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# Smarter Shrinkage: a Neighborhood-Scaled Rightsizing Strategy Based on Land Use Dynamics

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## Abstract

Despite global projections of increasingly concentrated urban population growth, many cities still suffer from severe depopulation (or shrinkage), which results in increased vacant land/structural abandonment. As a consequence, shrinking urban areas are now seeking ways to more intelligently inventory and manage declining neighborhoods. Smart Shrinkage, a means of planning for fewer people and less development, has become a popular approach to managing depopulation. This research explores current approaches to managing vacant urban land through case evaluations approach, using findings to inform an applied Smart Shrinkage strategy for repurposing vacant lots. Land use prediction modeling is integrated into the process using Dayton, Ohio, USA, as an application site. A GIS-based development suitability model was used to identify pockets of future nodal development, and the land transformation model (LTM) was used to predict areas of future decline. Typologies of vacant/abandoned lots were then developed based on spatial characteristics of each parcel. The result of the process is a framework for executing Smarter Shrinkage—a community-scaled approach integrating land use prediction modeling into the process for managing vacant lots. Findings suggest that forecasts from the LTM require policy mechanisms to be put into place that will allow land to be transformed for nonresidential uses that are consistent with where demand exists. Smarter Shrinkage approaches should emphasize the implementation of newly proposed development only within nodes of high development potential and should utilize temporary or green infrastructure-based functions in areas predicted to become vacant or with low development potential.

**Keywords** Shrinking cities · Smart Shrinkage · Vacant land · Land use prediction · Urban decline

## Introduction

The United Nations (2012) projects that between 2011 and 2050, the world's population will increase by 2.3 billion. Urban populations are expected to double during this time and will account for 67% of the global population by 2050. Despite these projections, some urban areas will experience large population losses. Shrinking cities are those facing extreme population losses over a period of two or more years (Tietjen and Jørgensen 2016). Globally, as of 2007, there were

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370 large cities that had shrunk in population by at least 10% over the previous 50 years (Oswalt and Rieniets 2007). Population loss or shrinkage is the predominant causal factor for increased vacant urban land and structural abandonment (Inkoom et al. 2017; Deng and Ma 2015). Therefore, the question of what to do with the resultant vacant land has attracted much attention from both academic researchers and planning practitioners.

The number of shrinking cities began to grow rapidly in the 1990s, with more than a quarter of all cities with populations over 100,000 losing population (Rieniets 2006). The 2007 global financial crisis and the subsequent collapse of the American housing market in 2008 increased foreclosures and led to widespread housing abandonment throughout many US cities (Mallach 2012). Cities in the Rustbelt region, a post-industrial region in the upper Northeastern and Midwestern USA characterized by declining industry, aging factories, and falling populations, were hit particularly hard, resulting in empty urban neighborhoods, growing numbers of abandoned houses, and destabilized neighborhoods. During this period, shrinking Rustbelt cities were also characterized by high unemployment, poverty, and crime rates (American Assembly 2011).

Many cities experiencing urban decline as a result of shrinkage developed vacant land inventories to more accurately characterize and more effectively respond to vacancy conditions. Some even practice Smart Shrinkage (sometimes referred to as Smart Decline or rightsizing), a method of planning for fewer people, buildings, and types of land use (Hollander and Németh 2011). A city's inability to retain viable developments in all vacant areas has gained wider acceptance among local officials who have embraced Smart Shrinkage policies (Schilling and Logan 2008).

Rather than force new development into decaying areas, cities rightsize themselves, preparing to take advantage of future opportunities for development when the potential appears. Tactical urbanism, guerilla urbanism, user-generated urbanism, insurgent urbanism, and pop-up urbanism are all grassroots attempts similar to Smart Shrinkage that seek to claim and repurpose vacant lots through the implementation of temporary ecological functions, such as urban agriculture, park space, or other community needs (Finn 2014). While current approaches to managing vacant lots in shrinking cities have typically started with inventories and assessments to identify opportunities for transformation, no approach has utilized land use prediction models at the neighborhood scale to assist in decision-making processes around vacant land use. This research integrates land use prediction modeling for vacant land uses into the management process of vacant properties for the purposes of guiding Smarter Shrinkage.

## Literature Review

### Vacant Land Prediction

#### Smart Shrinkage and Vacancy

Smart Shrinkage is still a relatively new concept and little research has been published in the peer-reviewed literature that empirically examines its potential. In fact, Smart Shrinkage is a controversial planning topic, and some cities have come under scrutiny due to its application (Campbell 2016). Smart Shrinkage has been used in cities such as (1) Youngstown, Ohio, as part of the 2010 comprehensive plan; (2) Cleveland, Ohio, as part of stronger code enforcement for abandoned structures; and (3) in multiple cities through the use of land banking strategies. The approach is, in essence, a way to repurpose large amounts of vacant properties by streamlining the legal process for returning tax-reverted properties back to a productive use. This use, of course, does not have to be a developed one. For example, Hackworth's (2016) critique examined five Rust Belt cities which employed a rightsizing strategy. He found that rightsizing tended to be deployed in temporary or superficial ways and questioned whether the approach represented anything new. This paper responds to Hackworth by demonstrating how planners and designers can apply additional technologies to make Smart Shrinkage smarter, more thorough, and more permanent.

#### The Land Transformation Model

Smart Shrinkage approaches have typically not utilized urban prediction models. Many land use/land cover change (LUCC) models have been developed over the last 50 years, ranging from statistical and econometric models to Geographic Information Systems (GIS)-based models. Researchers have typically used LUCC models to explore drivers and patterns of land use change (Verburg et al. 2011). More recently, urban planners and urban scholars have begun using more scientifically and technologically driven LUCC models (Landis 2011). These models consider the influences of both socioeconomic and physical characteristics to simulate spatial and temporal patterns of future land use scenarios. Hollander and Popper (2007) argued that this type of predictive modeling presented an opportunity to better understand opportunities for repurposing vacant land in shrinking cities.

The land transformation model (LTM) is a GIS and artificial neural network (ANN)-based LUCC prediction model that has recently become more widely used (Pijanowski et al. 2002). Developed 15 years ago and subsequently applied globally (Pijanowski et al. 2006), ANNs are self-programming networks that find and resolve complex interactions between input layers and predicted output layers, imitating the brain's ability to sort patterns and observe relationships in data (Vafeidis et al. 2007). The ANN learns the patterns of urbanization using historical land use data from at least two different time periods, calculates the change between these periods, and uses this change as an influencing raster dataset alongside input drivers, which are factors for creating the circumstance being predicted (Tayyebi et al. 2013). Spatially explicit LUCC models typically begin with a digital map of an initial time and then simulate a range of transitions to produce a prediction map for a subsequent time (Pontius et al. 2008). To stabilize the error level to a minimum value, the ANN is required to be trained over 4000 cycles but may use up to 250,000 cycles (Pijanowski et al. 2009).

Although other computer-based models are based on similar processes, a strength of the LTM is that it displays the accuracy of the model through Kappa statistics and percent correct match (PCM) scores, while other models only specify whether inputted factors result in a statistically significant change. It has been used to predict changes at the mega-regional (Pijanowski et al. 2009), regional (Brown et al. 2000), watershed (Tang et al. 2005), and city scale (Tayyebi et al. 2013).

## Vacant Land Prediction Modeling and Calibration Methods

Newman et al. (2016a) developed a model using the LTM to predict vacant urban land by analyzing historical vacant land patterns and incorporating potential causal factors and other variables to test the forecasted vacant land uses. In these models, variable selection can greatly alter the predicted outcome since each input driver can influence outputs to various degrees. Primary causes of vacant land can be classified into four categories: deindustrialization (Németh and Langhorst 2014), market conditions (Johnson et al. 2014), personal wealth, and physical characteristics (Németh and Langhorst 2014). Several other studies have supported these findings suggesting primary drivers of vacancy such as: (1) deindustrialization (Buhnik 2010), (2) housing market conditions (Johnson et al. 2014), (3) personal wealth (Mallach and Brachman 2013), physical location (Németh and Langhorst 2014), employment trends (Mallach 2012), educational attainment (Fee and Hartley 2011), racial makeup (Ryan 2012), and accessibility and proximity to transportation lines (Ye et al. 2018; Rappaport 2003). The LTM model utilizes a series of raster data sets as input variables to drive vacancy predictions. The principal causal mechanism contributing to vacant urban land is generally denoted as depopulation. Other drivers may include educational attainment of occupying populations, concentration of minority populations, manufacturing employment, housing market conditions, owner-occupancy rates, median built year of structures, property values, income, parcel size, and transportation accessibility (Fee and Hartley 2011; Ryan 2012; Newman and Kim 2017).

In developing the vacant land prediction model, the LTM was first calibrated according to input variable influence and prediction output accuracy by comparing the model's predicted vacancies to actual vacancies. These calibrations were performed to determine if appropriate levels of congruence and specific standards of statistical accuracy were met as part of the model validation. The proposed model was deemed acceptable using four types of assessment: Kappa statistic, PCM, allocation agreement/disagreement, and receiver-operating characteristic curve analysis (ROC).

Kappa coefficients have long been a standard component of accuracy assessments (Pontius and Millones 2011). The Kappa statistic measures the percent agreement between an actual transition map and a predicted transition map, taking into account the possibility of agreement occurring by chance. Generally, values between 0.01 and 0.20 indicate no or slight agreement, while 0.21–0.40, 0.41–0.60, 0.61–0.80, and 0.81–1.00 indicate fair, moderate, substantial, and nearly perfect agreement, respectively (Tayyebi et al. 2013).

This application of the Kappa coefficient has been criticized for being a one-dimensional index that fails to fully evaluate location accuracy in grid cells (Pontius and Millones 2011). For this reason, quantity disagreement (QD) and allocation disagreement (AD) can also be used to increase output reliability. QD indicates the amount of difference between an actual transition map and a predicted transition map, while AD describes the amount of spatial difference between the two maps. Overall agreement (OA) can be calculated based on the two disagreement values ($OA = 100 - (QD + AD)$). Good models typically have OA values of at least 85% (Pontius and Millones 2011).

While Kappa coefficients and agreement tests assess the proportion of misallocated pixels, PCM focuses on the transitioned pixels. The PCM value indicates the proportion of pixels that transition and it is typically used to improve our understanding of the transition of the land-cover categories under investigation. Generally, PCM values between 60 and 80% indicate an exceptional model and 40 to 60% indicate an acceptable model (Almeida et al. 2008).

Lastly, the ROC is also a quantitative measurement tool used to validate the goodness of fit of a LUCC model (Pontius and Si 2014). This binary classification prediction model produces four different outcomes: true positive (TP), false positive (FP), true negative (TN), and false negative (FN). Using the values, the sensitivity (TP rate) and specificity (TN rate) can be calculated. ROC curves represent sensitivity on the *x*- and *y*-axis against a 1-specificity axis. The area under the ROC curve (AUC) graphically displays the model's overall accuracy. Values between 0.70 and 0.79 indicate a fair model, 0.80–0.89 substantial, and 0.90–0.99 as excellent (1.0 is perfect) (Rutherford et al. 2008).

## Effects of Vacant Land

When a city depopulates, housing prices can decline and neighborhood quality may decrease. The resulting neighborhoods can be occupied by persons with lower socioeconomic status, while the amount of vacant land can increase. For these reasons, vacant land can be used as a proxy for measuring depopulation and economic decline (Cui and Walsh 2015). An increasing number or proportion of vacant or abandoned properties can threaten neighborhood stability, increase violent crime and/or vandalism rates (Cui and Walsh 2015), lower residential satisfaction (Spelman 1993), and lower rents or housing prices (Han 2014). For example, Spelman (1993) found that of the 41% of abandoned residences in low-income Austin, Texas, neighborhoods, 83% were used for illegal activities. Relatedly, Immergluck and Smith (2006) found that once a foreclosed property became vacant, violent crime rates can increase by more than 15%. Faced with growing amounts of vacant land (Newman et al. 2016b), local governments may struggle to address the underlying reasons for persistent vacancies (Hollander 2011).

## Case Evaluations on Managing Vacant Properties

### Introduction

With such a wide range of factors potentially contributing to new and persistently vacant land, urban studies scholars have embraced case study research in an effort to unravel complex relationships and explore causality. For example, Beauregard (2013) summarized several well-publicized case studies of shrinking cities adopting strategies to plan for decline. Here, we present an updated analysis of these same case study cities, paying particular attention to the methods each organization employed to manage vacancy data and model future scenarios. We conducted case studies of six widely studies Rust Belt urban initiatives implemented to address vacant lots and abandoned buildings. The cases were selected based on a review of the literature (in particular, the Beauregard 2013 chapter), national media coverage, and the authors' personal connections to each city. Data was collected for each case study city based on both scholarly and nonscholarly searches, with the aim of identifying the key dimensions and outcomes of each case study project. We present a brief synopsis of each case study and analyze the group of six cities across three sets of questions: How did they inventory vacant properties? How did they analyze and project the future of these properties? How did work transform on the ground in general and how did each parcel specifically transform?

### Buffalo, New York: Sustainable Neighborhood Project

Beginning in 2010, the Sustainable Neighborhood Project pursued partnerships between government agencies, local community development officials, and nonprofit organizations. According to the plan described on the Buffalo Rising website, "local officials will designate blighted homes for rehabilitation and sale to first time homeowners; houses will be marketed as long-term affordable housing and homeowners would be selected through a lottery process" (Buscarino 2010a, b). Like many projects that are heavily reliant on political leadership, the Sustainable Neighborhood Project quickly lost traction after the then Governor of New York, David Paterson, left office only months after proposing this initiative. While conceived of as a way to marshal the resources of state government in support of reducing the problems of urban vacancy, the lack of any systematic plan to designate targeted homes and an inability to foresee future abandonment meant the initiative never made an impact on the Buffalo landscape.

### Philadelphia Pennsylvania: Neighborhood Transportation Initiative

A Reinvestment Fund-led Neighborhood Transportation Initiative was much more successful in achieving long-term change for neighborhoods in the City of Philadelphia. Based on various housing, economic, and social characteristics, the Initiative made recommendations for the demolition of more than 5000 homes over a 5-year period (McGovern 2006). The program was innovative it its recognition of the strong market value of many declining neighborhoods, which were prioritized for public investments in demolition and reuse. The careful selection and prioritization of certain areas, informed by business market value data, helped spur investment where it otherwise may not have occurred. The drawback of this program was that the city devoted no resources or attention to those locations identified as "distressed" or "reclaimed" (McGovern 2006). Locations that were not deemed attractive to private capital investments were ignored and whatever problems that existed there may have worsened (McGovern 2006).

### Youngstown Ohio: 2010 Plan

Community leaders in Youngstown, Ohio—losing half of its population since 1950—adopted a new master plan in 2005 to identify priorities for its remaining population of 74,000 (U.S. Census 2013). In the master plan, the city came to terms with its past population loss and called for a better, smaller Youngstown, focusing on improving the quality of life for existing residents rather than attempting to grow the city (Rhodes and Russo 2013; Hollander et al. 2009). *The New York Times Magazine* recognized the city's master plan as one of the most creative ideas of 2006. To address the thousands of vacant properties in the city, the master plan included a general inventory of conditions in five planning districts, using land use and occupancy patterns. This preliminary work led to the identification of 127 neighborhoods for additional data collection and analysis and the classification of each as stable, transitional, redevelopment, semirural, or industrial (City of Youngstown Neighborhood Categories). Neighborhood planning around quality of life has continued in Youngstown for more than a decade, building on this relatively simple use of available data (Dewar and Thomas 2012).

#### Flint Michigan: Genesee County Land Bank

After the State of Michigan passed a law allowing land banks in 2003, the Genessee County Treasurer's Office quickly went to work to create their own on a county scale. With the loss of its industrial base, the city of Flint, Michigan, has experienced a massive loss of population and concomitant decline in occupied housing over the last half-century (Hollander 2011). The conventional model, as typically dictated by state law, requires that any property for which the owner fails to pay property taxes or utility bills be condemned by the local government and, after various waiting periods, sold to the highest bidder at auction with the hope that the local government will recover some delinquent taxes from the sale. Under this model, many absentee owners will not invest in unoccupied housing, instead holding them or selling them to other absentee investors. The legislation chartering the Genesee Land Bank implemented a more strategic process allowing for a public entity to effectively plan for the reuse of unoccupied properties through consolidation, repackaging, and marketing them to real estate developers. In Genesee County, planners are selective in screening for the most desirable properties, working to acquire them through land banking (Genesee County Land Bank 2004). Decisions about which properties to acquire and which to repurpose are made with minimal data or computer modeling support.

#### Baltimore Maryland: Project 5000

Facing massive vacancy and abandonment problems, Baltimore, Maryland, launched Project 5000 to introduce a rigorous, data-oriented process for identifying and reusing vacant properties. Like Philadelphia, the Baltimore project used enhanced data sources, collated across agencies to improve coordination and decision-making. Project 5000 also had a complaint-tracking dimension, helping to ease quality-of-life issues for city residents impacted by abandoned properties. Targeted Enforcement for Visible Outcomes (TEVO) was an aggressive code enforcement program applied to more than 6000 vacant properties in the most economically viable blocks (Ballard and Kingsley 2007). Like Philadelphia's Neighborhood Transportation Initiative, Baltimore's Project 5000 was focused on selling abandoned properties to investors. Project 5000 made it easier for private entities to acquire city-owned properties for the purpose of demolishing them and building new structures. Project 5000 was viewed as a success by many since more than 1000 properties from the city's tax foreclosure rolls were returned to private ownership, increasing tax revenue generated by those properties (Whiteman 2014).

In contrast to some of the programs described above, Project 5000 had an explicit goal of formalizing the decision-making process for which properties would be targeted for acquisition and reuse. Through a collaborative process, the City of Baltimore used GIS integrated with data from across government agencies to identify clusters of vacancy and prioritize clusters with the greatest market potential for acquisition, demolition, and reuse (Whiteman 2014; Johnson et al. 2015).

#### Cleveland Ohio: Dual Land Banking System

Like Michigan, the State of Ohio passed land bank legislation in 2008. In 2009, the Cuyahoga County Land Reutilization Corporation (Cuyahoga Land Bank) was formed. The Cuyahoga Land Bank's mission was to strategically acquire properties and return them to productive use to reduce blight, increase property values, support community goals, and improve the quality of life for county residents (Cuyahoga Land Bank 2017). One of the most innovative elements of the program was its reliance on data-driven decision-making. Through software applications developed by the Center on Urban Poverty and Community Development at Case Western Reserve University, analysts at the land bank can view each property and identify various factors that might drive reuse. Of particular note is that their systems use data mining technologies to seek out certain key words in public filings, like "confirmation of sale" and "decree of foreclosure" (Schramm 2014). The Cuyahoga Land Bank's software systems also develop complex algorithms to predict whether a parcel is probably vacant or on the verge of foreclosure, based on inputs like a "no building value entry" from the Assessor's office, lack of any tax abatement, and evidence of past demolition on the property.

Once the Land Bank acquires a property, they use these same software systems to inform decisions about next steps, considering one of the following five options (Schramm 2014):

1. Mothball the property for long-term holding
2. Sale to private buyer
3. Special programs for targeted sale to: side-yard, green space, urban gardens
4. Hold for strategic assembly and future development
5. Demolish

### Issues with Current Approaches

These six examples demonstrate a variety of ways in which shrinking cities actively address abandoned property issues. In Table 1, we offer some key findings across the six cases in an attempt to reveal the similarities, differences, and deficiencies from the analyzed cases. Returning to the three central questions, we first asked "How did each city inventory vacant properties?" Across the projects, there was large variation. Philadelphia and Cleveland used information systems and advanced algorithms to identify, catalog, and prioritize vacant properties, while programs in the other cities relied more on qualitative assessments of each parcel. Baltimore and Youngstown relied on newly assembled compilations of existing citywide data sources to more generally describe current conditions, without the use of new software or other data analysis tools.

For the second question, we asked "How did each city analyze and project future use of properties?" Here the projects demonstrated very little analysis by local officials. In Baltimore, the aim was to generate clusters of vacant and abandoned properties, primarily done through internal conversations among city officials with the benefit of some citywide data sources. The Philadelphia and Cleveland projects did involve substantial data analysis; however, they relied on existing available data sources as proxies for current abandoned properties and did little in the way of projecting future conditions. The Youngstown plan is noteworthy in its future orientation, but equally exemplary in its lack of any forecasting of future land use scenarios.

The final question we asked was "How did work transform on the ground in general and how did each parcel specifically transform?" This is a challenging question to answer. There is some evidence to support the notion that the newly formed land banks in Cleveland and Flint and the NTI program in Philadelphia effectively invested public resources to obtain real results on the ground as measured by demolishment, increased tax revenues, or dollars of private investment. For Youngstown and Buffalo, public attention notwithstanding, there is scant published evidence of what these efforts accomplished. Even the highly impactful NTI in Philadelphia has not fundamentally shifted the economics in some of the city's most distressed neighborhoods; millions of dollars of new investment might have simply shifted existing poverty and crime to other neighborhoods.

By looking across the efforts in these six cities to address abandoned properties, we have confirmed some of the key evidence from the urban studies and planning literature: that addressing abandonment and vacancy is extraordinarily complex, expensive, and often leads to unjust outcomes (Hollander and Németh 2011). These plans and programs were all developed with similar goals—to directly impact the physical form of a shrinking city. Several of them appear to have succeeded but given the forces at work shaping disinvestment and decline, these outcomes may not have mattered much. While the Youngstown plan is widely regarded as the first Smart Shrinkage master plan in the USA, its lack of analysis of outcomes and projections about the future makes it more philosophy than planning. The other programs are all firmly rooted in conventional economic development approaches, where economic development aims are paramount to all decision-making around future uses. The only exceptions are the land banks in Flint and Cleveland, where each have earmarked some vacant residential land to go to nonresidential uses. But given the scale of the properties involved, it is clear that neither city has made Smart Shrinkage a priority, since their first choices for future uses center around investors looking to create new economic activities.

## Study Area

Dayton, Ohio, a shrinking city in the US Rust Belt, is among the ten most rapidly depopulating cities in the USA. From 1960 to 2010, Dayton's population decreased by 46%; over the last 10 years, the number of unemployed persons increased by nearly 170% (United States Census Bureau 2013). In the 1980s, the number of manufacturing jobs in the Dayton metropolitan area began to significantly decline (NPA Data Services 1995), and by the early 1990s, the service and retail trade sectors of the city's economy employed more people than manufacturing (Howe et al. 1998). A large proportion of these new service jobs were in suburban locations due to lower costs and taxes. Increased suburban job opportunities intensified disinvestment and decay in urban areas and further reduced urban job opportunities. Currently, the U.S Census Bureau estimates that Dayton lost 14.8% of its population between 2000 and 2013. Dayton is also currently composed of 22% abandoned properties, and as of 2014, the total area of vacant parcels accounted for 23% of the city's total area (see Fig. 1). From 2005 to 2014, only education, healthcare, and art entertainment industries increased, while all other industries

**Table 1** Synopsis of case studies examined

| | How did they inventory vacant properties? | | How did they analyze and project future of properties? | | How did work transform on the ground? How did each parcel transform? | |
|---|---|---|---|---|---|---|
| | Categories/criteria | Who carried it out? | Categories/criteria | Who carried it out? | Successes of plan (transformation of parcels) | Criticism of plan |
| Buffalo NY: Sustainable Neighborhood Project | Broad stakeholder collaboration to identify potential neighborhoods | Governor Paterson announced this initiative in his 2010 State of the State address and 1 month later indicated that it was moving forward. State agencies, Governor's officials, and local stakeholders would be considering sites in the near future (New York State Office of the Governor 2010) hoping to use this as a model for the state (Buscarino 2010a, 2010b). | Governor's stated goal at the beginning of the project was to rehabilitate vacant and abandoned properties to make them available and affordable to new homeowners. Each "sustainable neighborhood" will use different project models and goals (Buscarino 2010a, b). | State officials in partnerships with local community development officials | At least one nonprofit organization was awarded a grant from the Sustainable Neighborhood funding to work on 3 separate projects (Sustainable Neighborhoods 2017). | Program ended with change in Governor's office. |
| Philadelphia PA: Neighborhood Transportation Initiative | Factors used to categorize neighborhoods included vacancy rates, housing sale prices, owner-occupancy rates, housing age, demolition activity, and consumer credit profiles (McGovern 2006)<br>• Regional<br>• Choice: high<br>• Value steady<br>• Transitional<br>• Distressed<br>• Reclamation | The Reinvestment Fund (TRF): a finance corporation commissioned by the city (McGovern 2006) | Policy recommendation made for each "cluster" that included demolition and land acquisition (McGovern 2006) | Mayor Street worked with TRF to make policy recommendations | Demolished 5000 homes during 5 years<br>Authorized over 5000 acquisitions | Demolitions were significantly less than the 11–14,000 anticipated<br>Did not prioritize equity and community engagement in the plan<br>Struggled to balance overall city improvement and focus on high need neighborhoods (McGovern 2006) |
| Youngstown OH: 2010 Plan | Assessed neighborhood conditions in 11 neighborhood clusters but focused on community needs and equity. | Urban Strategies Inc. from Toronto, Youngstown State University and local community members partnered<br>Focus groups made up of local community members completed a SWOT analysis and decided on four vision principles. | Community working groups worked to analyze different aspects of revitalization and would report results at neighborhood meetings. | | Recognized by the American Planning Association, Brookings Institute, and PolicyLink for the goals of smart-shrinkage and community engagement | Appears as though many aspects of the plan were abandoned as Mayor's office changed.<br>The plan has been criticized as not impacting the high rates of unemployment, poverty, crime, lack of access to fresh food and therefore the city continues to shrink. |
| Flint MI: Genesee County Land Bank | Most properties acquired through foreclosure process, but also through property transfers and private sales<br>Genesee county determines which properties will be acquired considering planned use of the | Genessee County Land Bank Authority (GCLBA) | Treasurer, the County, or the Land Bank Authority and transferred to individuals. The LBA could then use the land for the Side Lot Program, Residential Land Transfers or Commercial Transfers. The LBA could also | Genessee County Land Bank Authority (GCLBA) | Awarded GCLBA Harvard Innovations in Government Award<br>Demolished more than 3330 abandoned properties over the past 12 years (Alexander and Nunn 2015) | |

**Table 1** (continued)

| | How did they inventory vacant properties? | | How did they analyze and project future of properties? | | How did work transform on the ground? How did each parcel transform? | |
|---|---|---|---|---|---|---|
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| | property, nature and identity of the transferee of the property, and impact of the property transfer on the neighborhood (Genesee County Land Bank 2007) | | rehabilitate or keep properties off the market to increase value of properties (Genesee County Land Bank 2007). | | An average of 1200 separate parcels are acquired each year (over 12 year span)<br>$3.8 invested to rehabilitate an abandoned department store in downtown Flint for mixed use (Genesee County Land Bank 2016)<br>84% of participants in grant-funded community outreach program called Clean and Green saw declining rates of violence, prostitution, dumping of waste and other illegal activity in the neighborhood (Sadler and Pruett 2015) | |
| Baltimore MD: Project 5000 | The program involved the development of a number of information management tools, including:<br>• Property-based information database<br>• HousingView—an internal web-based visualization tool to view geographic features<br>• • A complaint-tracking system to help manage and track the resolution of issues for the large number of city-owned properties (Ballard and Kingsley 2007) | Initiative started by Mayor O'Malley but a collaborative process between city agencies and community partners looked at city properties block by block | Utilized tools such as HousingView to focus on redeveloping the cities 14,000 abandoned houses and then make them available to private developers, nonprofits, and investors<br>More specifically, the three main methods for disposing of city-owned property are as follows:<br>• Request for Proposals (RFP)<br>• Rolling Bid<br>• Selling City Owned Property Efficiently (SCOPE) (Ballard and Kingsley 2007) | City of Baltimore under Mayor O'Malley | Project 5000 was successful in quickly acquiring large clustered abandoned properties with large potential for redevelopment.<br>1000 properties returned to private ownership<br>2000 more properties programmed for a specific development outcome<br>Sales revenue between 2003 and 2006 total $4.5 million<br>Taxes and fees collected total $118 million | Challenges include:<br>Need for better coordination within and between government agencies during the acquisition and disposition process (U.S. Mayor Article 2006)<br>Improved structure to monitor properties to make sure they are being developed for the intended purpose (U.S. Mayor Article 2006) |
| Cleveland OH: Land Banking Systems<br>Mission: strategically acquire properties, return them to productive use, reduce blight, increase property values, support community goals, and improve the quality of life for | Acquired properties either from tax foreclosures or donated properties (Alexander and Nunn 2015) | Cuyahoga County Land Reutilization Corporation (the Cuyahoga Land Bank | Clusters lots near each other to make larger lots available for development or green space<br>Active preservation and upkeep of properties not yet ready to be demolished or rehabbed | Cuyahoga Land Bank | According to Alexander and Nunn (2015), the Land Bank's annual revenues, number of properties acquired and conveyed, and staff capacity made it the single largest land bank in the USA.<br>Has provided land for community gardens, rehabilitated homes for immigrants and veterans, | |

**Table 1** (continued)

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| county residents (Keating 2013) | | | Their "deed-in-escrow program" prequalifies the transferee, quantifies the nature and costs of the necessary rehabilitation work to be done, and then closes the transaction into escrow pending the completion of the work. Upon completion, the property is transferred to the new owner immediately (Alexander and Num 2015). | | and workforce re-entry program (Keating 2013) Four years after the Land Bank was created, it had completed 750 home renovations and more than 2000 demolitions. | |

decreased. The unemployment rate reached 12.5% in 2010, while the labor force was decreasing.

## Methods

### Introduction

The following sections illustrate this research's approach to integrate LUCC prediction modeling into vacant land management processes. Vacant land inventory for the case site are conducted, followed by GIS-based spatial modeling procedures. Development suitability modeling is coupled with spatial clustering of vacant parcels to determine primary sites of future nodal development-based regeneration methods. Then, the LTM is used to predict future vacant land. Smart Shrinkage functions are then suggested within areas of future decline for management purposes.

### Suitability and Vacancy Clustering

A GIS-based equally weighted suitability analysis was applied to determine where the most highly developable areas are in the city, identifying five neighborhoods in the southwest of Dayton as highly developable (see Fig. 2). Land use suitability mapping is a GIS application used to identify spatial patterns for future land uses according to specified requirements and inventory mapping overlays (Malczewski 2004). Bowman and Pagano (2004) identified three imperatives to consider when assessing vacant/abandoned parcels—development, fiscal, and social values, each equally important to the vacancy issue. Applying these imperatives, the suitability map was developed by overlapping raster-based maps using the weighted overlay tool in GIS based on eight socioenvironmental factors: (1) proximity to flood plain, (2) land cover type, (3) soil type, (4) public or private ownership; fiscal value—(5) property value; social value—(6) proximity to parks, (7) proximity to educational institutions, and (8) proximity to employment opportunities (see Fig. 3).

Raster maps for each factor were overlaid using equal weighting to produce a final suitability output. The final output was then reclassified into three equal categories from high to low based on scores per raster cell. Weighted overlays combine multiple rasters by applying a common measurement scale of values to each (Mutke et al. 2001). Each factor was treated as an individual data layer, rasterized and then reclassified on a scale of 1 to 3 (1 = less regeneration potential; 3 = more regeneration potential). The reclassification scheme allowed for the simplification of interpretation of the raster data based on the ability to assign values to each raster cell. For example, cells with the lowest property values were assigned a value of 1, while cells with the highest property values were assigned a score of 3, as it was assumed that areas

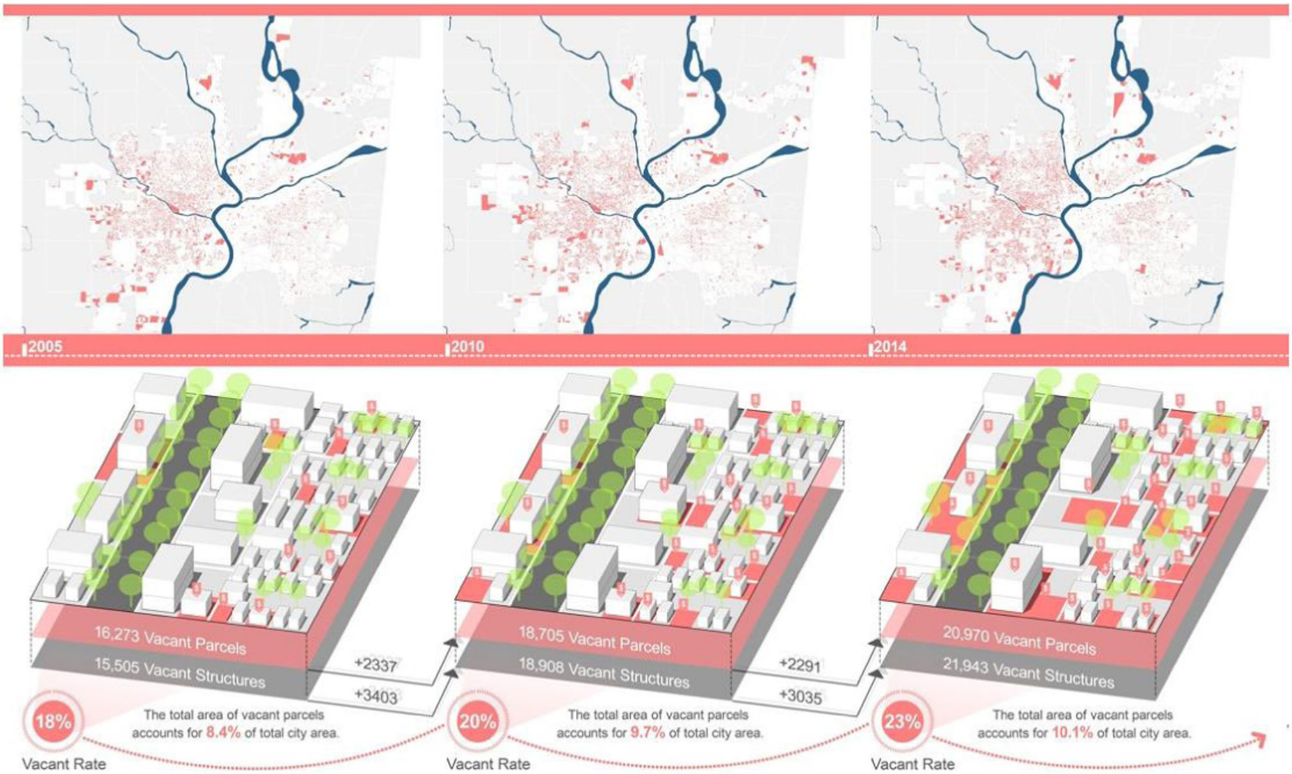


**Fig. 1** Vacancy and abandonment in Dayton, OH: 2005–2014


**Fig. 2** Suitability for nodal development in clustered vacant areas in Dayton, OH


**Fig. 3** Raster layers and weighting for suitability model

with higher property values would be more likely to be regenerated. This type of logic was applied when scoring all raster maps.

Global Moran's I and inverse distance weighted (IDW) interpolation were calculated using vacant parcels as the dependent variable to determine significant spatial clustering (Getis and Aldstadt 2010). Areas with high clustering and high suitability were then identified as areas for future nodal development. According to the final output, five neighborhoods could be targets for future nodal development. For example, the Carillon neighborhood is adjacent to several major anchors within Dayton, including the downtown, the Miami Valley Hospital, the University of Dayton, and several major parks. These findings parallel the goals of the City of Dayton's Comprehensive Plan, which suggests that universities, hospitals, and schools should be employed as reinvestment anchors for stimulating adjacent vacant land regeneration.

## Results

### Introduction

The LTM framework of Newman et al. (2016a) for forecasting vacant land was applied to the study area to predict future vacant properties. Carillon is characterized by an aging population, a high unemployment rate, a low level of education, and a relatively depressed housing market. As of 2014, Carillon's vacancy rate was 35%. To predict future vacant land, the LTM simulated urban land use change following four steps: (1) input data was stored and managed, (2) predictor variables were examined, (3) the likelihood of change was derived, and (4) the amount of land expected to transition was determined (Pijanowski et al. 2002).

Using the LTM, we predicted vacant land for the year 2023 using input patterns from 2005 to 2014. Identical input factors were used in the model created by Newman et al. (2016a) for each predicted year (e.g., distance from delinquent parcels, distance from commercial areas, distance from highway, distance from schools, appraised value, unemployment rate, and vacancy rate) (see Table 2 and Fig. 4). Prediction outputs suggest that the vacancy rate of Carillon will increase an additional 5% by 2023, primarily driven by new vacancies in parcels on the periphery of the neighborhood (see Fig. 5).

### Application of Smarter Decline

To properly integrate the LUCC prediction and suitability modeling into the process of inventorying, analyzing, and managing vacant properties, we developed a framework to both help regenerate existing vacant and abandoned lots for future permanent or temporary functions and prepare nonregenerated lots for managed decline. This framework is applied on a community scale within the Carillon

**Table 2** LTM statistical output for the model

| Input patterns | No. of input factors | Highest training probability | PCM* | Kappa** | OA*** | AUC**** |
|---|---|---|---|---|---|---|
| 2005–2014 | 12 | 50,000th | 50.02 | 0.42 | 95.7 | 0.70 |

*PCM—40–60% is acceptable

**Kappa—0.41–0.60 is moderate

***OA (overall agreement)—more than 85% is considered good

****AUC—0.70–0.80 is fair

Neighborhood of Dayton to provide a much needed example of executing a rightsizing strategy on a neighborhood scale.

### Task A. Procuring Nodal Development (See Fig. 6)

Step 1. Targeting: A thorough inventory of existing vacant lots is needed to analyze the causes and social/economic costs of continued abandonment/vacancy. Historical data on public and nonprofit expenditures for relevant community and economic development are collected and land suitability analyses are used to prioritize areas of potential revitalization. Land with low suitability for development, or in decline, is recorded and registered as a potential component of the city's land bank or some other form of vacant land accumulation. Some cities have ordinances requiring that vacant buildings be registered so municipal databases can be a useful source in the targeting phase.

Step 2. Thinning Out: Based on the targeting inventory, blocks in which the vacant parcel rate exceeds 50% are prioritized for renovation. The demolition of aging and deteriorating structures and land banking of vacant properties for better management and reinvestment may be necessary in these areas. When no owner can be identified for a vacant or abandoned property, the local government can acquire the properties through various mechanisms. Lots located in low vacant parcel clusters should be stabilized through rehabilitation efforts and housing assistance resources using available federal and state funding.

Step 3. Repurposing: Once thinned out, zoning reforms and updates to comprehensive plans can be used to facilitate vacant property revitalization and support neighborhood reinvestment plans to help attract private reinvestment. For example, a relaxed zoning overlay code may effectively broaden the range of

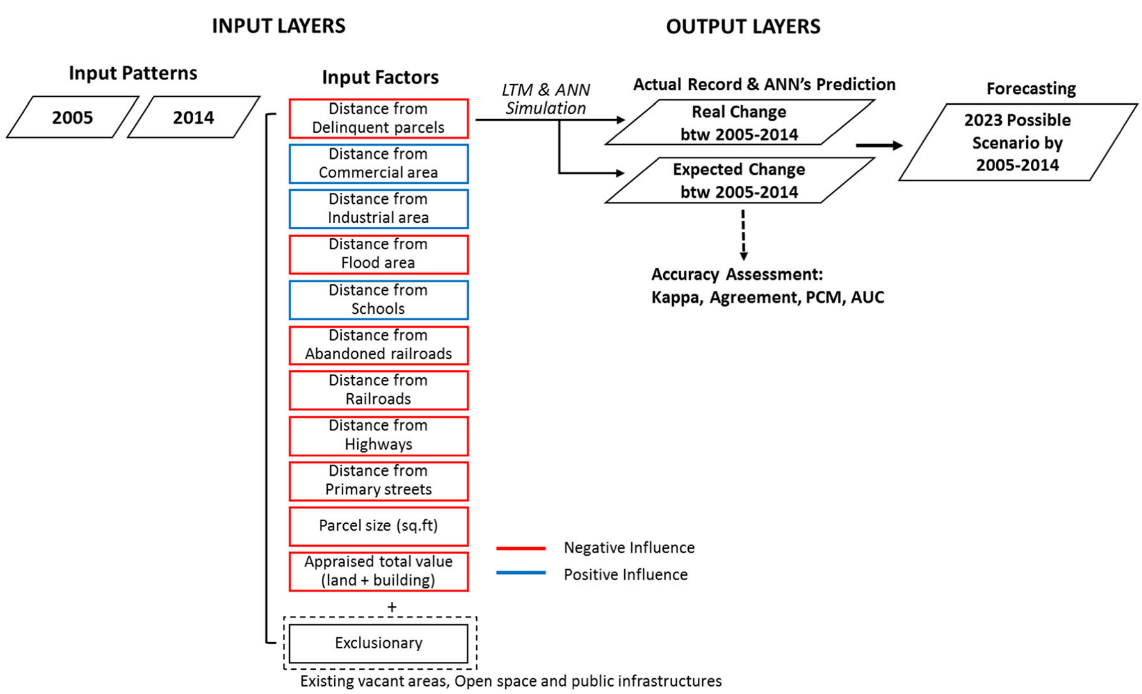


**Fig. 4** LTM process diagram

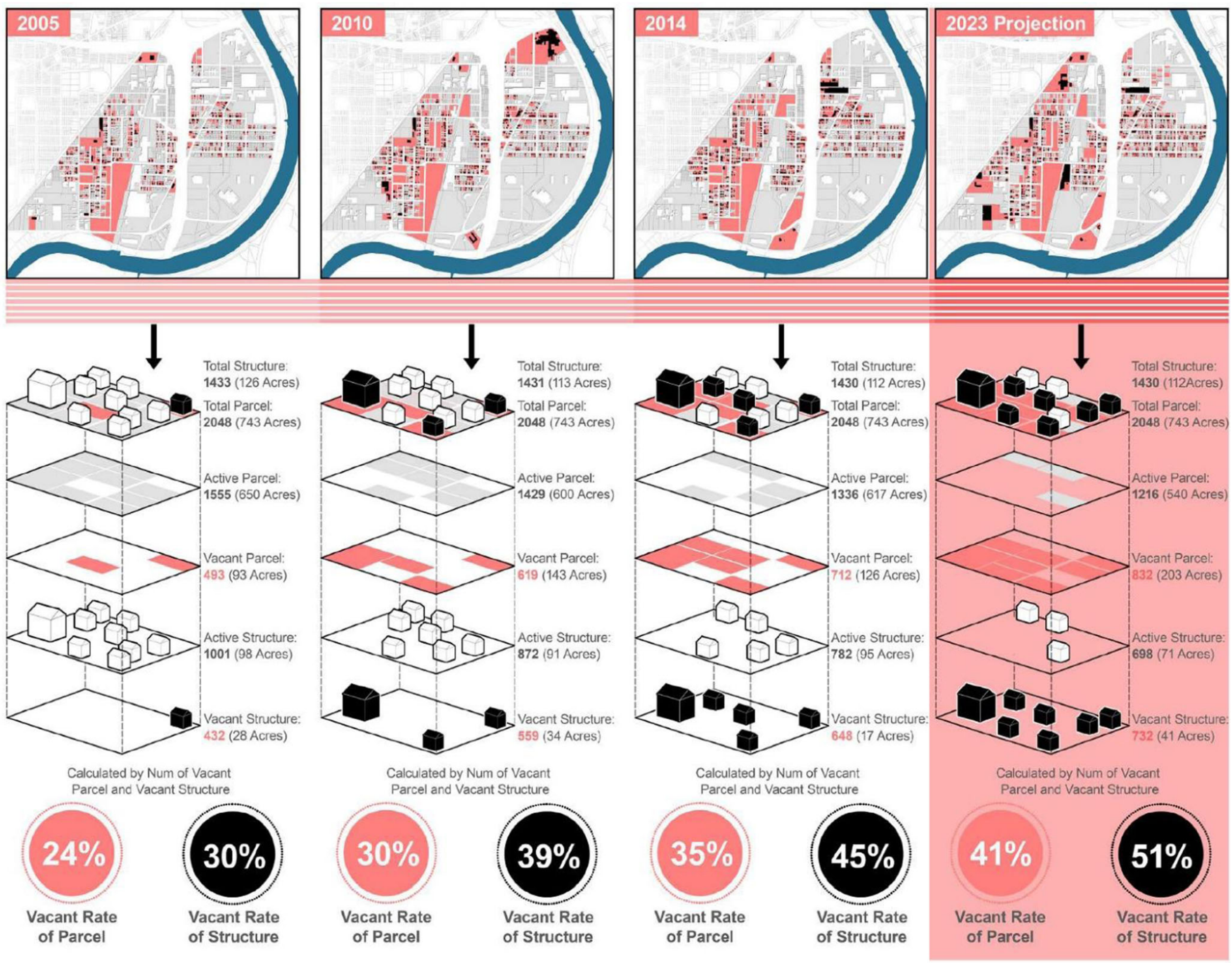


**Fig. 5** Predictions of future vacancies in Carillon using the land transformation model

possible reuses for vacant and abandoned properties or establish lower density zoning districts to better match a lower population density (Hollander 2011). Comprehensive plans can establish districts of high, moderate, and low density that match current and projected densities rather than historic densities.

Step 4. Razing the Remnants: All remaining vacant and abandoned land must be cleared, retrofitted, or implemented with temporary or green infrastructure functionality based on the results from the repurposing phase. Areas where development should occur are clear of all unnecessary abandoned structures, and temporary or permanent functions are suggested for future predicted vacant or abandoned properties. Districts that had previously been high density and are being transitioned to medium or low density will require accompanying revisions to amend the streetscape, greenspace, and architectural character to better match the lower densities. A form-based code that visually communicates a lower density can be used to retrofit a district from urban (heavy street furniture, manicured vegetation, multistory structures) to rural (narrow streets, naturalist vegetation, single-story structures). Currently, 301 parcels are being managed by the city's land bank and will be resold or rented in accordance with the goals of the Carillon master plan.

### Task B. Managing Declining Parcels

Step 1. Developing Typologies and Allocating Functions: For parcels that are currently vacant or predicted to become vacant and do not show high development potential, Smart Shrinkage principles should be applied. Within the Carillon neighborhood, there are 195 parcels that meet these conditions, as well as 81 abandoned structures (see Fig. 7). A majority of these parcels were zoned for commercial uses

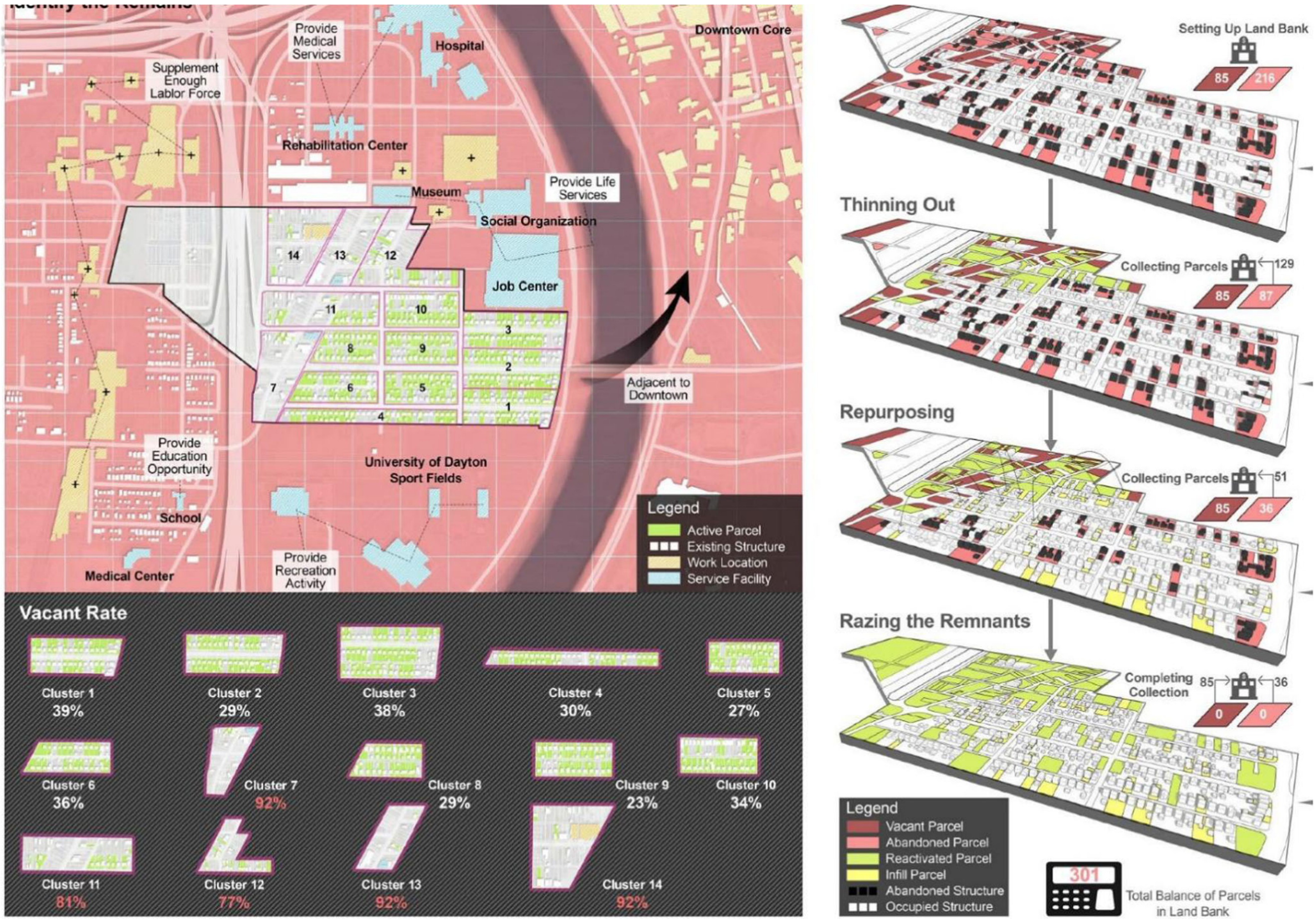


**Fig. 6** A framework for identifying, assessing, and regenerating vacant/abandoned parcels

(64%), with industrial (18%), residential (11%), and open space (≤5%) land uses being less prevalent. The average land value was approximately $64,000 per parcel and their spatial distribution ranged from large to small in size and from clustered to dispersed. Due to these variations, developing proper functions for the declining parcels requires more of a retrofit. For this reason, void typologies are developed based on each vacant parcel's spatial characteristics to determine potential functionality of future use. The typologies are listed and defined below (see Fig. 8 and Table 3):

- Mass Voids: Large clusters of multiple declining parcels
- Strip Voids: Linear collections of small amounts of declining parcels spanning through multiple blocks along different streets
- Interval Voids: Individual declining parcels separated by active parcels in a regular pattern
- Contiguous Voids: Linear collections of small amounts of declining parcels spanning through singular blocks along the same street
- Corner Voids: A declining parcel or parcels located at the intersection of two or more streets
- Flagged Voids: Declining parcels from multiple parcels that are connected and span across multiple portions of a blog in a "flag"-type shape
- Scattered Voids: Individual declining parcels separated by active parcels in a random pattern

Step 2. Allocating Functionality: The Carillon neighborhood is dominated by several larger swaths of vacant parcels; these mass voids take up nearly two thirds of the neighborhood. This is ideal for regeneration because small, odd-shaped, and disconnected vacant lands can be more difficult to develop (Newman et al. 2016b). However, this means that one third of the predicted vacant parcels are undersized and scattered, making them prime candidates for more temporary functions. Figure 9 displays a series of temporary and permanent programmatic functions for repurposing each vacant land typology.

As noted, LTM outputs predict that vacancies in Carillon will increase 5% by 2023. According to the model, 63% of existing vacant lands in Carillon

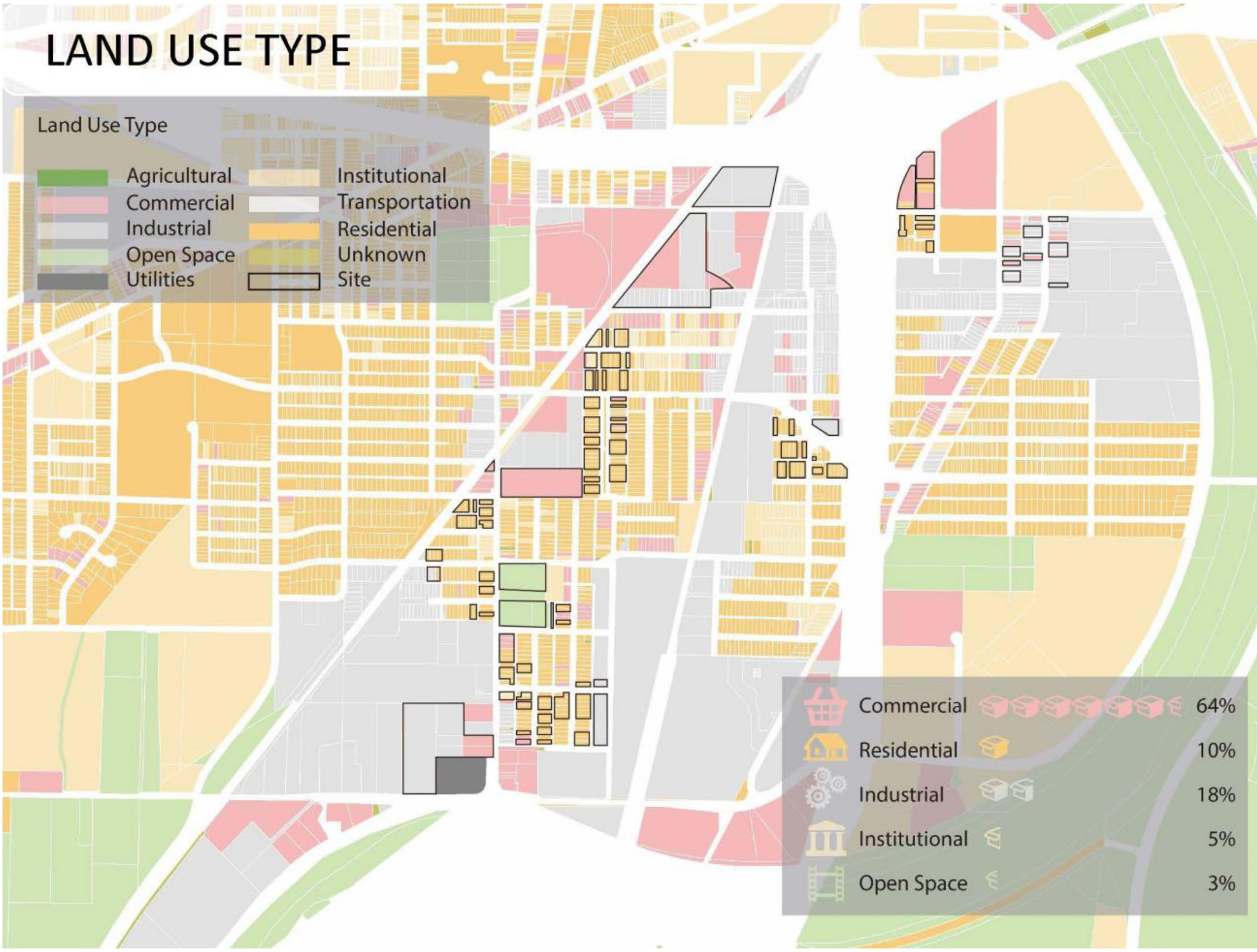


**Fig. 7** Subset of existing and predicted to decline parcels by land use type

should be regenerated through development, 16% should simply be prevented from further deterioration, and 21% should be allowed to decline. In areas allowed to decline, temporary and green infrastructure functions should be programmed (see Fig. 10). The current land bank system employed by the city also allows for residents to obtain vacant lots cheaply to extend yard space, thereby enlarging parcel sizes and allowing self-management of some vacant lots.

## Conclusions and Discussion

Despite overall global trends toward urbanization, many cities face severe depopulation and increases in vacant urban land. This project developed a framework for Smarter Shrinkage, integrating land use prediction modeling into the rightsizing process using the Carillion neighborhood in Dayton, Ohio, USA, as a case study site. We applied Smart Shrinkage principles to existing vacant parcels and those predicted to become vacant by 2023, while maximizing development and economic opportunities in areas with high development potential. This approach emphasizes new development in dense nodes and temporary or green functions outside of these nodes as areas for managed decline that allow the city to rightsize.

As noted, the utility of Smart Shrinkage (or Smart Decline) as a management strategy for vacant land has been criticized. Some may interpret Smart Shrinkage as giving up on certain cities and allowing them to decay. However, the intentions of Smart Shrinkage are quite different. Rather than allowing depopulating urban areas to simply fade away, Smart Shrinkage suggests ways to manage vacant land and unoccupied properties through a series of policies and temporary functions that allow them to remain dormant until a new economic opportunity can spur developmental-based regeneration. Patient planning will be required in these areas while waiting for the pendulum of economic growth to swing back toward the positive side in these once prosperous cities. In other words, Smart Shrinkage provides a framework for the active protection, maintenance, and reuse of vacant land and buildings until future demand increases.

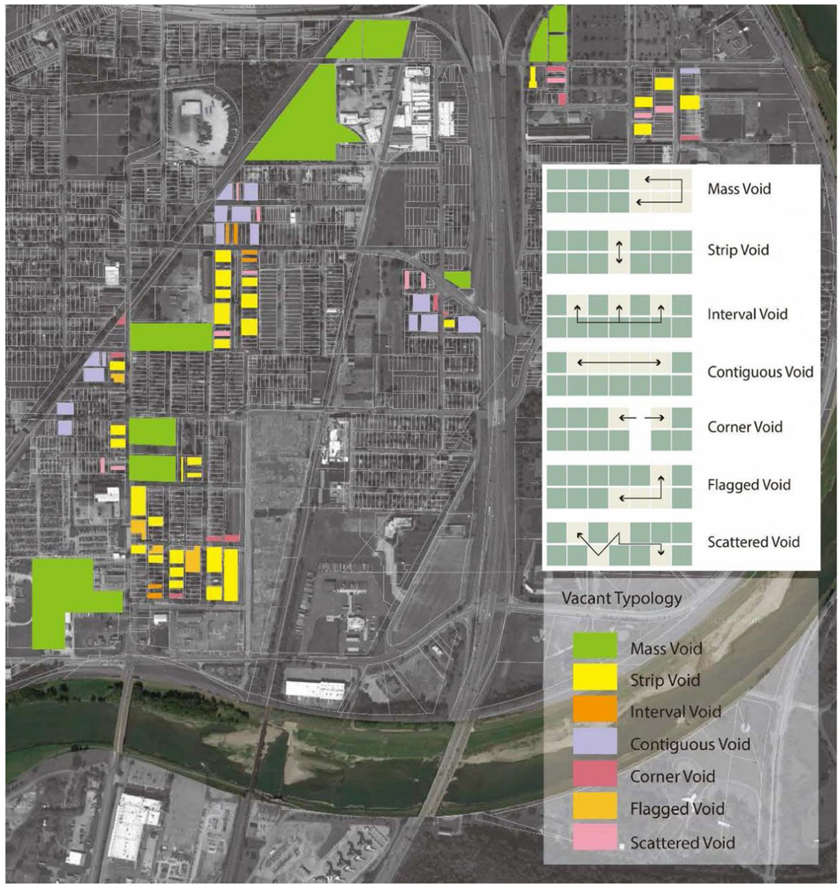


**Fig. 8** Declining parcel typologies

Hackworth's (2016) concern that shrinking cities purporting to be rightsizing are just making superficial changes (i.e., continuing to rely on conventional urban renewal-style planning strategies) can be addressed through a Smart Shrinkage approach. Through a rigorous, systematic, and transparent forecasting exercise, combined with aggressive implementation funding, shrinking cities can respond more effectively to the physical challenges brought by depopulation. Further, assumptions made as part of this research can be improved through consultation with community members and other stakeholders. The design strategies and typologies employed here are illustrative only and can be easily adapted and revised through a community-based process.

This work has important policy implications for shrinking cities. While form-based zoning codes are an increasingly popular approach, this research demonstrates the potential effectiveness of a focus on physical characteristics rather than use. Much of the future vision we present here for Carillon would not be possible even under the most unrestrictive form-based code. A relaxed zoning code that allows a significantly broader range of uses to neighborhoods experiencing high levels of vacancy would potentially allow it. Similarly, few large cities have explicit zoning provisions for urban

**Table 3** Spatial characteristics of declining parcel typologies

| Typology | Declining area (%) | Vacant land (%) | Abandoned structures (%) | Commercial/ industrial (%) | Open space (%) | Unused parking (%) | Unkempt landscape (%) | Residential (%) | Other (%) |
|---|---|---|---|---|---|---|---|---|---|
| Mass | 62.4 | 18.8 | 81.2 | 70.4 | 2.6 | 8.2 | 12.4 | 0 | 6.4 |
| Strip | 18.5 | 100 | 0 | 0 | 2.2 | 0 | 97.4 | 0 | 0.4 |
| Interval | 2.7 | 100 | 0 | 0 | 0 | 0 | 100 | 0 | 0 |
| Contiguous | 10.2 | 100 | 0 | 3.1 | 0 | 0 | 90 | 6.9 | 0 |
| Corner | 1.6 | 100 | 0 | 24.7 | 11.7 | 0 | 49.8 | 0 | 13.8 |
| Flagged | 2.7 | 100 | 0 | 0 | 45.6 | 0 | 54.4 | 0 | 0 |
| Scattered | 2.1 | 100 | 0 | 0 | 0 | 0 | 82.9 | 17.1 | 0 |

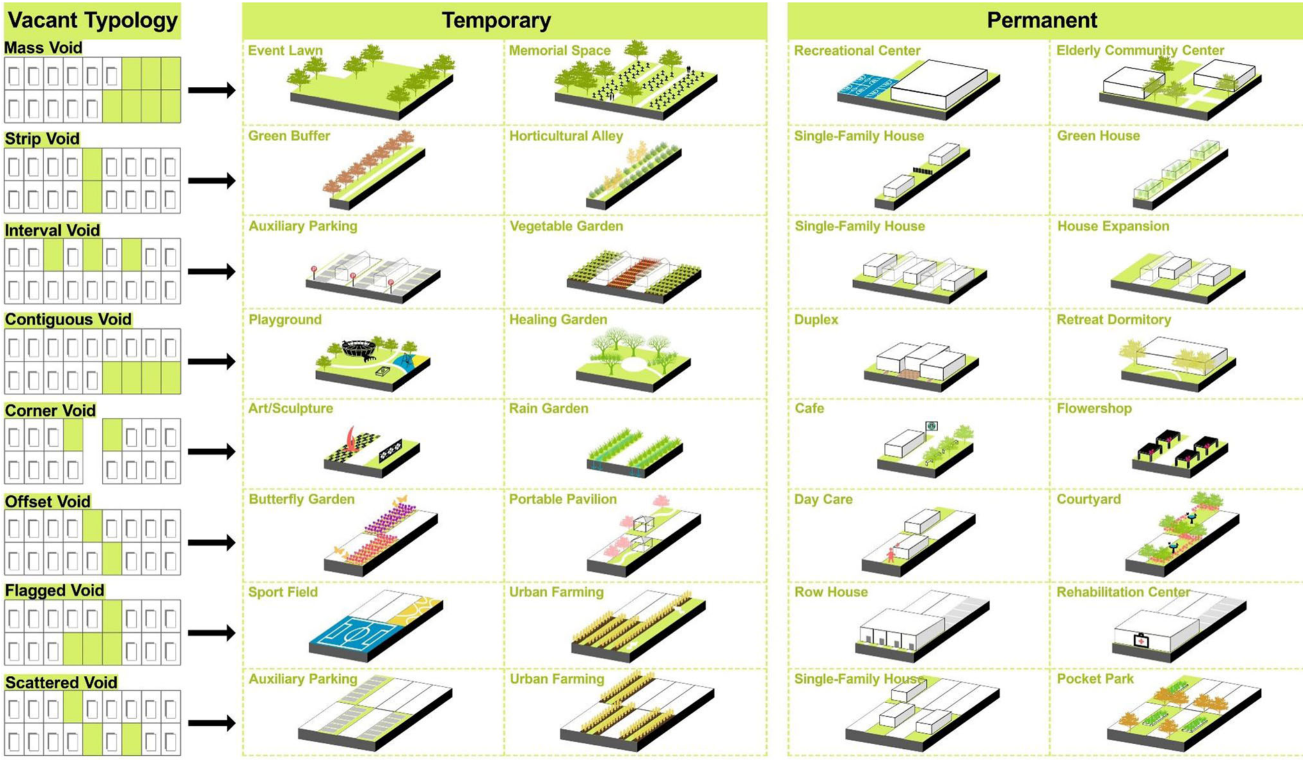


**Fig. 9** Possible functions for vacant land typologies

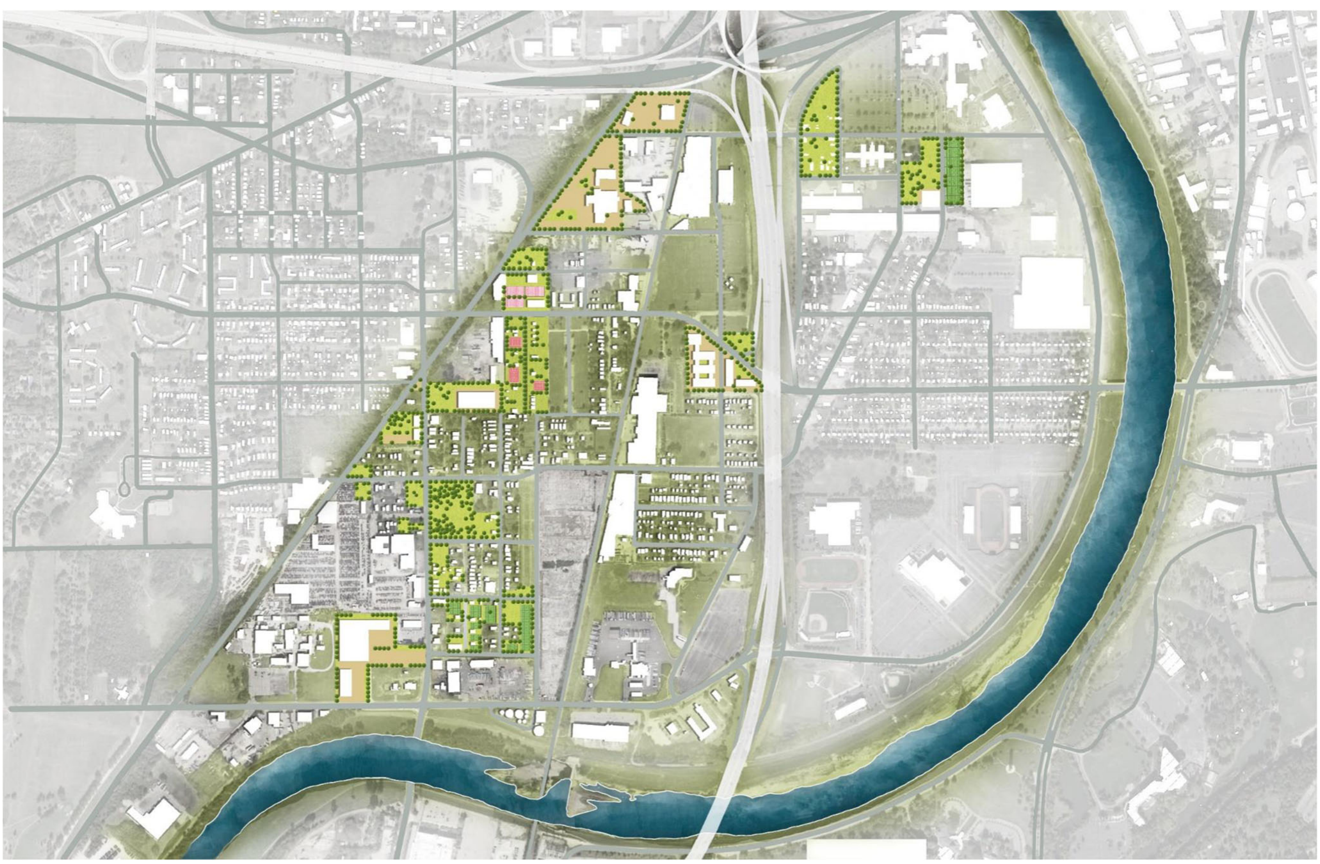

**Fig. 10** Retrofitting repurposes for vacant parcels predicted to decline

agriculture or forestry. However, forecasts from a LTM demand policy mechanisms could be used to allow land to be transformed for nonresidential uses that are consistent with where demand exists. Campbell (2016) wrote about the introduction of profitable poplar tree farms in vacated areas of Youngstown, Ohio, in the decade following the implementation of the city's Smart Shrinkage plan in 2005. Urban forestry, agriculture, and other nonresidential uses need to be formally considered in city zoning regulations and integrated into implementation budgets so that cities prioritize funding to implement a range of Smart Shrinkage futures.

Although the statistical results of the model demonstrate that the LTM may be a good resource to forecast future vacancy, there are limitations to using this modeling process. First, this research examined only one city, limiting statistical power and raising concerns about the generalizability of conclusions to other municipalities. Second, data availability in each time frame determines the feasibility to run the model. Third, since LTM modeling is a complicated GIS and ANN-based tool, it requires long training times for reliable outputs and might be difficult for planners and other practitioners to apply in real decision-making processes (New York State Office of the Governor 2010). Finally, like other land use change models, the LTM has difficulty adopting incorporeal ecological and social interactions such as competitions and cooperation between interest groups.

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## Compliance with Ethical Standards

All accepted principles of ethical and professional conduct have been followed during this research in accordance with Springer's standards.

**Conflict of Interest** The authors declare that they have no conflict of interest.

**Ethical Approval** All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

**Informed Consent** Informed consent was obtained from all individual participants included in the study.

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