Communities in Control: How communities develop their own models using CommunityViz

Abstract:
For decades the promise of large-scale urban models have intrigued both planners and policy-makers alike. If local governments know what the future will bring, then they should be able to better plan for that future. While some recent successes can be identified, an easy to implement, cost-effective and customizable urban model has remained out of the reach of most local communities.

CommunityViz's Scenario 360 is currently being used by local governments to implement relatively simple models driven by transparent assumptions. Being able to use functions of both a spreadsheet and a geographic information system, models developed in Scenario 360 has the benefit of:

1) Being internally maintainable and operated
2) Being automatically updatable
3) Allow for user editing assumptions and formulas for policy testing
4) Having built-in scenario testing and comparison tools

Transparent models have the benefit of being easily explainable to local elected officials and the public. Scenario 360 has proven to be a widely-used, user-friendly platform with which to implement these models. This paper uses the case study of the Town of South Kingstown Rhode Island to demonstrate these benefits.

Urban modeling context

Since the advent of computers, urban planners and computer scientists have been developing models of urban growth. And while many models have been developed and applied over the past 40 years, the environment for new large-scale urban models remains a rich area of study. DRAM/EMPAL/Metropolis, Polis, Meplan, and notably Urbansim, among others, have continued their development and, at times, implementation in regions across the country.

While much attention is paid to the development and implementation of these models, for the vast majority of planners, elected officials, and planning commissioners the utility of these models to their daily decisions, unfortunately, approaches zero.

Implementation of a complex model of urban growth is not only inappropriate in the vast majority of local governments but it is also impractical considering limited resources available. Yet, in the United States, virtually all development regulations are made by local governments. Indeed, they are often made by planning commissioners, citizen planners who live in the community, volunteer their time and make decisions regarding development regulations in the community. But if these people are not using our large-scale urban models to support their decisions, how are these decisions being made?

Clearly, professional planning staff support these commissioners and their decision-making process as best they can, but in many communities the entire planning staff consists of one or two people, if any full-time staff exist at all. It appears that there has evolved a disconnect in the study and implementation of urban models and the need of practicing professional and citizen planners.

In part to address this need, over the past several years decision-support systems have been developed and applied in many communities across the country. These systems are designed to support decision-making, and tend to be simple, easy to both apply and understand, and are transparent and customizable to the needs of a community. This paper describes the case study of South Kingstown, Rhode Island and how this small local government addressed their needs for quantitative models that served a local regulatory need, but which also provides information to support local land use decision-making.

Case Study: Town of South Kingstown, RI

The Town of South Kingstown is a semi-rural New England town in southern Rhode Island bordering the Atlantic Ocean. The town has about 30,000 residents and occupies 56.8 square miles of land and 6.1 square miles of water. The Town includes a portion of the Great Swamp, an ecologically important forested wetland. Another part of the Town is occupied by the main campus of the University of Rhode Island. Settled for over 300 years, the town features a variety of housing types and lot sizes. It has some seasonal housing, mostly in small beach bungalows on tiny lots. Only portions of the town have sewer service.

Administratively, the Town is notable for its active planning staff, a first-rate geographic information system (GIS) and GIS manager, and a town manager who has provided the community with strong leadership over many years.

The Town has a mechanism in its zoning ordinance that places a limit on building permits as a part of its growth management program. Briefly, the Town sets a 2-year maximum quota for new residential building permits that cannot be more than one-third of the Town's six-year housing capacity. As a consequence of this ordinance, the Town's housing capacity needs to be known. In 2001, the Town calculated this internally using GIS queries which summarized conditions and which fed into a spreadsheet that applied density assumptions to the data. The Town made a major methodological update to its model in 2004, but in that same year the Town also decided it needed a build-out system that would be more flexible, repeatable and easier to maintain and update every year.

In 2005 the Town engaged the Environmental Simulation Center to develop such a system. The scope of work for what became an in-depth process had three major parts:

- Replicating the Town's previous method and output
- Model design and implementation
- Installing the model and training South Kingstown staff on operations

Task 1 Replicating the Town's previous method and output
Considerable time and effort went into the Town's home-grown build-out model. The first task in developing a new model was to capture as much of the knowledge gained in that previous work as possible.

This involved reviewing the Town's build-out method and then replicating the results using the same data to ensure the method and the data were understood. The purpose of this exercise was three-fold. First, it required that the ESC understand how the Town had previously implemented build-out, which would inform subsequent model design. Second, it required the ESC to work with the Town's data thoroughly so it could understand the data's limitations, strengths and weaknesses. Third, this exercise required the implementation of a model similar to that which would ultimately be implemented and could inform optimum model operations.

After months of communication with the Town, the ESC was finally comfortable that it fully understood the Town's previous method and the data which informed it. The ESC was never able to produce exactly the same results as the Town had produced, however. Regardless, the result of this exercise was quite close to what the Town had produced and the goal of the Task—understanding the Town's previous method and data environment—was met.

Task 2 Model design and implementation
Design and implementation was an iterative process. A model was designed and implemented and the results were analyzed and evaluated with Town staff several times before final model results were produced. While much was learned through understanding previous versions of the model and through interviews with Town staff, having preliminary results inspired professional staff to provide very detailed comments on how and why development will and will not happen in the community. With each iteration the model was improved to incorporate this knowledge within the system. That being said, what is described in

this section describes the final version of the model. Components that were implemented, but ultimately dropped are, for the most part, not documented here. Further, this design is presented here to help tell the story of this one community and its challenges, rather than to be a model to be followed for other communities. The value of developing a method for use in a single community is that it can be custom designed to the needs and requirements of that community and take into account variations that make the place unique. Any community developing their own model should look inwardly at how development in their community happens and how data describing their community are organized, rather than using the following directly.

Software Architecture

Difficulties replicating the Town's already complex method informed ultimate design of the system. Because of the amount of data involved and the processing required for its use, it was clear that any system needed to include an automated data processing model, which would eliminate the need for multiple, order-dependent queries and also much of the opportunity for error that is introduced in such processing. Further, in discussions with the Town it also became clear that the ability to change assumptions and edit any method developed was desirable for planning purposes other than growth management, and that this flexibility needed to be relatively simple to implement.

Importantly, the Town used ESRI's ArcGIS system. With ArcGIS two desirable software elements became available to address the major requirements of the system. The first is ESRI's Modelbuilder extension, and the second was CommunityViz's Scenario 360 extension. Each of these tools loads directly into ArcGIS, which minimizes data processing/data extraction, simplifies implementation, and ultimately reduces training time required to train South Kingstown staff in model operations.

In brief, ESRI's **Modelbuilder** extension allows the construction of complex data models, which can be edited, viewed, and saved in a graphical user interface. More than just a picture, Modelbuilder generates and stores geoprocessing workflows and scripts, which speeds the design and implementation of complex geoprocessing models. Data models are developed as flow diagrams that connect functions and data. Consequently, all data queries required for the build-out model could be predefined and saved and then run with a few simple commands.

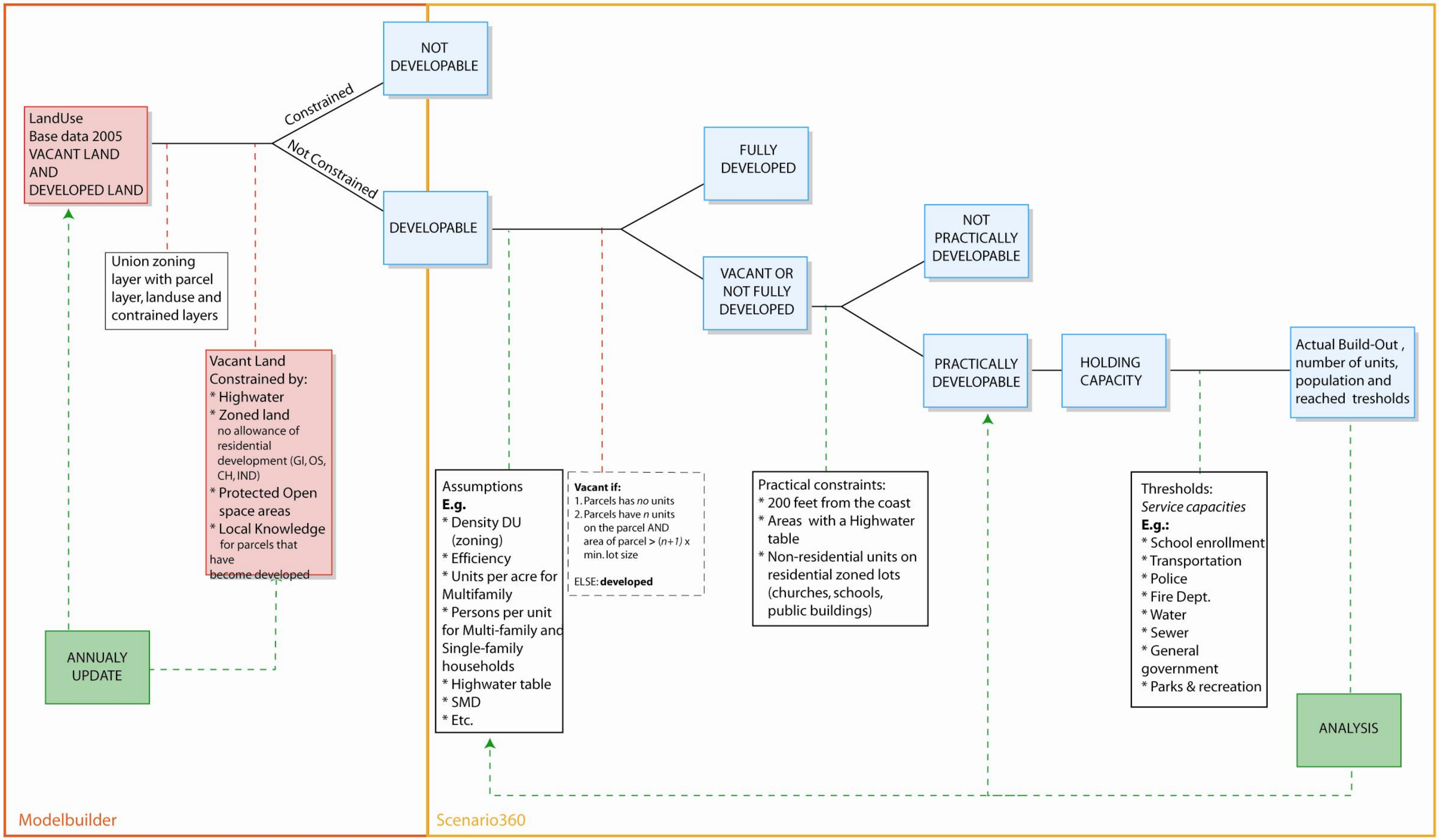
Conceptually, **Scenario 360** can best be described as a spatial spreadsheet. Like a spreadsheet it allows for formulas and calculations but it can perform these calculations on spatially related data and can include formulas that call standard GIS functions. There is, by definition, no "black box" element to a model defined in Scenario 360 as each formula, assumption and dependency is viewable and editable. A model developed in Scenario 360 shares genetic heritage with those described in the urban planning classic *Spreadsheet Models for Urban and Regional Analysis* (Brail and Bossard 1993), rather than the large-scale urban models mentioned earlier. As discussed later, transparency and the ability to edit formulas and alter assumptions became one of major strengths of the system developed.

Model Design

In consultation with Town staff, the ESC first created a conceptual framework for model function and data processing and sketched out what would eventually become the following flowchart, which describes the entire build-out model in a two part process. The first part—labeled Modelbuilder—unions land use, parcels and constraints to prepare the data for use in the build-out model. The second part—labeled Scenario 360—describes a decision tree for each parcel that ultimately produces holding capacity and ultimate build-out

Figure 1: Build-Out Model Flowchart (following page) shows the conceptual design of the Model and the division of functions between Modelbuilder and Scenario 360 components of the model.

Figure 1: *Build-Out Model Flowchart*



The ModelBuilder component
Input data for Modelbuilder are shapefiles. Outputs from Modelbuilder are newly created shapefiles. Input shapefiles (land use, zoning, parcels, local knowledge and the constraint layers) are all combined using ModelBuilder and produce data used in the Scenario 360 model. This portion automates GIS queries and unions that had been done manually and produces three shapefiles:

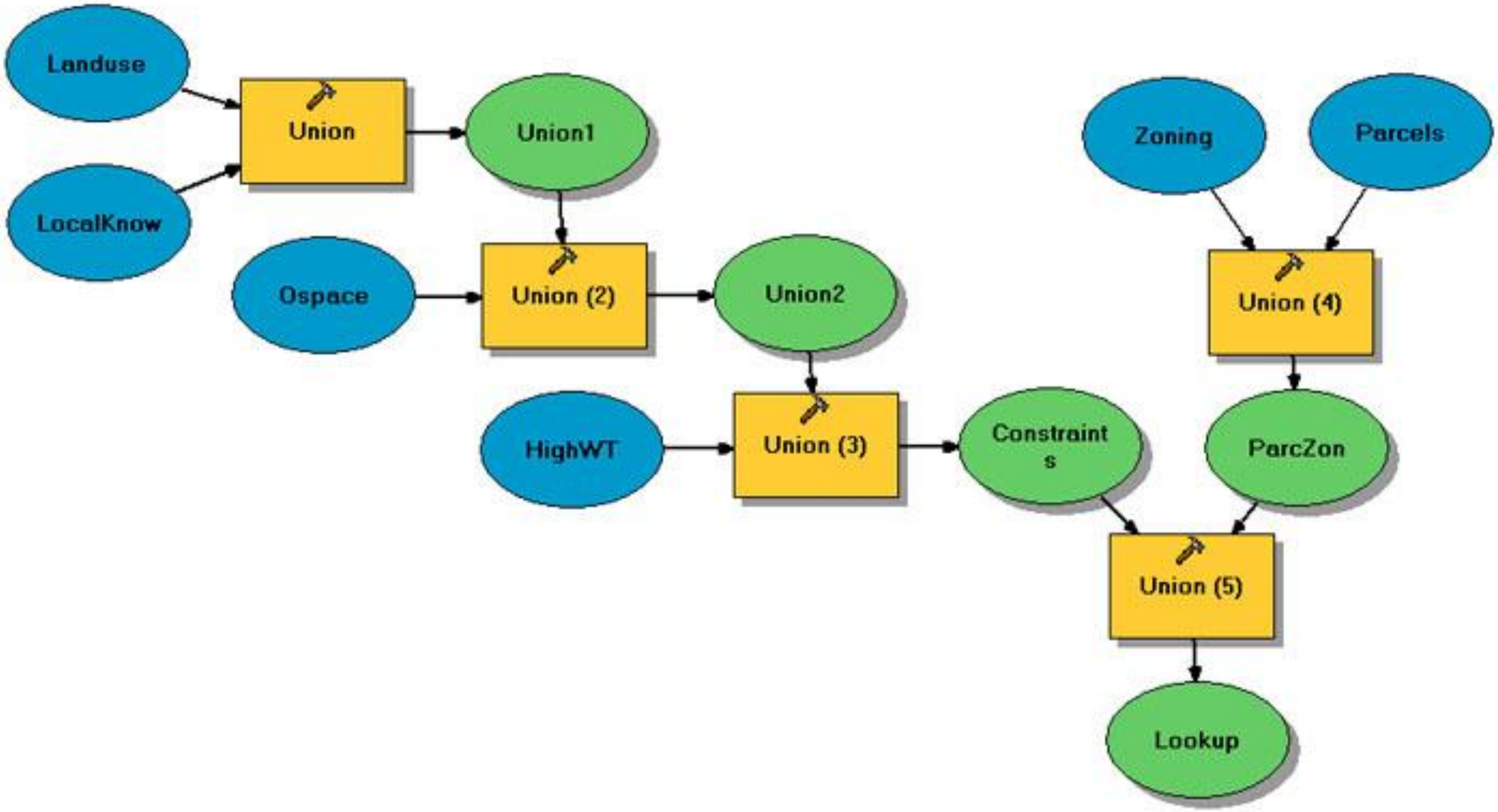
- The constrained shapefiles unioned (protected open space, land use (wetlands and water), zoning (non-residential land), high water table, local knowledge (parcels that are developable but for which the Town has knowledge that these parcels will not be developed);
- A union of the parcel and the zoning shapefile;
- A union of all the input layers.

The final ModelBuilder model is reproduced as Figure 2: Modelbuilder Model.

The initial build-out model developed during the iterative process described earlier did not have a Local Knowledge layer. During model development it was determined there were so many unusual situations and odd quirks regarding specific parcels of land that the Town needed to develop a new data layer that would take all this local knowledge about the land and inform the build-out model. Ultimately, this layer was called the Local Knowledge layer. It includes elements like cemeteries, which are theoretically developable, but for the purposes of build-out they were identified as undevelopable in that layer. Other examples included parcels recently built-out by recent subdivision approvals.

While it would have been ideal to have represented all of these elements in original data layers, there were so many unique or unusual cases that the only practical solution was to have this layer summarized as local knowledge that exists outside the base data.

Figure 2: *Modelbuilder Model*

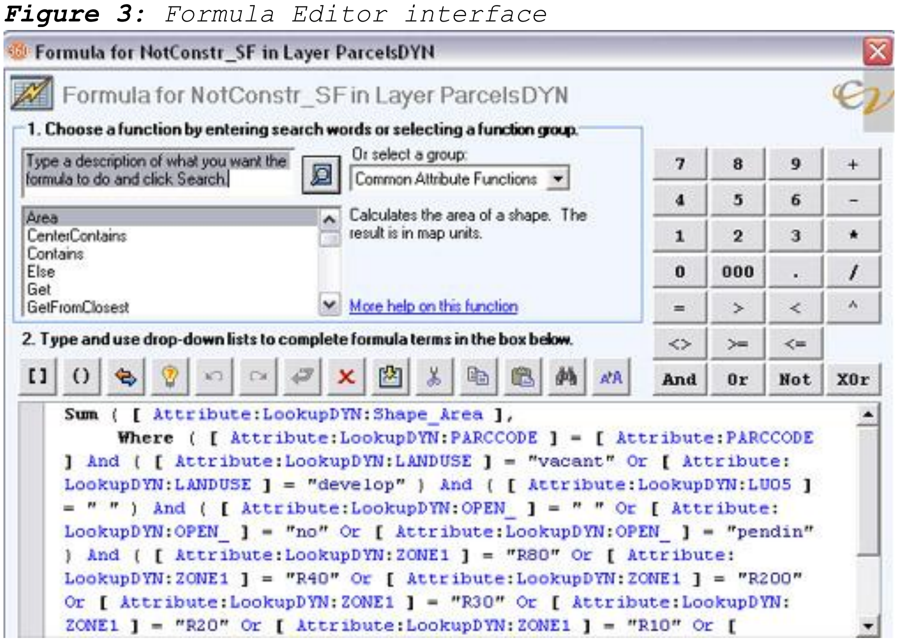


The Scenario 360 Component
Conceptually, CommunityViz's Scenario 360 handles spatial data the way a spreadsheet program like Excel handles tabular data. Models and / or formulas can read both spatial and tabular data, and formulas can be built with assumptions that are stored in Scenario 360, which are designed to be easily manipulated. Scenario 360 was used to construct, store, modify and apply the build-out model and its assumptions and produces holding capacity and ultimate build-out.

There are two primary types of input data required to run the model: layers necessary to calculate the build-out and the assumptions that drive the model. The model itself is a series of simple arithmetic equations, all of which are stored in Scenario 360. While simple mathematically, formulas that make up the final build-out model take up 10 pages in the appendix of the user documentation and will not be repeated in full here.

It was possible to create and manage such a system of because of Scenario 360's formula editor, which not only assists in the construction, display, and editing of the formulas, but also keeps track of dependencies, keeping all components of the model in sync. A snapshot of the formula editor with the formula that calculates the amount of developable land for single family units on each parcel appears below:

Figure 3: *Formula Editor interface*



Developable area on the parcel
Build-out calculates residential holding capacity for each parcel. Fundamental to this calculation is identifying vacant land available for development. Developable land is run through a series of formulas to determine if parcels are already fully developed, or are vacant or partially vacant. Vacant areas are then run through practical constraints and vacant holding capacity by parcel is produced. Calculations are made per parcel and the lookup table is used for calculating the developable area on a parcel. The following describes how developable land is identified.

An area is developable if it agrees to the following conditions:

Land use is vacant or developed
The land use layer was defined as four uses: water, wetlands, vacant and developed. The data are based upon aerial photography interpretation, which does not necessarily correspond to actual land uses, zoning districts or allowable densities. For example, areas marked as "developed" are often not fully built-out under current zoning densities. The build-out model includes vacant developable parcels, and calculates the undeveloped capacity of developed and partially developed parcels. Wetlands and water are never developable.

Remove protected open space
Like wetlands and water, protected open space is not developable.

Select areas that allow residential use
Only areas zoned for residential use are developable. In South Kingstown, these are zoning districts: R10, R20, R30, R40, R80, R200, RM, MU, CW, CN, CD.

Implement practical constraints
The Model includes practical constraints to development. Practical constraints include high water table, which makes some parts of South Kingstown difficult to develop, and conforming non-residential uses on residentially zoned parcels. These are typically churches, schools and other institutional uses which are allowed in residential districts in the community. The Model was developed so that the user can choose if these areas are buildable or not, and in case of areas covered with a high water table, the user can choose the percentage which reduces the development capacity of this land.

Assumptions in the model

Build-out is an assumption driven model and any of the assumptions in the model can be changed. When an assumption is changed, all formulas within the scenario that use that assumption are automatically recalculated. Parameters that were set up as assumptions are as follows.

Allowable Densities
The densities of current zoning districts are built as assumptions in the model. When combined with developable area, they produce holding capacity. When a user varies these assumptions the model will show how changing zoning density in a particular district would impact the Town's total build-out.

Persons per unit for multi-family and single-family
To calculate total population at build-out, assumptions have been created to vary the number of persons per unit in multi-family units and in single-family units. The default value is 2.56 for single-family and 1.25 persons per unit for multi-family and are based upon 2000 Census figures for households in the Town.

Number of units per year
This assumption allows the user to estimate the average number of building permits issued in any given year, which allows an estimate of the number of years until ultimate build-out.

Approved units for multi-family and single-family
This assumption allows Town staff to override certain components of the build-out model with exogenous information. Town staff calculate the number of units that have been approved or are in the approval process and then input that number as assumptions. There is one number for multi-family units in the Town and another for single-family units. Parcels on which this development is planned are included in the LocalKnowledge layer and removed from the build-out model. They are added back into the total number of units at the end of the analysis.

Actual number of units and actual number of people
These assumptions allow the user to calculate the number of units and people there will be at build-out. The default values are *12,633* units and *30,269* people, which is a 2005 estimate from tax assessor's data using a housing unit method.

Subdivision efficiency factor for vacant and developed land
The efficiency factor reflects the amount of developable land that is lost to roads, and inefficient lot splits during subdivision. Two assumptions address subdivision efficiency: the efficiency on vacant parcels and the efficiency on developed parcels (or areas on the parcel in case of split parcels). The default values are *15%* on vacant parcels and *50%* on developed parcels[1]. The default values were calculated empirically by studying recent development in the Town.

Assumptions for practical constraints
Conforming non-residential buildings on residentially zoned land
This assumption determines if conforming non-residential buildings (e.g. churches, schools, cultural buildings, fire department buildings, hospitals, police, governmental buildings that are located in residential zones) will stay or can be replaced with new residential units. The default value is *yes*, which means that they can be replaced with residential development. If only some of these can be replaced, others can be taken out through the Local Knowledge data layer.

High water table
This assumption determines if areas that have a high water table are buildable or are impaired by their physical constraints. The default value was *50%*; which means that the development capacity of this land will be reduced by 50%.

[1] Tear-downs of existing buildings on underbuilt lots do not happen often in South Kingstown. The large efficiency factor for lots that are already developed takes into account that most development on these development lots is a subdivision that preserves the existing home, which often was built in the center of the lot. To maintain required setbacks, this kind of lot subdivision often requires inefficient lot splits. If tear-downs become more common in the Town this number can be altered to reflect a more efficient use of land during subdivision.

Land within 200 feet of the coast
While this practical constraint was eventually dropped from the final model it is detailed here for the lesson learned. Development within 200 feet of the coastline is difficult and uncommon in South Kingstown. Building codes require that any development be built on stilts to protect it from flooding, and while it is not prohibited, this creates considerable added cost and makes this land difficult to develop. The build-out model was developed with all land within 200 feet of the coast having a user-modifiable practical constraint, like high water table, but this ultimately proved to be an example of the cost of implementation and operation not equaling the added benefit.

This practical constraint made a tiny impact on the overall capacity of the town, regardless of how it was set, yet made the entire model much more complicated. Every piece of land knew not only its parcel, zoning, wetland condition, open space condition, use, high water condition, but also if it was within 200 feet of the coast. The South Kingstown model operated on each unique combination of all these conditions, with capacity by parcel ultimately summed from each piece of land within each parcel that fit each unique condition. So while the model's formulas were mathematically simple, they were very long, which made them look complicated and difficult to edit. Overlays such as 200 feet from the coast also added much to data processing and model maintenance, and with the benefit of this added component to results being tiny, it proved to be too costly for ultimate inclusion in the final model.

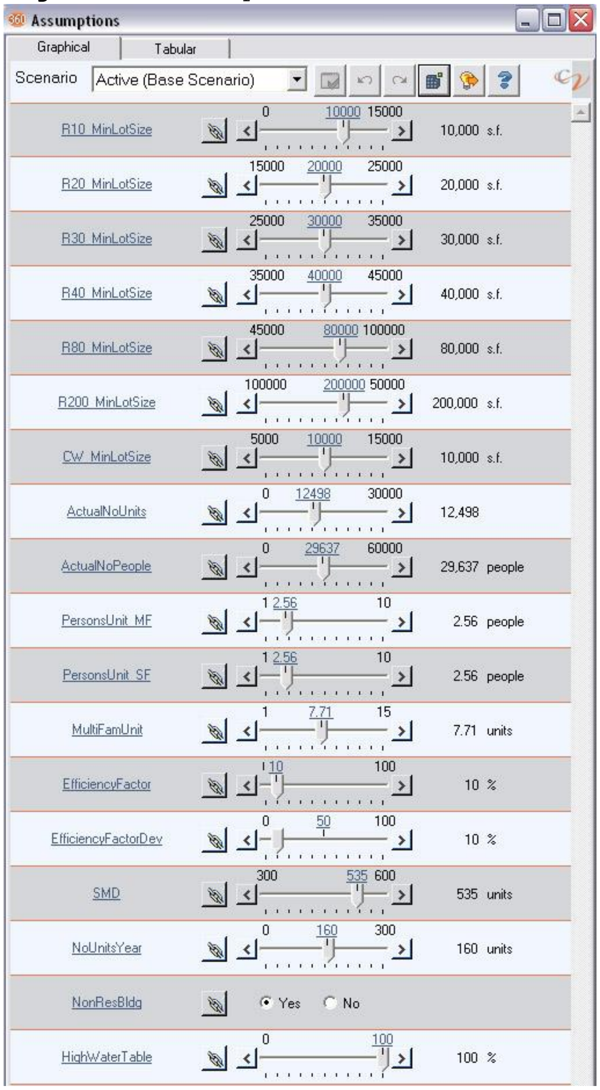
Calculating vacant holding capacity

After the non-constrained area per parcel is calculated (separately for multi-family and single-family), the next step is to calculate holding capacity. Based on zoning density, minimum lot size is calculated. In case of parcels split by a zoning district, the weighted minimum lot size on the parcel is calculated. The non-constrained area divided by the minimum lot size shows the holding capacity of the parcel. The final step for calculating the vacant holding capacity is to subtract existing units from total holding capacity.

Altering assumptions

Scenario 360 possesses an excellent interface for altering assumptions and a built-in infrastructure that allows policy or sensitivity testing. The assumption interface for the South Kingstown model is reproduced as Figure 4. The slider bars allow users to easily vary assumptions and then run the model to see how it impacts results.

Figure 4: *Assumption interface*



The scenario construction functionality of Scenario 360 provides infrastructure that allows side-by-side comparisons between two or more scenarios so that impacts of altered assumptions can be compared and evaluated.

An example of how this function might be used is experimenting with allowable density in particular zoning districts. The result of each experiment can be saved as a scenario and the output for each can be easily compared showing the consequence of such a decision.

Task 3: Installation and training

The build-out model was designed to be run and maintained by Town staff without the assistance of the ESC or outside consultants.

This required that all elements of the model be documented thoroughly, and that training materials be developed. These materials were used in a hands-on training with Town staff--their GIS administrator--who took responsibility for managing the model, updating the data and producing outputs.

The Town has very competent staff and the GIS administrator picked up the functionality of the tool immediately and demonstrated it to planning staff and a joint meeting of the Town Council and Planning Board in 2006.

The largest challenges in maintenance, not surprisingly, regard tasks that are only performed once a year (updating the data) or when there are updates to ArcGIS or Scenario 360. The ESC fields occasional calls with questions, but Town staff have been able to perform operations and maintenance largely on their own.

"Final" output

The 2005 build-out model was designed to test assumptions and to change as the Town develops and changes. Therefore, no results are truly final. Nevertheless, using all default values as assumptions, the build out model showed that the Town had vacant capacity for an additional 5,696 units and 12,943 people.

The following figure shows vacant holding capacity by parcel using default values. To be shown as having any holding capacity, a parcel must have room for at least one unit. If there is room for 0.99 unit, then capacity is shown as zero[2]. The parcel with the largest holding capacity has room for 181 units. The detail of the "core" of the Town shows that infill development on many already developed parcels is still possible under current zoning densities.

[2] Assemblages of multiple parcels, which would allow for more efficient subdivision, does not happen often in this Town and was deliberately not included in the build-out model.

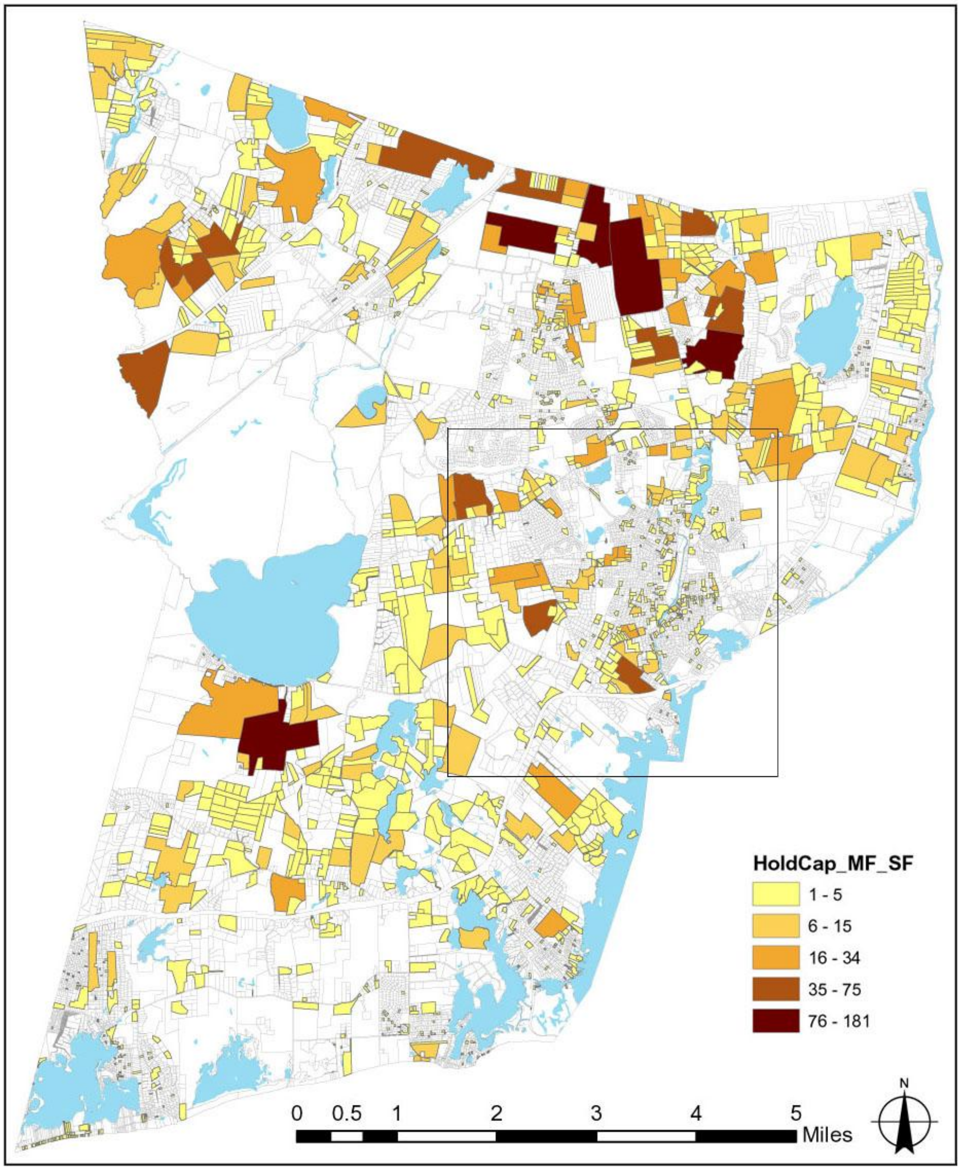


Figure 5: *Result of the 2005 Build-Out Model. Highlighted "Core" area is shown in Figure 6*

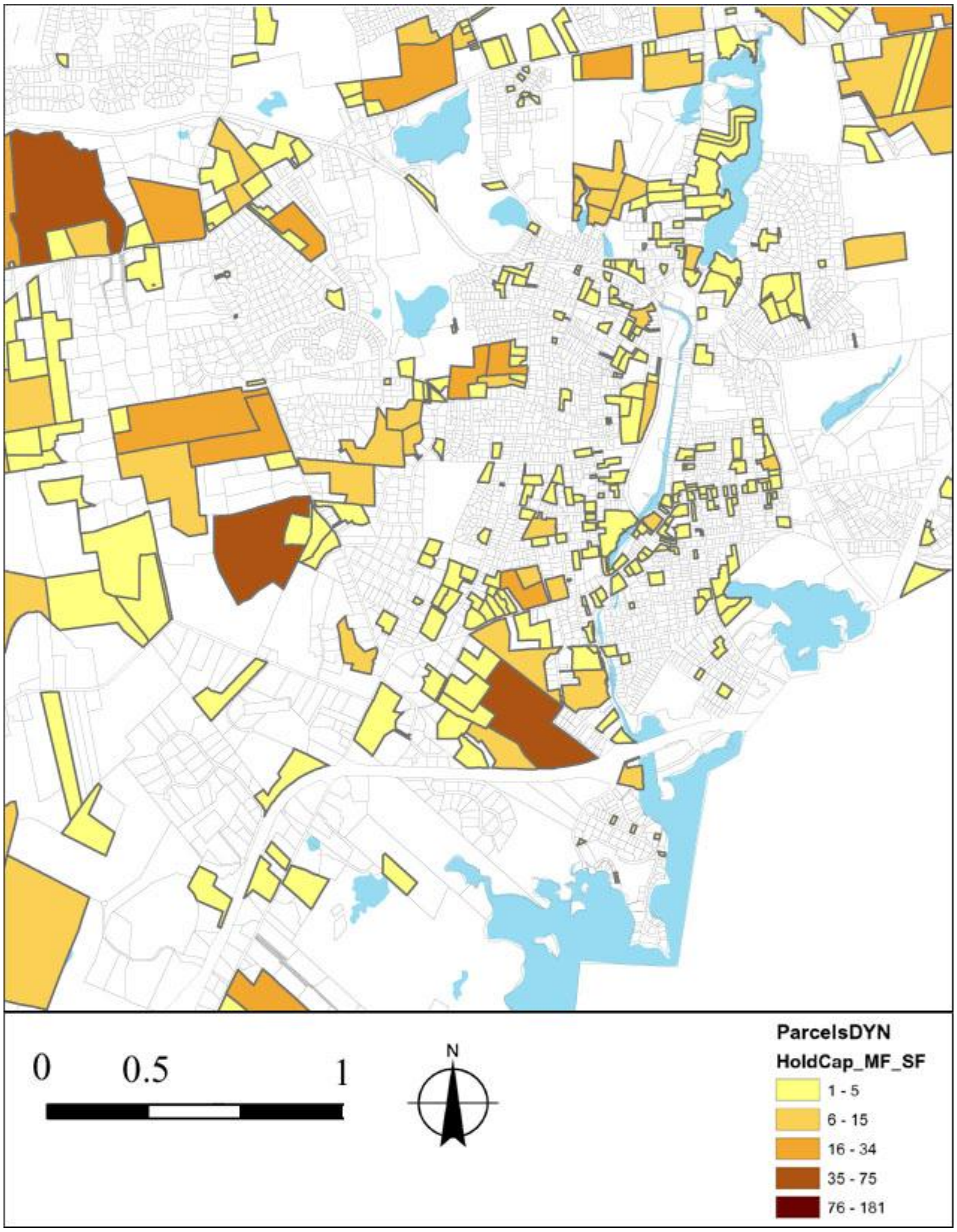


Figure 6: *Result of the 2005 build-out model, core area*

During recent communication with the Town, it was learned that several of the larger parcels shown as developable on these maps have been removed for a variety of reasons during the 2006 update. The ability to analyze the results at this level allows staff to question the results of the model, investigate its output and, if necessary, make changes (usually through the LocalKnowledge layer).

Challenges and lessons learned

The South Kingstown model was implemented by an ESC staff person who, while skilled with GIS analysis, had never before implemented such a model. The interfaces and wizards that are built into Scenario 360 allow individuals familiar with ArcGIS to pick up the functionality of Scenario 360 fairly quickly and no programming skills were required. This low "cost of entry" remains a major empowering aspect of a model developed in Scenario 360, as planners and technicians with common skill sets can develop and maintain models developed in Scenario 360. The Town engaged the ESC to develop this system for them, but if the Town had staff resources to commit to the development of this system, and it had fully understood the potential of the Scenario 360 platform, there is no doubt it could have developed the system itself, as it did not require an overly specialized skill set.

Nevertheless, the development of the model took considerable time. This had more to do with the iterative design of the model than any other single aspect. Iterative model design allows for optimum results as it allows for refinement during design in response to preliminary results. This kind of design approach also means that it is difficult to develop and keep to a schedule as it was not pre-determined how many iterations the model would go through.

The South Kingstown model is a custom designed application and as a custom designed application has quirks and conditions that need to be managed. Software with wider applications should be designed to handle usual exceptions out of the box, whereas custom designed applications are designed to function only in a certain environment. When that environment changes, however, it can cause issues with operations. For example, when the model was updated for 2006, the Town updated the records in one field in one table with values that were null. Previously, this field had been defined as a real number and was never null. The model was not designed to handle the null exception and stopped with an error. The fix was simple, but diagnosing the problem took some time. These kinds of conditions should be expected to happen in a custom designed application and need to be accepted as a part of having a model built for the unique conditions of a single community. Extra time needs to be allowed during the annual data updates, during upgrades that involve the ArcGIS or Scenario 360 base application, or with the Windows operating system to allow for time to solve issues that may occur during these events.

Conclusions

In the United States most land use decisions are made at the local level. Local development regulations interact with each other, state and federal regulations and the decisions of local landowners and institutions to create a panoply of overlapping and interacting regulations. It is impossible for the professional or citizen planner to fully understand how changes in a single component of regulations will impact the entire system without a way to track and measure the interactions between all the elements that affect development in the community. The South Kingstown build-out model attempts to be the system that tracks all these elements.

But unlike many larger-scale urban models, it does not attempt to forecast what will happen in the future. Rather, it attempts to take what is known about the land and the laws that govern the land and tries to inform planners and decision-makers about the consequence of those conditions to the ultimate community. If those consequences are considered unacceptable, the build-out model is also designed to show how changing those conditions will impact the ultimate community. It does this with comprehensive, up-to-date data, straight-forward and changeable assumptions, and simple formulas that use mathematics just about anyone can understand.

The value of simple formulas, transparent assumptions and accepted and understood data sources is extremely valuable for people who make these decisions. Most people who become commissioners or selectmen and women are committed to their community and understand it deeply. These people must have the opportunity to drill down into the assumptions, formulas and data so that if questions arise, if something does not seem right, the issue can be investigated and explained.

Further, it is also useful when formulating policy to be able to analyze each component and to be able to say, "Assuming there are no changes to any other regulations, if this regulation is changed it will alter our capacity by X." This kind of design also means that common steps found in large-scale urban models are completely missing. Calibration, for instance, is not a part of the South Kingstown model, as it is both unnecessary and undesirable as it adds parameters that are not easy to explain.

The current movement in the field of planning toward tools that are designed to support practical decision-making is a major step forward for planners and elected officials. These straight-forward tools are providing timely, customized information to decision-makers so that they can better plan for the futures of their communities. Indeed, the South Kingstown model is but a single application in an entire system (Scenario 360) that has countless applications including a 3D component that allows future conditions to be visualized. Other systems are likewise being applied in other communities addressing additional issues. But the common thread in most of these applications is that they are being driven by the needs of the local planners and decision-makers. Indeed, local planners and decision-makers are beginning to take more control and drive the applications as they write Requests for Proposals (RFPs) and describe the tools they need. Eventually, as the tools become even simpler and easier to use, I expect that we may start seeing the wide-spread application of home-grown tools and instead of issuing the RFPs, communities will take complete control of the design and implementation of their decision-making tools.