AUDIENCE AND PURPOSE

The team's job has been to visualize how these broad planning forecasts would potentially look in particular districts. Planning data is often abstract and challenging to understand. Planners generally develop, store and analyze planning schemes in databases and spreadsheets, which generate two-dimensional map graphics. The purpose of this research is to make the data accessible and legible to a wider audience by piloting a workflow for generating three-dimensional illustrations.

The resulting illustrations are intended to help communicate the planning scenarios to stakeholders so they may provide input on what strategies and investments they support for their community. Images can help planners, policymakers and the public develop a common understanding about how policies could affect specific places. For example, transforming vacant land or surface parking lots into new retail centers served by transit while adding new sidewalks and bicycle routes can help create a vibrant, pedestrian-friendly environment. Perspective illustrations can make these possibilities legible, and help build support for these investments as well as other policies such as retrofitting streetscapes to include street lighting, trees and plantings.



3 Workflow Concept shows decision points and operations.



4 Metro's DevType gridcells from Envision Tomorrow mapped onto City of Portland tax lots with current and potential valuations, then cell DevTypes are mapped to lots.

The stakeholders include taxpayers, government officials, planning specialists, and business owners. Each group may gravitate to a different form of graphic communication. A mayor might want to see new development from an aerial view to quickly grasp of implications of development on a district level, while a business owner might want to see a street view showing modified access to storefronts and public transportation. Both views are relevant but require different types of illustration. We were interested in addressing these varied needs with a workflow that would allow easy updating.

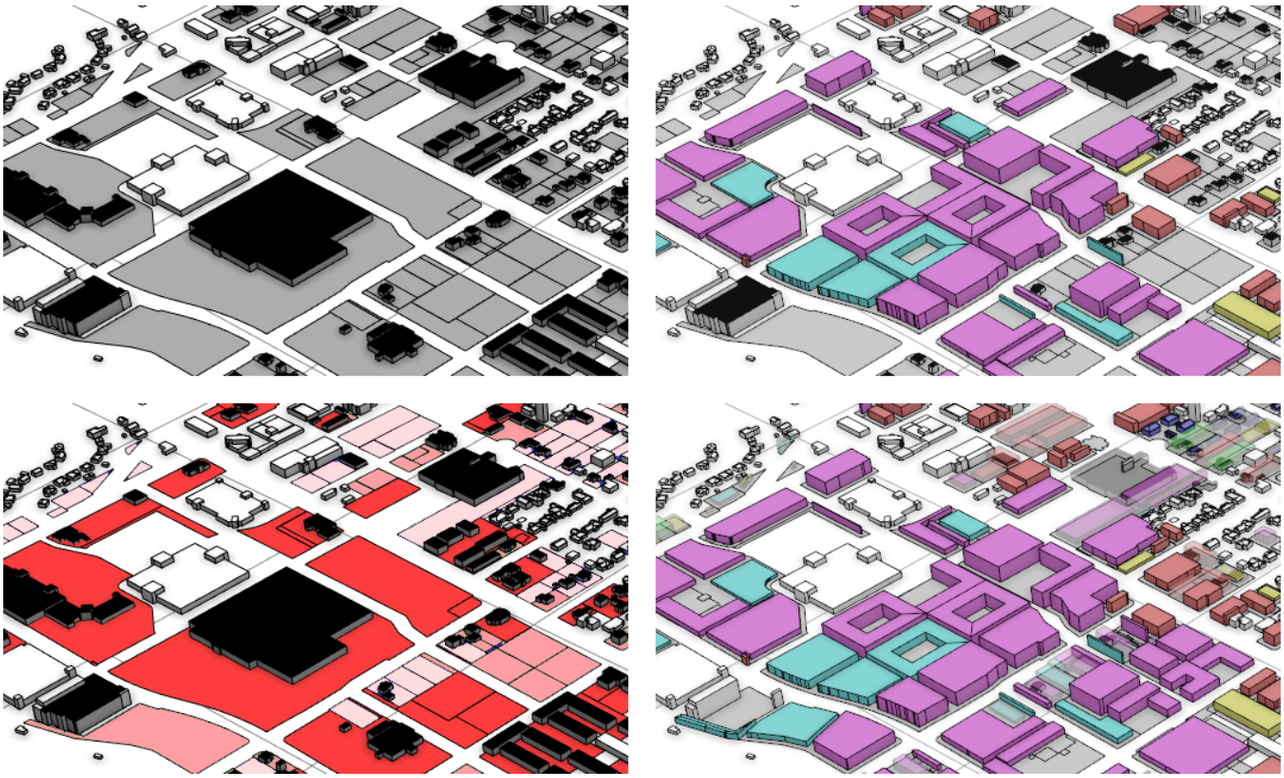
DATA-DRIVEN PARAMETRIC URBAN MODELING

Our research automated and streamlined data modeling and rendering using customized scripts, libraries and procedures. The project comprised two efforts: 1) driving the urban model from Envision Tomorrow's planning map, and 2) developing images from the model. The graphic workflow assessed relevance and interoperability of multiple tools in modeling Portland's Gateway District, a suburban node with mixed residential and big box stores. (PDC 2012)

Parametric urban modeling tools use procedures or patterns to layout major arteries, generate secondary road networks, divide lots, and place prototypical buildings. Derix (2012) reviews the history of these modelers and thetheir approaches. Starting with Envision Tomorrow maps and Metro's robust metropolitan urban database, we chose *CityEngine 2012* (CE), a procedural modeling and visualization software designed to bring 3D modeling to 2D GIS mapping. Originally developed to create virtual worlds at ETH (Parish and Mueller 2001), CE can model existing blocks using GIS data and visualize alternative development strategies. It can generate fluid urban environments through shape grammar rules known as .CGA scripts. Random seeds driving the shape grammar generate alternative versions of urban models as in < r>McElvaney (2012).

Learning the shape grammar is required to grow streets from centerlines, to generate building masses from lot boundaries, and to customize specific façade, roof or other generation rules. The software worked well in creating new urban regions but when used with existing GIS data or places with lots of open space in between buildings, created geometry conflicts and bugs. An upfront investment cleaning up the urban database and customizing build-

04_ACADIA_Template_LP_F39.indd 3 8/18/14 1:15 PM



5 Data-driven building growth selects lots most likely to develop (lower left) and iteratively adds massing according to the gridcell's DevType until housing and job targets are met. (lower right)

ing types provided the ability to quickly model a wide variety of place types. CE excels at packing believable buildings into dense urban environments. It was less successful at modeling suburban or rural locations where buildings have loose relationships to their lot shapes and potentially have multiple geometries.

CONNECTING BUILDING DEVELOPMENT TO JOB AND HOUSING PROJECTIONS

We first examined how to make the Envision Tomorrow *DevTypes* drive urban massing in CE. We used the DevType categories assigned to grid cells to grow appropriate building types until we hit target job and housing numbers. The steps included:

1. Generate massing of existing buildings from GIS data.

2. Identify building lots ripe for development.

3. Select appropriate CE building types and define their vertical massing.

4. Measure the change in job and housing numbers resulting from demolition and redevelopment.

5. Iteratively continue to redevelop property until target numbers were reached.

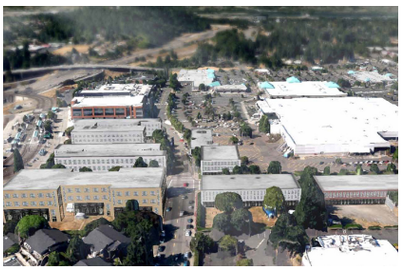
We diagrammed this path from the GIS data, reflecting Envision Tomorrow and MetroScope analysis, through the software platforms. The Envision Tomorrow development grids, property tax lots and existing building footprints were imported into CE on separate layers annotated with relevant GIS data.

Switching to the *Python* environment within CE, lots are first mapped to development grid cells and assigned corresponding DevTypes. Lots are then iteratively selected and redeveloped based upon the Envision Tomorrow goals for housing and jobs within each grid cell. Figure 3 diagrams this workflow. Grid cells are selected and evaluated relative to target jobs and housing numbers. An underdeveloped lot within the grid cell is chosen based on underutilization of the existing property. Existing buildings are removed and new ones created based on percentage of building types (e.g., single-family, office or industrial) assigned in the lot's DevType (e.g., commercial node, urban residential or light industrial) from its associated grid cell. New buildings are generated and the grid reassessed relative to the goals. This iterative redevelopment continues until all grid cells meet their targets or no further progress towards them is possible.

04_ACADIA_Template_LP_F39.indd 4 8/18/14 1:15 PM







6 Google Earth Image of Existing Land (top) with CityEngine buildings (middle) and Photoshop (bottom).



7 Street-level views exaggerate distortions of aerial site photos and require supplementary foreground information.



8 2D image-processing for palette reduction lacks edge precision, requiring manual collaging or non-photorealistic model rendering for building definition.

To implement this workflow, tax lots identified as underutilized by the City of Portland were first sorted according to their assessed value per square foot and divided into three groups. Beginning with the most underutilized, each group was "redeveloped." Large lots were subdivided and a building type for each lot or sub-lot selected . based on the percentage of types within the associated Dev Type. Figure 4 shows Metro's DevType grid from Envision Tomorrow mapped onto City of Portland tax lots with current and potential valuations, and then grid cell *DevTypes* mapped to lots. Our prototype did not utilize additional job or housing targets to bias building type selection. Existing building masses were deleted and new ones created using CGA rules appropriate to the building types. Figure 5 shows the redevelopment process with snapshots taken at 33, 66 and 100 percent completion.

SOFTWARE PLATFORM ANALYSIS

In developing workflow, much was learned about the overlapping strengths and capabilities of the three programming environments: GIS, *Python* and CGA. Each performed certain operations easily; none was sufficient alone. There was some leeway about specific development steps took place; we depended on local expertise for each part of the workflow development. Below we outline the application, strengths and weaknesses of each environment:

ArcGIS

Used via the *ArcGIS* GUI to select and separate shapes into layers prior to importing into *CityEngine*.

Used for:

* 2D pre-processing to identify overlapping elements and separate shapes into groups assigned to different layers in *CityEngine*.

* Annotating shapes with initial data (i.e. DevType).

Strengths:

* Source format and tool for most of the data.

* Existing, stable tool with a large feature set.

* Strong existing tool expertise.

Weaknesses:

* 2D only.

While in this iteration the data was manually processed, *ArcGIS* provides custom programming capabilities for automating these steps.

Python

The most flexible, *Python* provides a general software language for data manipulation and the iterative loop. Within *CityEngine*, the development environment tended to be brittle and minor syntax errors caused modules not to load but provided no additional information.

Used for:

* Loading Envision Tomorrow data from Excel spreadsheets.

* Assigning Envision Tomorrow Development Types to grid cells.

04_ACADIA_Template_LP_F39.indd 5 8/18/14 1:15 PM

* Aligning tax lots to grid cells and tagging corresponding DevTypes.

* Aligning existing buildings to lots for redevelopment.

* Calculating lot value based on GIS data.

* Sorting and selecting lots for redevelopment.

* The iterative redevelopment loop. Incrementally redeveloping lots, deleting conflicting existing buildings, assigning theCGA rules, and creating new buildings.

Strengths:

* Flexible and capable of advanced computer algorithms and data structures.

* Interpreted environment allows incremental development and interaction with *CityEngine*.

* Provides access to additional data sources such as Excel.

Weaknesses:

* Brittle programming and challenging debugging.

* Limited *CityEngine* API to date.

* Limited geometry support.

CGA

This rule-based programming language for *CityEngine* shape generation is extremely useful for generating massing models. It provides a feature-rich environment impossible to duplicate in a traditional imperative programming environment such as *Python*.

Used for:

* Probability-based selection of building types and heights.

* Form generation.

* Pattern-based lot subdivision.

Strengths:

* Ease in creating mass forms.

* Ease of selecting alternatives based on probability values.

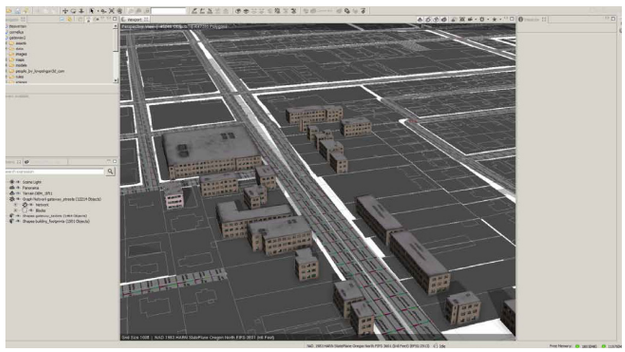
Weaknesses:

* Lacks support for external data input.

* Specialized language and knowledge required.

DEVELOPING DATA-DRIVEN MANIPULATION FURTHER

While CE can be used as a data-driven visualization tool, the environment of GIS/*Python*/CGA requires stabilization and refinement.



9 CityEngine uses rules to generate streets from street centerlines and buildings from lot footprints, which can leave gaps at right-of-ways.

A more complete *Python* programming environment and command interpreter interface would make it possible to quickly and interactively create data-driven views of urban landscapes. The primary hurdles are stabilizing the *Python* debugging environment, then building a family of *Python* routines and associating CGA building type files for repeated use.

The current CE workspace appears to be based upon the powerful Eclipse Interactive Development Environment. As Eclipse supports *Python* development, through integrating that capability, it may be possible to create a more robust programming and debugging environment for manipulating data and coding needed for iterative programming loops. Identifying a fast and robust 3D *Python* geometry package is also necessary. While CGA-rule files excel at creating building masses, preliminary data manipulation and rule assignment could be incorporated into *Python* routines driven by Excel spreadsheets defining alternative development scenarios. Once the workflow and associated routines are in place, Excel spreadsheets would provide an easily accessible interface for setting model parameters without additional *Python* programming.

MODEL REFINEMENT METHODS

Separately from the data-driven modeling, we examined how to generate perspective images from the urban model. A variety of visualization styles were discussed, including cartoon-like graphics using non-photorealistic rendering (Semmo 2012 & Saliesen). We thought that the simplified colors and shapes of children's storybook illustrations could make the spaces both appealing and abstract. But the planning scenarios lead to specific pedestrian streetscape amenities that were hard to automatically portray with abstracted forms. To make the work accessible to future team members, we tried two easy-to-use 3D platforms for refining CE urban models: Google Earth and SketchUp.

04_ACADIA_Template_LP_F39.indd 6 8/18/14 1:15 PM

CITYENGINES BUILDINGS WITH GOOGLE EARTH BASE MODEL

We tested Google Earth as a model platform as an alternative to an entirely CE synthesized geometric urban model. Because all procedurally modeled geometry created from georeferenced GIS data was automatically placed accurately when imported into Google Earth, we could quickly place CE buildings exported as .KMZ files. For East Portland's Gateway district, we created roughly a dozen buildings sized according to MetroScope data and a recent Urban Design plan (PDC 2012), then imported these directly into Google Earth. Using Google Earth's 3D environment created by LIDAR scanning, the buildings imported from CE fit right into their existing surroundings.

Using Google Earth worked well to create aerial images with compelling background entourage that were easy to edit, but the specificity of source LIDAR and aerial photographs also often resulted in glaring geometry conflicts (for example trees, which emerge from new buildings). Applying image filters could produce simplified color palettes, sophisticated edge detection is needed for intelligent urban model simplification (see Döllner 2007, Semmo 2012).

CITYENGINES BUILDINGS WITH SKETCHUP SITE DEVELOPMENT

CityEngine's real-time interactive graphics can be compelling, as it can incorporate texture mapping and level of detail. But because our client wanted to get away from the look of computer game images, we looked for tools to help us refine *CityEngine* graphics into appealing stills.

The geometric rules used by parametric modeling programs to create blocks, buildings and streetscape elements, work efficiently and precisely when creating imagined cities but have challenges with the anomalies in real-world GIS data. Moreover, even a neighborhood scale database with detailed buildings can be unwieldy to manipulate. To streamline graphic development, we exported CE's buildings into a Sketchupbase model created from GIS maps. Due to the smaller amount of data, exporting individual buildings could be done much more consistently than largeneighborhoods.

To complement the CE buildings and patch the gaps between sidewalks based on street centerlines and building facades based on lot lines, a 3D streetscape toolkit was developed in SketchUp. This toolkit. with linear streets, swales, sidewalks and other amenities from Metro green street design guidelines (2002)</r, allowed efficient, consistent modeling of pedestrian-friendly urban streets. Buildings from CE were then placed in their appropriate locations, images exported to rendering software and further refined in Photoshop with an entourage library.

Although exporting the 3D model from *CityEngine* to SketchUp makes the visualizations one step removed from their interactive "data-driven" sources, SketchUp provides an accessible level of modeling control and refinement. These elements could be incorporated into the urban modeler for automatic deployment.

ISSUES: PLACE SPECIFICITY, PLANNING ABSTRACTION AND SOFTWARE FIT

SPECIFICITY: FROM VIRTUAL CITIES TO REAL NEIGHBORHOODS

Our conceptual workflow for moving from GIS to *CityEngine* to SketchUp went smoothly when working with small hypothetical examples and became much more complicated when applying the workflow to the East Portland Gateway district. The tools are optimized for generating new city fabric, working on an existing neighborhood is much more complex. Sliver lots and small parcels may need to be aggregated to create usable lots. Relationships between different kinds of data must be articulated: building footprints need to be tied to lots and lots matched to planning units, sometimes of different sizes.

Given their ability to create archetypal urban forms, parametric urban modelers have the potential to create more robust sets of *DevType* descriptions. CGA scripts could generate abstract block types with 3D color-coded massing icons visualizing housing and jobs quantities. The *DevTypes* painted in Envision Tomorrow could then generate either Lego-block massing, with colors revealing the development type, or more photorealistic neighborhood views. Being able to select a building

to see its Dev Type and related jobs or housing units can make 3D models more informative. Being able to zoom in on detail—from Lego blocks to building façade–accommodates different stakeholders.

Bringing together different kinds of information in a usable form requires teaming up individuals with diverse skills, and orchestrating their skills towards solving these issues. A central data repository with a log system for reporting progress and communicating questions could streamline communication. Similarly, a shared storehouse of typical parametric buildings, street types and DevTypes would accelerate adoption of this method for creating powerful visualizations.

04_ACADIA_Template_LP_F39.indd 7 8/18/14 1:15 PM

DEPICTING ABSTRACT PLANNING SCENARIOS

Throughout the research, it was difficult to pin down how the investment scenarios would translate into funding for built amenities and the real consequences of broad planning initiatives. For example, new greenfield sites brought into the urban growth boundary change growth distributions and impede development in central areas, even in high-growth scenarios.

The example Gateway district revealed the difficulties of developing specific neighborhood street-corner visualizations. The intention was to show how it could prosper from transit and other investments while reducing greenhouse gas emissions; however, Gateway is already well served by public transportation and, despite its relatively low cost real estate and central Metropolitan location, market factors have deterred its development.

The impact of planning policies must be well understood before the tangible experience of a place can be visualized. While we want to show attractive environment composed of retail shops, plantings, benches and an active pedestrian environment, achieving those results require investment and design decisions well beyond initial planning.

PARAMETRIC MODELING FOR PLANNING VISUALIZATION

In summary, we have shown that rigorous development forecasting can drive a powerful parametric modeler to depict 3D land-use and transportation scenarios. It works well for neighborhood scale planning and abstract massings. Developing CGA building descriptions, consolidating and filtering real-world GIS data and creating a data-driven urban model requires a substantial time investment. Once created, the system provides a flexible and powerful tool for urban planning discussions. Because visual standards for static images are very high, the parametric models require further processing and benefit from artistic judgment that is difficult to automate. Our conclusions:

1: Use the proper level of abstraction

We translated planning abstractions to real-world locations too early in the process. While street-corner perspective images can effectively show how people interact in a pedestrian-friendly street, programming the greater detail needed is laborious and can trigger criticism that derails the larger vision. We could tell the human-scale story better through 2D street sections and enlarged plans that can show sidewalks, swales, trees, building canopies and vehicles, etc. in a more general way.



10 Streetscape Toolkit Provides Linear Components for Pedestrian-Friendly Green Streets.

04_ACADIA_Template_LP_F39.indd 8 8/18/14 1:15 PM

After conclusion of the project, the subsequent communications plan used simple icons and catch phrases to emphasize abstract concepts as portrayed in video testimonials by articulate stakeholders and leaders. Memorable icons and phrases suited the early stage of decision-making and setting appropriation levels for broad planning initiatives, whereas perspective images would better suit specific implementation measures.

2: Portray the desired outcome to look normal

Video clips of funding supporters gave a human face to the planning concepts and revealed different ways that people found it appealing. By including people from many walks of life along with powerful leaders from diverse districts, the videos portray support for the funding as normal. Sociologists explain that peer pressure is one of the most powerful motivators for sustainable behavior (McKenzie-Mohr 1999).

In a similar way, the scenario designers defined Scenario C as so idealistically ambitious that it made the approved funding level of Scenario B look stingy and boring. The tactic worked in the summer of 2014, as it raised the proposed initiative funding levels about 10-20% per cent above the Scenario B levels.

3: Messy Digital Ecotones: It's not a perfect world

Cities are complex and even the most competently designed software works best within a specific domain. A lot of time is required where things get messy, especially boundaries at systems interfaces. Data from different sources must be coordinated and filtered to minimize problems. And while parametric urban modelers may generate city massing smoothly for 95 percent of the conditions, the remaining 5 percent (such as odd edge conditions and sliver lots) can require a great deal of custom attention.



10 Scenarios A, B & C show growth of parametric buildings and streetscape amenities revealed through a raised viewpoint.

4: Develop a complementary ensemble

By showing different kinds of information, an ensemble of targeted images can build a case for a development scenario. 3D concept diagrams and color-coded massing to indicate growth potential can complement 2D maps and photographic references. As with all infographics and place-making visualizations, the challenge is to simplify vast amounts of information into a straightforward, clear message. The form of the message needs to be tuned to the audience and the scale of the information: building, street corner, neighborhood or region.

This project also underlined the importance of interdisciplinary collaboration. Our common mission brought together expertise in economics-driven planning, GIS visualization, 3D architectural design and market communication. Expertise in complementary fields kept discussions lively, drawing out the best from each individual.

ACKNOWLEDGEMENTS

This work was developed with the Data-Driven Illustrations for Climate Smart Communities Scenarios project team including Kim Ellis, Metro Project Manager for CSC Scenarios; Molly Vogt, Metro Project Manager for the Data Resources Center, and team members Clint Chiavarini, Justin Houk, Brian Lockyear, Boyce Postma, Peggy Morell and Ericka Brendel.

04_ACADIA_Template_LP_F39.indd 9 8/18/14 1:15 PM

Thanks to the Oregon Transportation Research and Education Consortium, Metro and University of Oregon who supported the project. The project summary report can be found online: http://www.otrec.us.

REFERENCES

Carlson Communications, "Metro Climate Smart Communities Communications Final Report." Oregon Chapter of the American Planning Association. March 2, 2011. http://resources.oregonapa.org/sites/resources.oregonapa.org/files/Metro_Climate_Smart_Communities_Report_FINAL_3.2.11.pdf

Derix, Christian. "Digital Masterplanning: Computing Urban Design." In Urban Design and Planning: Institution of Civil Engineers, 165 no.4. Thomas Telford Publishers, (2012): 203-217.

Döllner, Jürgen. "Non-Photorealistic 3D Geovisualization," in Multimedia Cartography, edited by William Cartwright et. al., ,229-240. New York: Springer, 2007. http://www.hpi.uni-potsdam.de/doellner/3dgi/

Fregonese Associates, "Envision Tomorrow" software suite. http://www.envisiontomorrow.org/

Metro, "Creating livable streets: Street design guidelines for 2040", June 2002 http://www.oregonmetro.gov/tools-partners/guides-and-tools/guide-safe-and-healthy-streets

Metro, "Green streets: Innovative solutions for stormwater and stream crossings", June 2002

http://www.oregonmetro.gov/tools-partners/guides-and-tools/guide-safe-and-healthy-streets

Metro, "Forecasting models: MetroScope documentation." March 24, 2014, http://www.oregonmetro.gov/forecasting-models-and-model-documentation

Metro, "Climate Smart Communities Scenarios Policy Discussion Guide" 2014, available at the project library, http://www.oregonmetro.gov/public-projects/climate-smart-communities-scenarios

McElvaney, Shannon. Geodesign: Case Studies in Regional and Urban Planning. Redlands, CA: ESRI Press, 2012. http://esripress.esri.com

McKenzie-Mohr, Doug. Fostering Sustainable Behavior: An Introduction to Community-Based Social Marketing. Philadelphia: New Society Publishers, 1999.

Parish, Yoav and Pascal Mueller. "Procedural Modeling of Cities" in Proceedings of ACM SIGGRAPH, 301-308. New York: ACM Press, 2001. http://graphics.ethz.ch/Downloads/Publications/Papers/2001/p_Par01.pdf

Portland Development Commission (PDC), Johnson Reid LLC and SERA Architects, "Gateway Urban Design and Market Study." Portland, OR: PDC, 2012.

http://www.pdc.us/Libraries/Gateway_Regional_Center/Gateway_Urban_Design_and_Market_Study_Report_pdf.sflb.ashx

Salesin, David. Non-photorealistic rendering. Seattle: University of Washington, 2014 http://grail.cs.washington.edu/

Semmo, Amir and Trapp, Matthias and Kyprianidis, Jan Eric and Döllner, Jürgen, "Interactive Visualization of Generalized Virtual 3D City Models using Level-of-Abstraction Transitions"

Computer Graphics Forum 31, no. 3 (2012): 885–894.

IMAGE CREDITS

Figure 1. Fregonese Associates' Envision Tomorrow

Figure 2. Graphic cards by Ryan Sullivan of Paste in Place graphics.

Figure 3. Image by Boyce Postma edited by Nancy Cheng

Figure 4. Image by Brian Lockyear

Figure 5. Images by Brian Lockyear

Figure 6. Image by Boyce Postma

Figure7. Image by Boyce Postma

Figure 8. Image by Nancy Cheng

Figure 9. Image by Boyce Postma

Figure 10. Image by Boyce Postma

Figure 11. Image by Boyce Postma edited by Nancy Cheng

04_ACADIA_Template_LP_F39.indd 10 8/18/14 1:15 PM