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A constructability assessment method (CAM) for sustainable division of land parcels

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ABSTRACT

Historically the land development process has lacked a decision support structure for evaluating undeveloped parcels of land for compatibility with land use policy and engineering constraints. This paper demonstrates an applied multi-criteria decision support structure for characterizing the spatial distribution and classification of a parcel's potential to support residential lot construction. This support structure is based on parcel attributes quantified in a typical site feasibility report, to include: potential house yield, wetlands area, soil types, streams (surface drains), and steep slope areas. The analytical capabilities of geographic information system (GIS) are employed in the decision support structure named the constructability assessment method (CAM). CAM integrates a dynamic multi-criteria attribute assessment method, based on the Analytical Hierarchy Process (AHP), for a given set of administrative requirements, and engineering constraints and judgment.

The results of a case study using CAM characterized the approximate location of ideal lots for homes construction in an R-1 zoning district located on a 1290 acre land parcel in Loudoun County, VA, while avoiding existing hydric soils, floodplains, steep slopes, and forested areas. The number of ideal lots for a given set of engineering and administrative constraints represented a 65% reduction from the maximum lots permitted by regulatory constraints alone. The methodology used in this case study provides a consistent and repeatable land parcel analysis technique for undeveloped land parcels, and can be adapted and/or extended to a number of similar publicly available geographic datasets and constraint. In estimating optimal development density, CAM meets the needs of zoning administrators as well as the developers, thus offering a demand-driven market-based solution for sustainable land development.

1. Introduction

Seven design concepts related to sustainable urban forms include: compactness, sustainable transport, density, mixed land uses, diversity, passive solar design, and greening (Jabareen, 2006). While the elements of sustainable development are a function of the goals established by individual communities, compactness of the built environment is a widely acceptable strategy through which more sustainable urban forms might be achieved (Gordon and Richardson, 1997; Burton, 2000; Gusdorfa and Hallegattea, 2007).

As measured by growth in population by distance from a town center or City Hall, suburbanization in US is widespread among urban areas of all sizes. For example, the 2010 decennial census indicates that among all metropolitan statistical areas (MSAs), 49.4% of the population growth between 2000 and 2010 occurred in a doughnut area contained within a 15–40 mile radius of the City Hall (Wilson et al., 2012, page 27). The same data show that only 27% of the population growth happened within the 15-mile radius of the City Hall. Suburbanization is even more pronounced for MSA population sizes between 1.0–2.5 million, where the growth in population for the areas within the 15–40 mile doughnut and of 15 mile radius are 57.1% and 26.7%, respectively. This demand trend for suburbanization, which is also prevalent worldwide, is likely to continue through the current decade and the foreseeable future.

Suburban developments in the United States (US) are often low-density with a high dependency on automobile travel. Therefore, the market-demand for suburban housing is at odds with the sustainable compact urban form. Furthermore, due mainly to resource constraints, cities, counties, municipalities and other local jurisdic-

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tions that are vested with the power and responsibility of making zoning decisions are often not nimble enough to quickly meet market demands for rezoning. Local land use regulation often adds long delays to the development process by introducing multiple reviews by zoning agencies before construction can be approved. These stages generally include issuing subdivision permits, re-zoning existing parcels, soliciting environmental impact statements, and issuing building permits (Mayer and Somerville, 2000). The term 'Resource constraints' is a ubiquitous challenge faced by most zoning agencies worldwide. For any development plan on a given land parcel, the zoning and/or rezoning analysis is performed by analyzing the plan's ability to meet sustainability goals (e.g. compact development) as well as constructability constraints. "Smart growth" policies tied to transportation infrastructure are found to significantly influence land conversion, which in turn requires the development of, or changes to, clustering policies and rezoning (Irwin and Bockstael, 2004).

Political and public institutional support for sustainable development is not without controversy. Jones (2014) argues that the focus of the planning agenda in most countries still remains on the institutional processes to meet the 'public' interest and 'utopian' ideals, of which sustainable development is the latest manifestation. Planning aspirations and planning policies in a capitalist economy cannot impose a 'socially just' solution. One view of the planner's role is therefore to work with the market to facilitate economic processes while ensuring they are environmentally benign. (Davoudi, 2001; Jones, 2014).

An ideal situation for sustainable land development would be where a market-based solution results in a 'socially just' outcome. The accomplishment of this type of outcome is a major challenge for the policy makers and planners. A bigger challenge lies in developing Decision Support Systems (DSS) that simultaneously meets the criteria for sustainability and market-acceptance, while at the same time meeting the design constraints on each land parcel.

In the absence of a standard DSS to assist in systematic evaluation of changes to zoning and land use policy, potential exists to arrive at sub-optimal or even erroneous solutions that could ultimately lead to divergence from the community's sustainability goals. A few DSS for sustainable development include strategies for increasing the urban density per net acre (Churchill and Baetz, 1999). Although the proximity to utilities, town centers, and transportation infrastructure heavily influence land development decisions, it is arguable that when determining a lot's construction potential it is the physical and regulatory criteria that impact the number and locations of potential house pads.

A need exists for a reexamination of the DSS for the land development process, by including such critical functions as establishing standard methodologies to produce consistent site feasibility results based strictly on design constraints that are independent of the housing market, construction costs, and labor availability. The goal of this research is to develop a DSS tool that will assist regulatory agencies in market-sensitive sustainable division of land parcels meant for development into individual lots.

2. Optimal development density on a given land parcel subject to local constraints and sustainability priorities

Sustainability goals and land use policies drive zoning decisions on developable urban land. Most agencies that are responsible for sustainable development and land use regulation also maintain a publically available GIS parcel database containing zoning designation, land cover types, drainage, soils, parcel boundaries, roads, and topography. In most cases, the data sets are kept in a vector format that can be readily used to determine design constraints for a variety of construction projects. These constraints can be divided into two groups: administrative or regulatory constraints (AC) and the engineering constraints (EC). The AC group is generally defined within a zoning ordinance, while the EC group is defined in a construction specification.

Although technically feasible by the EC group, the AC group may limit construction. Conversely, although the AC group may allow a specific number of lots, based on the continuity of the potential lot areas, the EC group may be the limiting factor. Manual analysis of constraints in both groups results in suboptimal division of land parcel into lots, which is neither sustainable nor market-based. Furthermore, each of the constraints in both groups may have a different priority, which should also be taken into consideration while performing constructability assessment analysis.

The primary objective of this paper is to discuss the methodology and development of a geographic information system (GIS) based DSS tool called Construction Accessibility Method (CAM). CAM will be useful for zoning agencies (and also for developers) in determining the optimal development density (conversely, optimal number of constructible lots) on a given land parcel subject to a set of administrative and engineering constraints, and their priorities.

3. Background

The idea of "cluster" or "pod" housing, in which houses are built more closely together with open space between housing clusters, may be considered preferable to conventional suburban and urban fringe development due to some conservation of open land (Baetz, 1994). The process of land subdivision involves splitting up of a larger land tract (parcel) into streets and smaller subspaces (lots). In general, the process is carried out by developers and land owners based on field surveys, empirical designs and legal criteria after their subdivision plan is approved by planning officials (Dahal and Chow, 2014). In the urban areas of the US, cluster housing is a popular form of single family housing. For this reason it is important to focus on the development of methods and tools that will enhance sustainability of this form of housing. One such approach is to divide land parcels to accommodate the optimal number of house lots. McIntyre and Parfitt (1998) outlined the three fundamental needs of land parcel subdivision process as:

1. Reexamination of the land development process.
2. Formulation of an appropriate preliminary planning model, and
3. An objective decision support system (DSS) that will assist the developer and the development team in making critical decisions.

The use of GIS based DSS tools and methodologies in the field of civil engineering in general, and land development in particular is not new. The potential range of applications for GIS in this area is vast and yet to be fully explored (Venigalla and Casey, 2006; Venigalla and Baik, 2007). When performing a site-study or a feasibility report, consistent information based on computer analysis including GIS, are necessary for comparing potential construction areas (McIntyre and Parfitt, 1998). Only a few scientific studies have dealt with the automated simulation of the process of parcel subdivision using vector data format (Dahal and Chow, 2014).

3.1. Literature review/relevant work

To date, there have been no automated tools that include methodologies that simultaneously account for engineering and administrative constraints of the land development process. However, a number of tools have been developed using CAD and GIS to spatially represent the subdivision of a land parcel using input based on user needs. Both CAD and GIS techniques are typically