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Balsas, C. (2021). GIS Buildout Analysis and Urban Planning. *Chinese Journal of Urban and Environmental Studies*, *9*(1), 1-21. Article 2150006. Advance online publication. https://doi.org/10.1142/S2345748121500068

Published in:
Chinese Journal of Urban and Environmental Studies

Publication Status:
Published online: 13/03/2021

DOI:
10.1142/S2345748121500068

Document Version
Publisher's PDF, also known as Version of record

OPEN ACCESS
Chinese Journal of Urban and Environmental Studies
Vol. 9, No. 1 (2021) 2150006 (21 pages)

DOI: 10.1142/S2345748121500068

World Scientific
www.worldscientific.com

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Received October 28, 2020; Accepted December 15, 2020; Published March 13, 2021

A buildout analysis is an important methodology in land-use planning. The GIS technicalities of doing a buildout analysis tend to be the purview of professionals with a background in geographical sciences. However, it is argued that planners ought to be able to conduct buildout analysis in order to develop a better understanding of how land-use patterns could change sustainably over time depending on a community's regulatory environment and pace of development. A state buildout analysis is compared and contrasted with buildouts conducted for two local jurisdictions on the opposite ends of Massachusetts: the towns of Amherst and Georgetown. The town of Amherst's computations identified lower values of developable and new commercial/industrial land and 1,878 more new dwelling units than the state-led planning initiative three years earlier. In the case of Georgetown, the UMass Amherst planning consultancy identified lower values of developable land and fewer new dwelling units and 3.5 million square feet more of new commercial/industrial land than the state-led analysis. A series of implications for teaching buildout analysis in Urban and Regional Planning studio courses is presented.

Keywords: Urbanization; land change modeling; planning pedagogy; Massachusetts.

Balsas, Carlos J. L. 2021. "GIS Buildout Analysis and Urban Planning." *Chinese Journal of Urban and Environmental Studies*, 9(1): 2150006-1 to 2150006-21.

1. Introduction

Geographic Information System (GIS) is critical to understand the world around us (Greene and Pick, 2012). As developmental problems become ever more complex, technological innovations are needed to facilitate our comprehension of the transformations on the surface of the earth. Moreover, knowledge of various geographical methodologies is likely to enable more holistic and responsible multiscalar data collection, analysis, deployment, and decision-making in research and public policy processes. Open-source technologies usually at the city and county levels now enable users to produce their own maps. However, GIS technologies have also become more sophisticated in recent years and their accurate utilization with statistically relevant findings requires advanced skills and expertise as well as sensible interpretation (Barcus and Muehlenhaus, 2010).

Planning education enables the acquisition of knowledge and the development of professional competencies and skills (Balsas, 2019). Care *et al.* (2017) has recently called our attention to the need for assessment and teaching skills to meet the needs of the 21st century workforce. Globalization is impacting communities in a variety of ways and therefore future planners ought to have a diverse set of skills to help communities withstand the processes of change (Kunzmann, 2007). Chapin (2003) demonstrated that GIS has been a rare element of the core curricula in North American accredited Urban and Regional Planning programs. In fact, at the undergraduate and graduate levels, the teaching of land-use buildout analysis has received scant attention, even though GIS and map-making have been addressed in Geography programs, and more recently also in cognate disciplines such as Public Administration (Ferrandino, 2014) and Landscape Architecture (Wu, 2008). This paper aims to fill this knowledge gap in the planning curriculum by specifically building upon prior studies (e.g. Chapin, 2003; Kamruzzaman, 2014), and demonstrating the potential for utilizing a buildout analysis as a critical land-use and environmental planning methodology.

A buildout analysis is an important methodology in land-use planning. Simply defined, a buildout analysis is an estimate of the maximum development that could occur in a community based on the current zoning and environmental constraints. The GIS technicalities of doing a land-use buildout analysis tend to be the purview of professionals with a background in geographical sciences (Müller and Munroe, 2014). However, it is argued that planners ought to be able to conduct buildout analysis in order to develop a better understanding of how land-use patterns could change sustainably over time depending on a community's regulatory environment and pace of development. Furthermore, a buildout analysis enables communities to understand the impact of current regulations on various planning elements, such as land resources, open space, built form, affordable housing, and public services.

In this paper, a state buildout analysis is compared and contrasted with buildouts conducted for two local jurisdictions on the opposite ends of Massachusetts: the towns of Amherst and Georgetown. It is demonstrated that sensible land-use assumptions are critical to reaching plausible and accurate results. The slightly different results between the state-led and the local communities' buildouts allow us to infer that technical analyses need to be complemented with consultation of the community to fully understand their potentialities and shortcomings, which are not easily comprehended from simply examining maps remotely. Furthermore, it is contended that a buildout analysis ought to be taught in planning programs with the clear understanding that only anticipatory, proactive, and integrated planning will lead to the changes needed to create more sustainable communities. Finally, a series of implications for teaching buildout analysis in Urban and Regional Planning studio courses is put forward.

This paper is organized into six parts. Following this introduction, Sec. 2 is the analytical mechanism subdivided into three subsections: land-use planning (Sec. 2.1), technological innovations (Sec. 2.2), and buildout analysis (Sec. 2.3). Section 3 analyzes the planning pedagogy and teaching methods. Section 4 introduces buildout analysis in Massachusetts by focusing on the cases of Amherst and Georgetown. Section 5 discusses lessons learnt and the implications for planning pedagogy. Finally, Sec. 6 makes some concluding remarks and identifies some future challenges.

2. Analytical Mechanism

2.1. *Land-use planning*

Land-use planning is critical to each community's social and territorial cohesiveness. Local planning is traditionally executed by municipalities. Although home rule states have a higher degree of local autonomy to plan their jurisdictions, exceptions exist in states that have adopted growth management strategies. Typically, land-use planning results in a land-use plan and associated policies. The land-use plan is traditionally an element in a municipality's comprehensive plan (Berke and Conroy, 2000), although many metropolitan areas also tend to have regional land-use strategies. A land-use map indicates the various land-use categories and the location of key future projects in a municipality. However, the planning of land transformations requires the use of specific control tools of which zoning, subdivision regulations, transfer of development rights, cluster zoning, and form-based code are some of the most common ones.

There are instances where regional planning is in order and this is the case with metropolitan areas and watersheds (Conway and Lathrop, 2005). Regional land-use attempts require high coordination, which usually is enabled by the Councils of Government (COGs) and Metropolitan Planning Organizations (MPOs). However, at the regional level, land-use planning is usually only one more category of regional studies, mostly because direct vote elected officers in regional agencies are usually non-existent. There is an important relationship between land use and environmental planning though. Land use ought to conserve the sensitive natural resources of a jurisdiction, such as rivers, lakes and ponds, wetlands, hillsides, and agricultural land from development (Freeman and Bell, 2011). Urbanization has the potential to generate conflicts between pro-development and conservation factions. Autonomy and leaving local decisions to communities contribute to higher levels of sales tax thus generating development, usually in suburban locations. The sprawl in the northeast is relatively different from the sprawling suburbs of the sunbelt of the United States.

Weitz (1999) reviewed state growth management programs in the late 1990s and concluded that smart growth programs had evolved considerably under the guise of sustainable development [see also Landis and Pendall (2009) and Park *et al.* (2012)]. Smart growth legislation has been enacted in various states such as Oregon, Maryland and Massachusetts (Pfister *et al.*, 2007). Most smart growth strategies comprise a combination of 10 principles aimed at creating more sustainable communities. Usually, there is some level of integration between smart growth programs and regional and local land-use goals and principles. Although in theory these principles are sound, in practice they have proven difficult to implement (Downs, 2005).

One critical approach to more sustainable land-use planning takes into consideration scarce land resources such as agricultural land, wetland, marshes, and landscapes with important ecological and cultural values. Within this ecological tradition, Landscape Ecology has emerged as a semi-autonomous disciplinary field connected to Environmental Planning and

Landscape Architecture (Wu, 2008). Land-use planning centered on Landscape Ecology has a long tradition in Massachusetts with the work of Professor Emeritus Julius Fábos in the development and application of Metland — Metropolitan Landscape Planning Model, and the Center for Rural Massachusetts. Metland's approach contemplated the development of enhanced versions of McHarg's overlay and land suitability methods throughout Massachusetts and elsewhere. According to Ndubisi (2002, p. 92), the Metland model "described the landscape as parameters and use[d] quantitative techniques and computer technology to facilitate ecologically informed and intelligent land-use". This early work led to the identification and proposal of greenway planning as a key land-use planning strategy in the 1990s and 2000s.

Determining the suitability of land for various uses is also a fundamental aspect of land-use planning. Land-use planning includes the following methods: land resource inventories, land suitability analysis, community development, open space, scenarios and buildout analysis (Couclelis, 2005; Calthorpe, 2010). Landscape metrics are fundamental to conscientious land-use planning. Some of the new challenges and opportunities in land-use planning include: sustainability, landscape ecology and modeling, climate change and visualization technologies, and civic participation (Bibby and Shepherd, 2000; Godschalk, 2004; Hamin *et al.*, 2014; Stevens and Senbel, 2017). Since Warren *et al.* (2011, p. 82) has recognized that previous land-use studies have only rarely "quantified the connections between land use policies, actions and land use change", it is important to understand the potential of buildout analysis to integrated land-use planning. Other land-use studies such as Hersperger *et al.* (2018) looked only at the role of strategic spatial planning in urban land-use change. This study is valuable because it sheds light on the potential brought forward by conducting the methodology of a buildout analysis. However, before reviewing the literature on buildout analysis, it is important to clarify how technology innovations have evolved to the actual GIS and buildout analyses.

2.2. *Technological innovations*

Technology consists of a set of procedures to accomplish one's multiple job tasks well. The traditional tracing paper and pens used to make maps have long given place to sophisticated GIS, remote sensing, and many other geospatial and geodesign software tools (Norwood and Cumming, 2012). The knowledge economy, global network technologies, and the digital revolution have all changed society and the planning profession quite profoundly. The information super-highway and ICT technologies have also democratized access to information. Geographic Information System, Global Positioning Satellite (GPS), and remote sensing were the tools traditionally utilized by geographers in the same way that Computer-Aided Design (CAD) was mostly used by architects and designers. However, geospatial tools have been increasingly made available under license or in open-source mode to professional planners as well (Norwood and Cumming, 2012), and also even to the public at large. However, more advanced and specialized procedures require in-depth knowledge of software, statistical, and modeling tools.

GIS is a planning tool aimed at obtaining, analyzing, retrieving, and exporting data and usable information. Pfister *et al.* (2007) identified four main areas for GIS: hardware, software, data, and people. Information technology has enabled online and real-time access to databases, and computing power has enabled new technologies to be available remotely. In the case of land-use planning, planners, geographers, and in certain cases also landscape architects have taken the lead in conducting studies, doing analyses and proposing strategies aimed at identifying suitable locations for development, new roadways, equipment, open space, parks, etc. Land-use planners surely help with the decision-making processes. Drummond and French (2008) have argued that GIS has changed with the advent of Web-based systems. Although planning tools may be more accessible now due to the advantages created by open-source geospatial software, planners have to improve their technological skills to respond to the ever more challenging territorial transformations shaping their jurisdictions.

Computer support systems (Batty, 2003) have evolved into planning support systems. What If, GeoDa, and CommunityViz are examples of geodesign software applications used in land-use planning. Public-participation GIS (PPGIS) enables wider public participation processes and a wider role for concerned citizens in environmental planning processes. Gaunt and Jackson (2003) reviewed models for assessing the effects of community change on land-use patterns. Clarke's (2011) cellular automata (CA) SLEUTH model, Waddell's (2002) UrbanSim, and Guhathakurta's (2003) various applications of integrated land-use and environmental models are some of the better-known land-use examples. Stevens *et al.* (2007) has also created a GIS–CA modeling tool for urban planning and decision-making, which has recently been improved by Koziatek and Dragićević (2017) in the form of iCity 3D: a geosimulation method and a tool for three-dimensional modeling of vertical urban development. Various cellular automata models provide opportunities for simulating complex territorial problems while accounting for an increasingly high number of spatial, environmental, socio-economic and climatic situations (Verburg, 2006; Bruns, 2008).

The interconnectedness of seamless interoperable technological systems is referred to as Smart Cities. Smart Cities map and partially recreate the physical world into a virtual environment as a referencing framework for decision-making (Townsend, 2014). E-government, e-commerce, and the use of new technologies to help conserve energy, and Wi-Fi in public spaces are examples of Smart City applications (Evans-Cowley and Conroy, 2006). Visualization techniques have also gained prominence due to technological advances and affordability. The sketching and visioning of ideal community conditions have been put forward with before and after illustrations aimed at gaining community support for site design, neighborhood planning, and streetscape improvements. Smart Cities also reflect a new mentality in planning theory and practice, which to a certain extent, encapsulates a significant change from digital to intelligent development.

Technological advancements are also being appropriated by planning's cognate profession of urban design (Arefi and Al-Dourib, 2016). Ferrandino (2014) has written about how GIS as an interdisciplinary pedagogical tool has also been incorporated in the Master of Public Administration (MPA) programs. Safety and homeland security agencies are also utilizing new technologies to improve safety conditions in cities. Finally, *big data* collected and utilized to identify trends is one of the latest tendencies in technological developments.

2.3. *Buildout analysis*

From the preceding paragraphs, it is easy to realize that land is a valuable resource and therefore it requires an ethical and conscientious use. Public policy ought to recognize this premise and consider it adequately. A buildout analysis is a useful method to calculate an estimate of how much land is available for development according to current zoning regulations. The analysis includes mapping the location of all developable land in a jurisdiction using GIS and calculating the number of housing units, commercial and industrial acreage, and the demographic changes that could result if all buildable land was developed. The results can potentially propel regulatory changes in order to accomplish desirable urban form and to find tax revenues to sustainably finance infrastructure development, and the necessary tax increases to pay for public services, such as schools, water and sewer systems, waste disposal, police, fire protection, parks, and roads.

According to the Massachusetts Community Preservation Initiative (CPI) (Executive Office of Environmental Affairs, 2002), a buildout analysis usually allows the following questions to be answered.

- What growth patterns does current zoning dictate?
- What long-term impacts does that growth create such as traffic, water quality and quantity, and education?
- What is the maximum potential growth possible under existing zoning?
- What are the likely impacts on municipal services from that growth?
- Is there an alternative, more favorable future and what would that look like?
- What can be done now to enhance the pattern of new development?

According to Amengual (2001), there are various ways to conduct a buildout analysis. The methodology to be employed is usually chosen based on the time and data available to conduct the analysis. The three most important types of buildout analysis are: (1) the parcel buildout, (2) the land-use buildout, and (3) the site design-level buildout. The parcel buildout analysis enables the estimation of the number of units that can fit on each parcel individually. The land-use buildout is conducted when parcel data are not easily available. It displays the distribution of different types of densities in large zoning districts. Finally, the third type, the site design-level buildout analysis, tends to be very accurate, and also quite time-consuming. The aim is to draw potential site designs for every vacant parcel in a community, and then to add up the total number of units for each particular site.

The buildout methodology was initially devised by McHarg (1969, 1995) in his seminal book *Design with Nature*. The advent of automation and the growing existence of data to aid planning processes as well as the extensive use of microcomputers in professional practice and educational settings have all enabled the refinement of land-use planning inventories, mapping, and forecasting capabilities. A land-use buildout procedure includes these steps: a determination of the amount of land in each zoning district, a determination of the amount of land within the zoning district that cannot be built on (e.g. conservation easements and parks), the computation of the amount of buildable land, the subtraction of land for roads and infrastructure, and finally, the buildable land minus the percentage taken out for roads is then divided by the minimum lot size in order to estimate the number of units.

State-wide buildout analyses were conducted in the state of Massachusetts in the early 2000s as part of the Community Preservation Act (CPA). Lang and LeFurgy (2007) analyzed boomburbs' (i.e. large, fast-growing suburbs) future development intentions as they approached "buildout" conditions and became land-locked — a typical situation where development has exhausted all developable land in a jurisdiction. More specialized buildout analysis at the site level serves to assess the impact of specific developments and to compute their fiscal implications (Pfister *et al.*, 2007). This paper is mostly concerned with land-use jurisdiction-wide buildouts. The next section explains how a buildout analysis can be used effectively as a pedagogical methodology in planning studio courses.

3. Urban Planning Education

Planning studios are critical courses in urban and regional planning. They constitute invaluable opportunities to conduct work in the community. Planning studios are integrative courses where students have to apply the skills acquired in other courses to novel real-world situations. Usually, most graduate programs have two studio courses: an introductory studio followed by a more advanced one; the difference being the level of complexity of the problems dealt with and the robustness of the solutions demanded to resolve those same problems. Studios have also evolved to take advantage of technological developments (e.g. virtual collaborations among students in various parts of the world, utilization of technology in conducting data inventories and field reconnaissance with handheld devices, immersive technology and digital terrain models, etc.).

Studio courses emerged out of service learning and applied learning models. They represent scaled versions of the extension and land grant university collaborative approach with communities. Service learning is the main goal of these courses: to create opportunities usually outside of the classroom to practice planning skills. This model benefits various constituencies: the students, the faculty, and the community (Angotti *et al.*, 2012). From a planning pedagogy perspective, the studio approach depends on the instructor's teaching philosophy and the complexity of the problems being addressed. It can vary from a whole cohort of students working on multiple topics in the same geographical area or multiple projects in various geographical locations simultaneously. The former may have a stronger identity since all students are likely to coalesce on a particular community. The latter offers relatively more flexibility and independence to each group of students. Nonetheless, the teaching methods and the research skills needed are relatively similar in the two cases. Data are collected, analyzed, triangulated, synthesized, and findings are presented to interested parties. Initial visits to the area or study site are also needed, which involve reconnaissance and windshield surveys and walk-through analysis. Return visits for in-depth analysis, data collection, inventories, and administering thematic surveys are usually also conducted.

Typical studio courses range from territorial analysis, urban form, neighborhood revitalization, to economic development strategies and infrastructural analysis (Long, 2012).

Design and geographical analyses are one of the many other types of methods utilized in studios. Social sciences methods tend to dominate studio courses. Studio courses traditionally employ quantitative (Clifton *et al.*, 2008) and qualitative (Dandekar, 2005) methods. The quantitative methods involve the collection of statistics and the identification of trends through the use of indicators. The goal is to understand change over time and to anticipate future evolutions. The qualitative methods involve interviews, focus groups, and charrettes. Mixed methods that combine both quantitative and qualitative methods are also needed to analyze specific problems and to strengthen the reliability of suggestions.

Ellis (2005, p. 138) has cautioned that planners need to consider the methods of "three-dimensional physical planning"; and the same author also identified five types of methods (i.e. site analysis, public participation, design methods, urban and architectural codes and evaluation). New technologies have enabled specific applications to help visualize urban form, which have also included "the integration of GIS, SD model and 3D visualization, called GISSD system, [to] better explain the interaction and the variation of the sustainability indicators for residential development" (Xu and Coors, 2012, p. 272).

Some planning studios produce studies and others produce plans. The processes used to conduct these plans are, nonetheless, relatively similar; albeit with perhaps lower participation levels than the plan-making processes in municipalities. Clifton *et al.* (2008) have argued for some level of standardization in operational definitions given the diversity of approaches and evaluation practices utilized in planning studies, while Kamruzzaman (2014) has suggested the deployment of hybrid instructional methods.

4. Buildout Planning in Massachusetts

The state of Massachusetts has a long tradition of doing state-wide land inventories and analysis and there is a logical reason for those planning efforts (Hamin *et al.*, 2006). According to Geigis *et al.* (2007, p. 231),

> "Massachusetts is home to a population of 6 million people who share 5 million acres [20234.2 square kilometer], with approximately two-thirds of that population inhabiting the eastern third of the state (. . .), [however] between 1950 and 1990, Massachusetts experienced a population increase of only 28 percent, yet land development increase by more than 188 percent."

This unbalanced growth is responsible for rural sprawl and large lots in former prime farmland in communities like Amherst, South Hadley and Northampton in Hampshire County in the Pioneer Valley's western part of the state, and the amalgamation of suburban communities around the Greater Boston metropolitan area in places like Georgetown, Lawrence and Ipswich on the Plum Island Ecosystem of Northeastern Massachusetts, about 56.3 km north of Boston (Pontius and Neeti, 2010). Therefore, attempts to reverse these land-use development patterns have been sought at multiple governmental levels.

The most recent land-use planning attempt was done under the Governors Paul Celluci and Jane Swift and became known as the Community Preservation Act. This initiative was launched in 1999. Its goal was "to enable towns and cities to tax themselves and receive state matching funds to achieve a limited set of objectives often connected with smart growth" (Hamin *et al.*, 2006, p. 53). This initiative was followed by Executive Order 418 aimed at providing state assistance for community development plans. The buildout analysis was one of the analytical center pieces of the CPA. The Massachusetts CPI aimed to create a set of buildout maps and analyses for all 351 cities and towns in the Commonwealth.

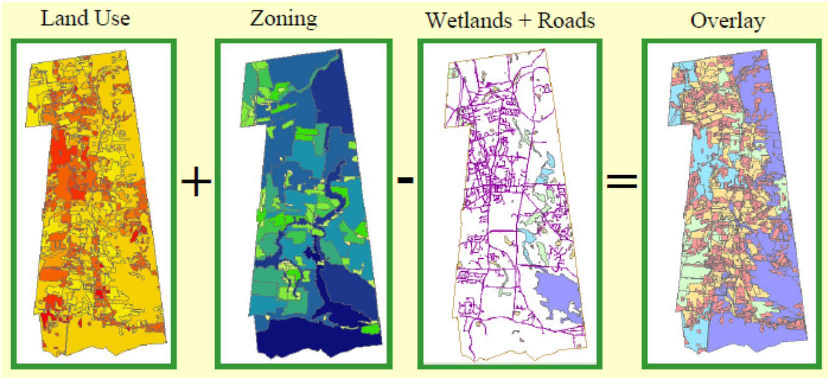
The maps produced under the aegis of this initiative depicted developed and protected land within each local jurisdiction and what each community's volumetry would be if its remaining undeveloped land was completely developed in accordance with the legally approved local zoning regulations. In other words, the buildout maps produced by this initiative showed the default growth scenario by graphically depicting what a community would look like if all remaining developable land was developed to its maximum potential. CPI also included a number of public forums throughout the state. Therefore, the buildout analysis provided a sound basis for the land-use and developmental decisions about growth, preservation and revitalization scenarios, and their potential impacts on each community. The CPA allowed communities to create a local Community Preservation Fund for open space protection, historic preservation, affordable housing and outdoor recreation. According to the Community Preservation Coalition's (2018) website,

> "[c]ommunity preservation monies are raised locally through the imposition of a surcharge of not more than 3% of the tax levy against real property, and municipalities must adopt CPA by ballot referendum. To date, 172 municipalities in the state have adopted CPA."

4.1. *Case I: Amherst*

Amherst is a medium-size (71.7 km^2) college town of 37,819 people in 2010 located in Hampshire County, Western Massachusetts, just north of Springfield and Westfield, the largest cities in population and area in Western Massachusetts, respectively. Amherst is home to the flagship campus of the University of Massachusetts system and Amherst College. The Connecticut River, which runs through the Pioneer Valley, has always shaped the region in very indelible ways. On the one hand, the fertile soils on its banks have enabled agriculture to flourish for generations. On the other, the kinetic force of its waters and the river falls have propelled the industrial revolution in cities like Holyoke and Chicopee.

Amherst has had two buildout analyses conducted in the last two decades. The first buildout analysis was conducted in the context of the statewide CPI and the second was conducted in 2002. The second analysis was conducted with higher quality planimetric and parcels data acquired by the town subsequent to the Executive Office of Environmental Affairs' (EOEA) analysis, and according to the consultants, it "represent[ed] a vast improvement over standard, statewide layers" (Applied Geographics, Inc. and Philip B. Herr & Associates, 2002). Figure 1 depicts the simplified buildout methodology employed by EOEA and the Pioneer Valley Planning Commission (PVPC) for Amherst in 1999. Figures 2 and 3 show the details of North Amherst's MA zoning and composite maps,



Source: Courtesy of the Commonwealth of Massachusetts (2003).

Fig. 1. The State's CPI simplified buildout methodology in Amherst, MA.

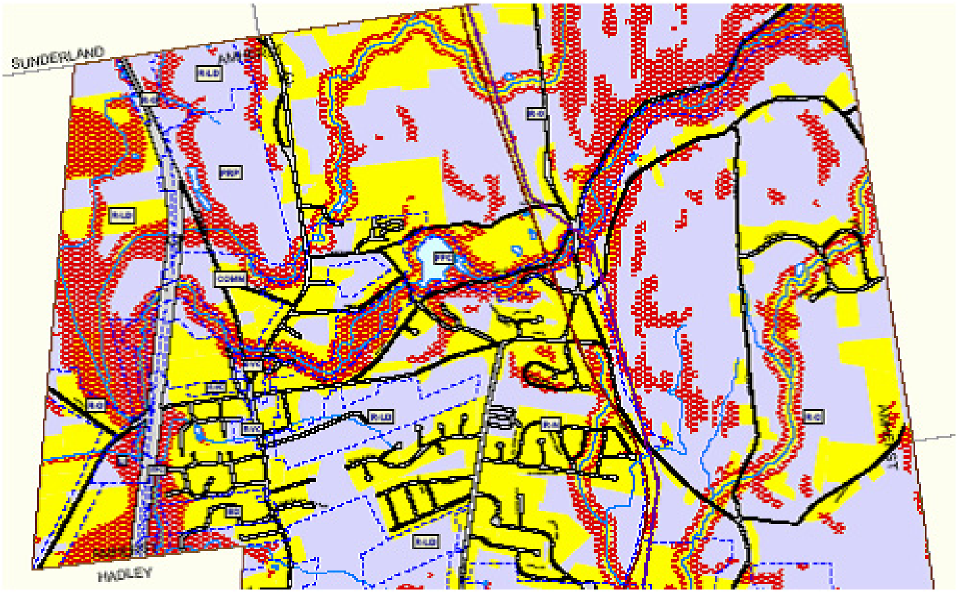
Source: Courtesy of the Commonwealth of Massachusetts (2003).

Fig. 2. Details of North Amherst's MA zoning map.

respectively. Finally, Table 1 is a summary of the buildout parameters for the town of Amherst.

4.2. *Case II: Georgetown*

Georgetown is a small suburban town (33.9 km^2) located in Essex County just 45 km north of Boston. Georgetown is part of the Plum Island Ecosystem in Northeastern



Source: Courtesy of the Commonwealth of Massachusetts (2003).

Fig. 3. Details of North Amherst's MA composite map.

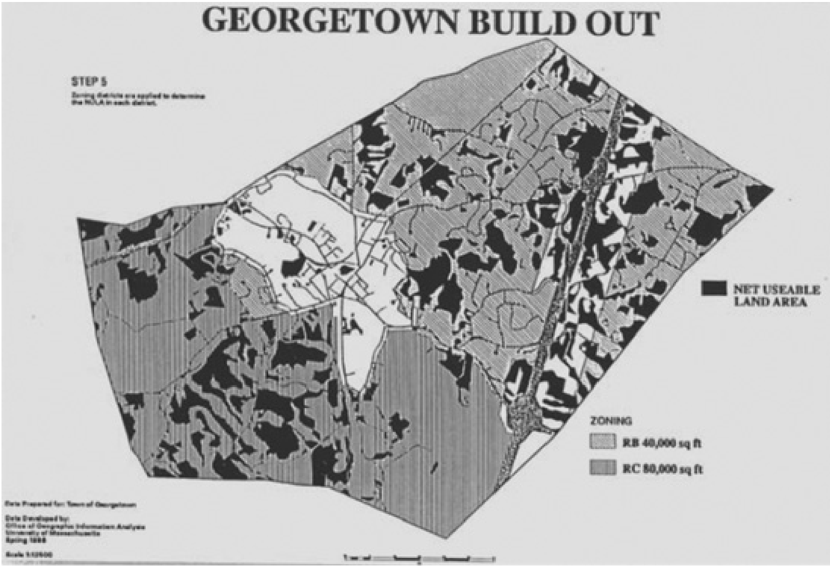
Massachusetts, tucked between the Ipswich and the Merrimack River watersheds to the south and north, respectively (Pontius and Neeti, 2010). The town's population was 8,183 in 2010, which at the beginning of the 2000s represented an increase of 16% over the previous decade (Georgetown Master Plan Committee, 2004). Its good accessibility and affordability compared to other communities in the Greater Boston has made it an attractive location for new families to relocate in recent years. However, as more central locations become urbanized, developmental pressure has also increased (Glaeser and Ward, 2009). Georgetown offers small town rural living within the reach of employment centers via Route 95 connecting to Route 128 and via Route 97 connecting to Route 495.

In the mid-1990s, the town's supervisor reached out to the Department of Landscape Architecture and Regional Planning at the University of Massachusetts, Amherst in hopes

Table 1. Summary of the buildout analysis for Amherst, MA.

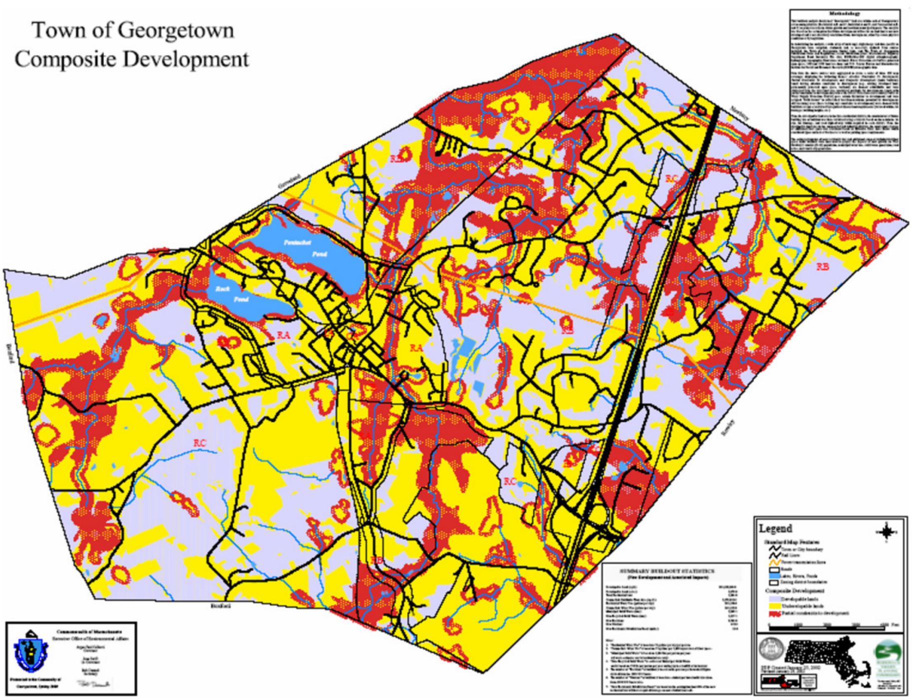
Developable Land Area (km^2)	23
Additional Residential Units (homes)	1,522
Additional Commercial/Industrial Floor Area (m^2)	656,611.2
Additional Residential Water Use (m^3 per day)	1,132.1
Additional Commercial Water Use (m^3 per day)	2,006.5
Additional Residential Solid Waste (ton)	2,046
Additional Students (students)	533
Additional Kilometers of Roadway (km)	39.7

Source: Courtesy of the Commonwealth of Massachusetts (2003).



Source: Courtesy of Calabrese *et al.* (1996).

Fig. 4. UMass Amherst planning studio buildout analyses for Georgetown, MA.



Source: Courtesy of the Commonwealth of Massachusetts (2003).

Fig. 5. Town of Georgetown, MA composite development map 2003.

of obtaining technical assistance to help prepare a new master plan, since the town's master plan was decades old. Five graduate students spent a semester doing preliminary analysis and sharing their findings with the town's council, interested residents, and property owners (Calabrese *et al.*, 1996). The students' goal was to perform various technical background analyses conducive to updating the town's master plan. Those analyses included studies of the town's land use, demographics, housing, transportation, and finances, among others. Figures 4 and 5 show the UMass Amherst planning studio buildout analysis for Georgetown, MA and the Georgetown's 2003 composite development map produced during the State's initiated buildout program, respectively.

5. Discussion: Lessons Learnt and Implications

A buildout analysis is critical to understand the land-use patterns of a community. Furthermore, such an analysis provides a clear overview of how zoning regulations impact the course of development. The accuracy of the estimates depends on the input data and the adequacy of the assumptions used in the model. A sensitivity analysis allows an understanding of whether variations in developable land are equally proportional to variations in the number of housing units. Although conducting a buildout analysis is relatively straightforward, it is important to realize that sensible assumptions about wetlands, residential, commercial and industrial water-use consumption, additional students, solid waste generation, and new miles of roads, among others, will dictate the reasonableness of the outcomes.

Tables 2 and 3 provide comparative locational and socio-economic data, as well as an analysis of three selected buildout indicators for the two case studies, respectively: developable land, new dwellings, and new commercial/industrial land. These indicators are

Table 2. Comparative case study data.

	Amherst, MA	Georgetown, MA
Area (km^2)	71.7	33.9
Distance to large city (km)	14.4	45
Population ($\times 10^3$)	37,819	8,183
No. of households ($\times 10^3$)	9,259	2,937
Housing units ($\times 10^3$)	9,711	3,044
Transportation (%)		
- Drove alone	48.8	93
- Carpooled	6.6	4.5
- Public transportation	10.10	1.3
- Walked	18	1.2
- Biked	2	0
- Worked at home	14.3	0
Median household income (MHI) ($)	108,141	107,343

Source: U.S. Census (2010), American Community Survey 2006–2010 five-year estimates, American Community Survey (2013), and MHI Georgetown (2016 estimate).

Table 3. Comparative analysis of selected buildout indicators.

Amherst	Developable land acres/(km^2)	New dwellings (units)	New commercial/ industrial land million square feet/($\times 10^6$m^2)
1999 EOEA's computations	6,708/(27.1)	1,522	7.1/(0.659)
2002 Town's computations	4,000/(16.1)	3,400	3.9/(0.362)
Georgetown	**Developable land acres/(km^2)**	**New dwellings (units)**	**New commercial/ industrial land million square feet/($\times 10^6$m^2)**
1996 UMass's computations	1,766/(7.1)	1,009	5.5/(0.510)
2000 EOEA's computations	2,379/(9.6)	1,284	2/(0.185)

Note: The 1996 UMass studio report utilized the expression "new house lots implying new dwelling units".
Source: Commonwealth of Massachusetts (2003), Applied Geographics Inc. and Philip B. Herr & Associates (2002), Calabrese *et al.* (1996), and Georgetown Master Plan Committee (2004).

the most commonly utilized in conducting a buildout analysis and the ones for which data were available to perform the comparative analysis. In the Amherst case, it was found that the town's computations identified lower values of developable and new commercial/ industrial land and 1,878 more new dwelling units than the state-led planning initiative three years earlier. In the case of Georgetown, the UMass Amherst planning consultancy identified lower values of developable land and fewer new dwelling units and 3.5 million square feet more of new commercial/industrial land than the state-led analysis. These differences may be partially explained by the close interactions between the graduate students and the consultants, who took time to confer with the towns' interested stakeholders through focus group meetings and interim and final presentations; while the statewide effort to create buildout analysis for all cities and towns in Massachusetts might have been more focused on regional trends to either accommodate or stimulate future growth patterns.

Nonetheless, these two towns' buildout analyses reflect broader statewide trends, explained by Geigis *et al.* (2007, pp. 235–236) in the following terms: "The buildouts showed that the majority of Massachusetts's communities zoned a disproportionate amount of commercial/industrial development that, if built, would not be residentially supported within the community and therefore would have an impact on surrounding areas." Daniels (2014, p. 626) called this phenomenon overzoning, basically a situation where "overzoning makes a community vulnerable to the loss of open space, increasing traffic congestion, and new and expensive public service demands, such as schools to meet rapidly growing enrolments". On the other hand, Pfister *et al.* (2007, p. 97) identified that community's reactions to the results of their buildouts ranged from "disbelief about the number of units that could be built, consternation about how much time was left before reaching complete buildout, and alarm to discover their community's vulnerability to sprawl and drastic changes to community character".

The main difference between the two cases is perhaps the fact that graduate students from UMass Amherst engaged in applied learning with a community at the other end of the state almost 160 km away, while the University's host town of Amherst hired a private consultant to perform its own buildout analysis. From a pedagogical perspective, it is important to note that students gained applied planning skills; the faculty members established professional connections and teaching and research opportunities, and Georgetown received professional and para-professional planning services at a fraction of the cost of hiring a consulting firm. The studio's challenges comprised the learning and implementation of the buildout methodology, the need to locate data and produce maps with the supervisory help of the instructor and the technical staff at the municipality. It appears to us that reviewing the various steps of the method, debriefing and validating the findings with technically competent staff form an adequate mode to overcome some of the challenges encountered during the studio. The pioneering work of UMass Amherst faculty and students in the Center for Rural Massachusetts and in the Department of Landscape Architecture and Regional Planning was then followed by a statewide initiative to apply the buildout methodology to all 351 cities and towns in Massachusetts.

Common to the two non-state-led buildouts is the fact that extensive interaction between the towns' leaders, interested residents, and property and business owners occurred at various moments of the buildout analyses. Feedback from the public on the results of a buildout analysis is critical to subsequent land-use planning (Pfister *et al.*, 2007). The buildout provided an overview of how the community would look like in the future. This collective realization of the impact of current regulations enabled a reaction from the public and the possibility to change and adjust the subdivision and zoning regulations to accomplish a more desirable future cognizant of community's preferences, which could potentially include permanently protecting open space, higher urban densities, and directing development away from the fringe and towards neighborhood cores. It is important to recognize that a full fiscal impact analysis ought to follow a land-use buildout study.

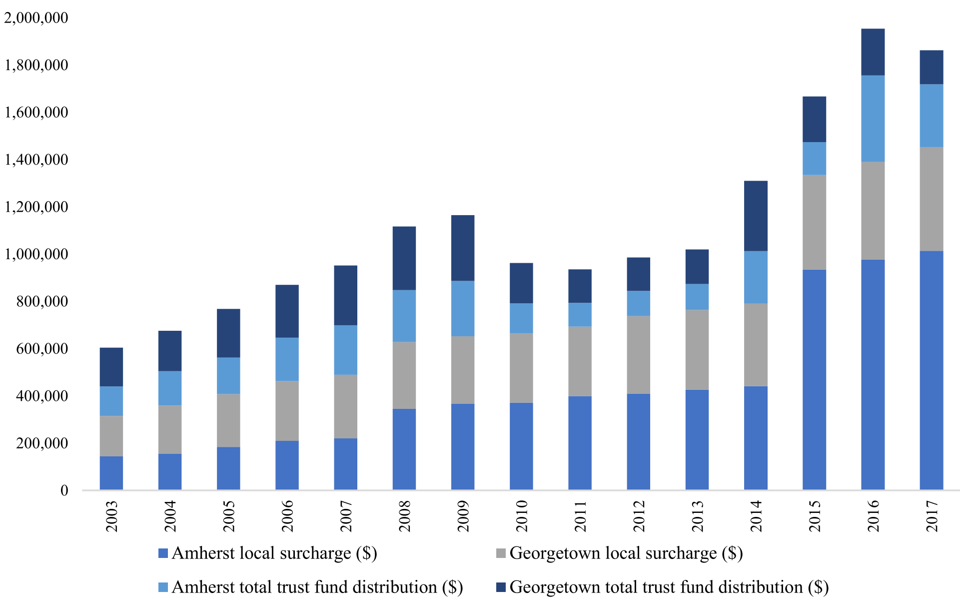
In the case of Georgetown, the graduate planning studio work was complemented by three major planning initiatives: The 2004 Community Development Plan, the 2007 Master Plan, and the 2011 Housing Production Plan. On the other hand, the town of Amherst also conducted a 2004 Amherst Comprehensive Planning Study aimed at defining village boundaries and open space preservation strategies (this time with the support of landscape architecture students from the University of Massachusetts, Amherst), a 2010 Master Plan, and a 2013 Housing Production Plan.

The buildout analysis is a relatively mainstream land-use planning technique. However, its effectiveness depends heavily on each community's disposition to make the necessary changes to other planning regulations in order to accomplish a desirable urban form and socio-economic dynamics. In spite of various plans for the town of Amherst, the town has seen its traditional downtown lose small businesses, while the suburban thoroughfare Route 9 between Amherst and Northampton has experienced burgeoning strip commercial development. Similar trends seem to also have occurred in residential land use. According to the Amherst Master Plan (2010, p. 3.2), although

> "approximately half of the Town's land currently enjoys some form of protection from development and a significant percentage (4,850 acres [19.6 square kilometer], or 27.3 percent) of the community's total land area (17,762 acres [71.8 square kilometer]) is permanently protected (. . .) since the year 2000, the total developable land area in Amherst that consists of residential lots larger than 1/2 acre grew by 65 percent, while Amherst's population remained relatively stable."

Moreover, although both the PVPC and the Merrimack Valley Planning Commission (MVPC) have both prepared or updated regional land-use plans in the last decade, the two case studies have both adopted CPA to create local community preservation funds. Amherst's CPA was adopted in April of 2001 with a 1% surcharge tax and Georgetown adopted its CPA a month later with a 3% surcharge tax. Amherst has since raised its surcharge to 3% in 2008. Figure 6 shows a comparison of CPA's surcharge and trust fund distributions in Amherst and Georgetown from 2003 to 2017. It is easily observable that the trust fund distributions were much lower in both towns from 2010 to 2013 with the local surcharges increasing for both towns from 2014 onward.

Recently, Geneletti *et al.* (2017) conducted a review of approaches and challenges for sustainable planning in urban peripheries, which confirmed the earlier results by Lokocz *et al.* (2011) that sustaining rural landscapes in Massachusetts has been deemed highly important. Furthermore, Levesque *et al.* (2017) has also concluded that planning for



Source: Community Preservation Coalition (2018).

Fig. 6. Comparison of CPA surcharge and trust fund distributions in Amherst and Georgetown, MA (2003–2017).

sustainability in small municipalities is dependent on interest groups, growth patterns, and institutional characteristics. Community partnerships between university planning departments and municipalities can deliver fruitful results for both constituencies (Barcus and Muehlenhaus, 2010). However, the transformational leadership that can be obtained from students' and instructors' active roles in studio projects (Nagy and Edelman, 2014) has to be followed up with bold political decision-making at the local and regional levels.

Buildout analyses are excellent opportunities to learn and practice GIS and land-use skills. From a content perspective, this particular type of geospatial activity requires the ability to acquire, manipulate, and present data both in tabular and spatial formats. The reasoning goals involve interpretation, visualization, and quantification of spatial, socioeconomic, demographic, cultural, and environmental phenomena. On the other hand, the technical skills comprise learning how to work with various software packages. At a minimum, the student assessment of any buildout analysis ought to be able to produce a series of maps for various communities in different planning regions and to write a short report discussing and quantifying some or all of these characteristics: (1) The existing zoning regulations in each community, (2) the existing land available for future development, (3) the changes in existing zoning regulations to allow more cluster and open space preservation, (4) how proximity to a major metro area affects propensity to grow, and (5) the accuracy of the buildout analysis for public policy and decision-making purposes.

6. Conclusions

The purpose of this paper was to shed light on how to use a spatial analysis tool known as GIS buildout analysis to understand different planning concepts: land-use planning, zoning regulations, urban growth, smart growth, fiscal impact analysis and open space preservation, among others. It is important to recognize that "buildout analysis can be an effective wake-up call to a community that is growing faster than it desires" (Daniels, 2014, p. 626). When conducted early, buildouts can facilitate political leaders to champion changes in land-use regulations and help to save land for its use value instead of only for its exchange value. Warren *et al.* (2011) have argued that Land Trusts in poor communities can be an effective way to preserve land in the path of urbanization.

There are multiple pedagogical advantages to conducting a buildout analysis. The input data needed to enable manipulation, analysis, and visualization is relatively easy to obtain and compute. Furthermore, the existence of control maps can enable supervised pedagogical activities to take place within introductory urban and regional planning courses as well. The relative disadvantages may result from students' limited exposure to GIS software. Geospatial and geodesign skills can be critical to facilitate research, teaching, and applied learning processes aimed at resolving land-use, transportation, housing, public spaces, big data, and social, economic and environmental problems. Furthermore, the interoperability of various innovation systems [Smart Cities, e-government, e-work, telecommuting, intelligent transportation systems (ITS), and other novel approaches] are contributing not only to the creation of multi-faceted digital and professional communities, but also to the alleviation of real problems in cities. Furthermore, 3D GIS has the potential to facilitate the study of complex urban environments more fully than traditional GIS applications.

Pedagogical cautions to bear in mind include the accuracy of the methods and scientific reporting of findings, the concrete public policy and decision-making implications of the activities, and finally, the quantification of land uses and their practical economic implications derived from associated fiscal impact analysis. In conclusion, buildout analysis, Public Participation Geographic Information Systems, space syntax, the Internet of Things (IoT), mapping, and the analysis of flow patterns can also be applied to the human utilization of site designs and improvement of walkable cities, and the optimization of public policy decision-making processes. Future challenges, concerns, and possibly opportunities that require proper attention during land-use planning processes include: climate change adaptation, planning for multiple publics, and being cognizant of the proper ends of technology.

Acknowledgment

The author thanks James Mower, Jeff Owen, and Kira Liu for providing thorough comments on earlier versions of this paper.

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