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Design Efficiency: An Analysis of Sewer Differences between Form-based and Conventional Neighborhood Development Designs in Lancaster County, Pennsylvania

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DESIGN EFFICIENCY: AN ANALYSIS OF SEWER DIFFERENCES BETWEEN FORM-
BASED AND CONVENTIONAL NEIGHBORHOOD DEVELOPMENT DESIGNS IN
LANCASTER COUNTY, PENNSYLVANIA

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DESIGN EFFICIENCY: AN ANALYSIS OF SEWER DIFFERENCES BETWEEN FORM-BASED AND CONVENTIONAL NEIGHBORHOOD DEVELOPMENT DESIGNS IN LANCASTER COUNTY, PENNSYLVANIA

Abstract: Form-based development is often championed as a tool to use land and fiscal resources more efficiently. Whereas conventional development patterns commonly consist of large lots, low density and cookie-cutter designs, form-based development offers an alternative that uses land more efficiently and attractively. Infrastructure cost savings is one of the purported advantages of this type of development. Using data from Lancaster County, Pennsylvania, This study presents an empirical assessment of infrastructure efficiencies of form-based neighborhoods over conventional neighborhoods. This paper contributes to the empirical literature by presenting a quantified assessment of the impact of development design on sewer infrastructure at the neighborhood level. Findings indicate that both neighborhood form and lot size have a statistically significant impact on the amount of sewer utilized, suggesting that communities built with greater attention to design result in a more efficient use of infrastructure.

INTRODUCTION

Form-based development has received a great deal of attention in the planning, urban design, and development communities over the past twenty years as a way to combat the perceived inadequacies of conventional development patterns. Conventional suburban development is often associated with *sprawl*. Spatial characteristics of sprawl generally include: large lots, unconnected roads terminating in cul-de-sacs, isolated neighborhoods, homogeneous housing units, and lack of character. Sprawl is blamed for many of the ills that plague suburban areas today including auto-dependence, increased runoff, segmentation of habitat, and inefficiencies in infrastructure such as roads, schools and sewers (Katz, 1994). Form-based development offers an alternative. Its development characteristics include: smaller lots, inter-connected roadways, a mix of uses, a “neighborhood feel” and designated open space. Form-based development is purported to offer a number of environmental, aesthetic, and socio-economic benefits, including protecting rural and cultural resources, creating a sense of place, and reducing infrastructure costs; while simultaneously providing a place for growth (Dover, 1996).

The overall goal of this study is to empirically assess the infrastructure efficiency of

form-based development over conventional development patterns, by analysing sewer use. Lancaster County, Pennsylvania was selected as the study area for the research. Lancaster County has been a leader in adopting form-based development approaches to manage development. Today there are a number of form-based development communities that exist alongside conventional developments so the area serves as a rich laboratory to compare the two. This study adds to empirical literature in the field of planning by presenting an empirical assessment that uses neighborhood-level data with actual sewer lengths for existing communities.

The study is presented in five parts. The next section summarizes the literature on form-based development and provides the theoretical research context; the following section provides background information on the study area; the methodology is then presented, followed by a discussion of the results. A concluding section provides discussion of the implications of the findings.

LITERATURE REVIEW

A body of literature has emerged that investigates the theoretical and empirical aspects of form-based development. A note on terminology is important: *form-based development*, as it's being used in this research, refers to development that complies with a set of zoning and building design regulations that prescribe desirable design aspects of development such as clustering housing units, safeguarding community character through prescribing architectural features and materials, managing the relationship of buildings to each other, and preserving common open space. In the literature on form-based development, there are a number of overlapping terms and approaches including: *new urbanism*, *traditional neighborhood development (TND)*, *conservation subdivisions*, and *cluster development*. Each of these is a little different and bears some discussion as to how it relates to form-based development as considered in this research.

New urbanism and TND typically refer to the new development, usually in suburbs, that is designed to support higher densities and incorporate features of traditional towns such as sidewalks, alleys and closer building placement (Berke, 2006). Conservation subdivision and cluster development refer to residential development specifically designed to provide environmental benefits by balancing preservation of natural features while clustering houses on smaller lots (Mohamed, 2006). Form-based development, as used in this research, is a catch-all term that includes any of these design-based approaches that are promoted as an alternative to conventional patterns.

Much of the early literature on form-based development was normative in nature, advocating for the benefits of form-based over conventional designs. Since the advent of the first Levittown, shortly after WWII, conventional development has been criticized for creating cookie-cutter developments (Langdon, 2006). Because form-based developments tend to use less land and require less impervious surface, they are often regarded as more environmentally friendly than conventional development forms. In addition proponents of form-based planning contend that the pedestrian focus and compact mixed-use structures make form-based developments less auto-reliant and thereby decrease carbon emissions (Berke, 2006).

Since the late 1990s, there has been growing attention to re-crafting development regulations to incorporate form-based initiatives at multiple scales. Under conventional development scenarios, growth is managed by zoning and other legal mechanisms that predominantly reinforce a conventional development pattern (Ohm and Sitkowski, 2006). Conventional zoning divides municipalities into mapped districts and specifies a use for each zone, such as single-family residential, multi-family residential, commercial, industrial, etc. and a density (Dover, 1996, Katz, 2004). Residential densities are generally low. Form-based codes were developed as an alternative to conventional zoning. They aim to accommodate

higher densities, provide for a mix of uses, and encourage social interaction. Form-based codes shape the physical form of development, not just the use, and thereby foster development that is more attractive and more pedestrian oriented (Dover, 1996). Form-based codes prescribe uses, but they also include specific physical standards for building and parking placement, architectural form, sidewalks, trails, and landscape requirements (Katz, 2004). Written by design professionals, there are a number of publications that describe and encourage the use of form-based codes (see, for example, Parolek, et. al. 2008).

Form-based planning employs a number of tools to help guide and simplify the development planning and approvals process and ensure the physical outcome of a development project. For the most part, conventional zoning ordinances rely on written codes whereas form-based codes include textual material supplemented with graphics, images, illustrations and other visual elements to better communicate visions, interpret requirements, and guide development (Langdon 2006, Katz 2004). Form-based planning creates design consistency by developing a master plan for the entire project area, rather than an individual lot. This approach allows all buildings in the larger development project to be planned as a unit rather than incrementally as often happens with conventional development. Zoning regulations for an individual lot can be more flexible as long as the developer is meeting the overall goals of the development (Dover, 1996). With this flexibility, governing bodies can negotiate with developers to ensure integrated street patterns, trail networks, or shared recreational facilities by allowing them exceptions to setbacks, lot sizes and street standards. This give-and take is generally not possible under the rigid and uniform standards of conventional zoning (Dover, 1996).

The empirical literature on form-based development is just beginning to emerge. With the advent of GIS technologies, data and analytical tools are now available to perform quantitative analyses. Recent empirical studies have estimated the impact of different

development patterns to one or more focused areas such as environmental impacts, neighborhood quality and economic impacts. Findings on environmental impacts are mixed. Form-based developments have been found to consume eight times less land than local conventional developments and provide more environmental buffers (Berke, 2006). Suburban developments using form-based codes were at least twice as likely to protect steep slopes and natural drainage depressions (Berke, 2006). Air quality and biological integrity have been found to improve with form-based development (Stone, et. al. 2007; Sorrentino, et. al. 2008), but water quality decreased slightly (Sorrentino, et.al, 2008). Many of these studies are based on hypothetical development scenarios, not existing developments.

Other empirical studies analyzed the quality of life in form-based communities by measuring neighborhood satisfaction and land use mix. Early findings indicate that residents of form-based communities have higher rates of satisfaction than those in conventional developments (Yang, 2008).

To date, there has been relatively little study of the economic impacts of form-based development. Research on some of the first new urbanist communities found that buyers were willing to pay a price premium for homes in new urbanist communities over conventional suburban communities (Epli and Tu, 1999), but they don't identify which design features are most valued. Later research tested the relationship of certain features of urban form with residential property values (Song and Knapp, 2004). Findings revealed that some, but not all, of the design elements of new urbanist communities have a positive impact of prices. Internal circulation patterns and external accessibility to commercial areas and transit were the most valued.

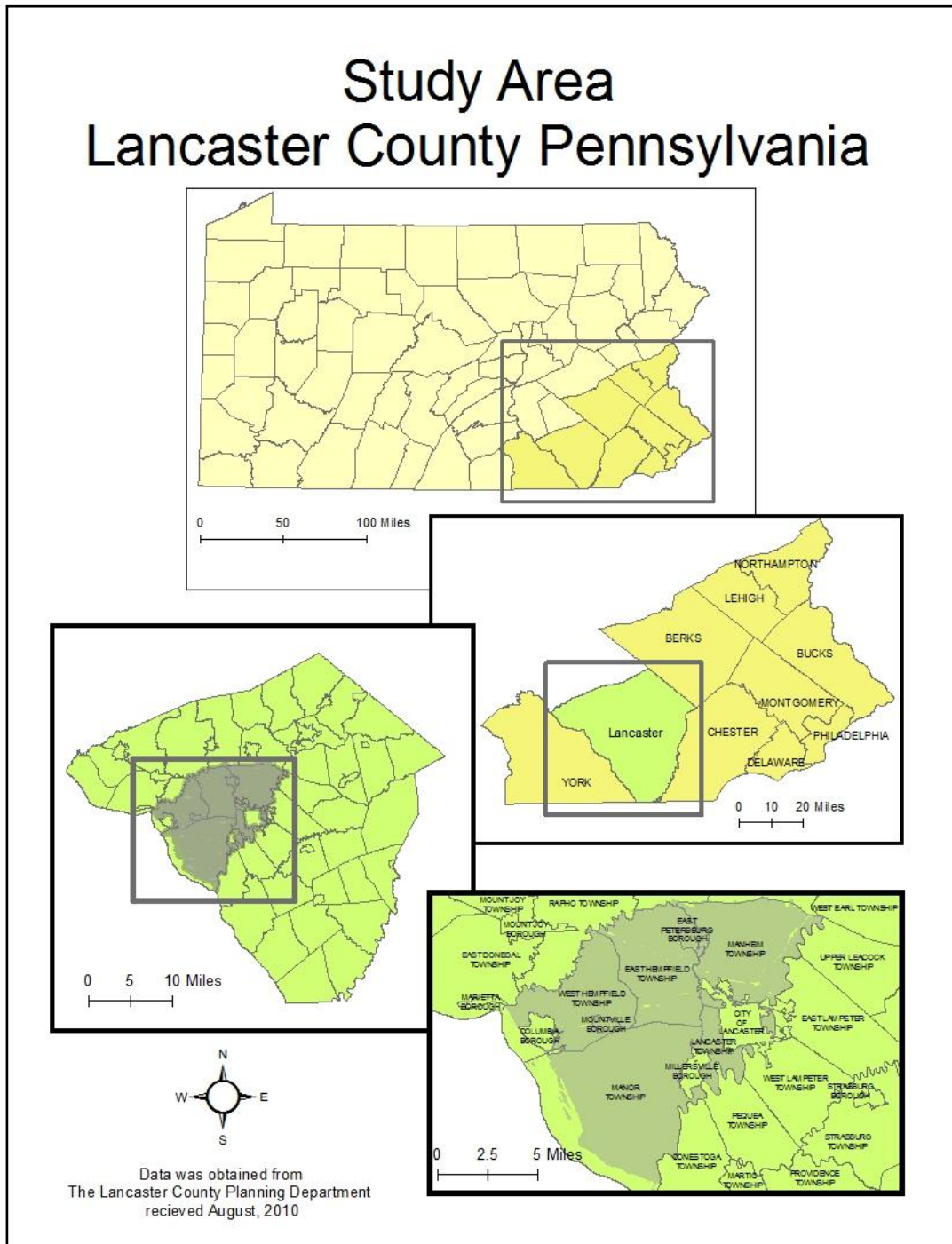
This research aims to add to the body of empirical research on form-based development by analyzing infrastructure efficiencies of form-based development over conventional development. While analysis of hypothetical development scenarios over

regions suggests such efficiencies (Burchell and Mukherji, 2003), to date there has not been empirical validation on existing developments.

STUDY AREA

Lancaster County, located in southeastern Pennsylvania, is nationally recognized as a leader in smart growth planning. A mandate from Lancaster County's comprehensive plan to preserve farmland led the county, in 1996, to impose an Urban Growth Boundary (UGB) with targeted urban growth areas (UGAs). The UGAs permit higher development densities, and thereby reduce development pressures in outlying areas. Within the UGAs, form-based developments have been encouraged and a number have been built. The existing mix of development, which includes form-based neighborhoods and conventional neighborhoods, provides an ideal mix for the study. The study area was further refined to include areas within the Lancaster Area Sewer Authority (LASA). This area is located in the northwest of the county and encompasses land both inside and outside of the UGAs. This area was selected due to the availability of geo-referenced sewer data, essential to the analysis. Map 1 shows the study area and its context.

Map 1.

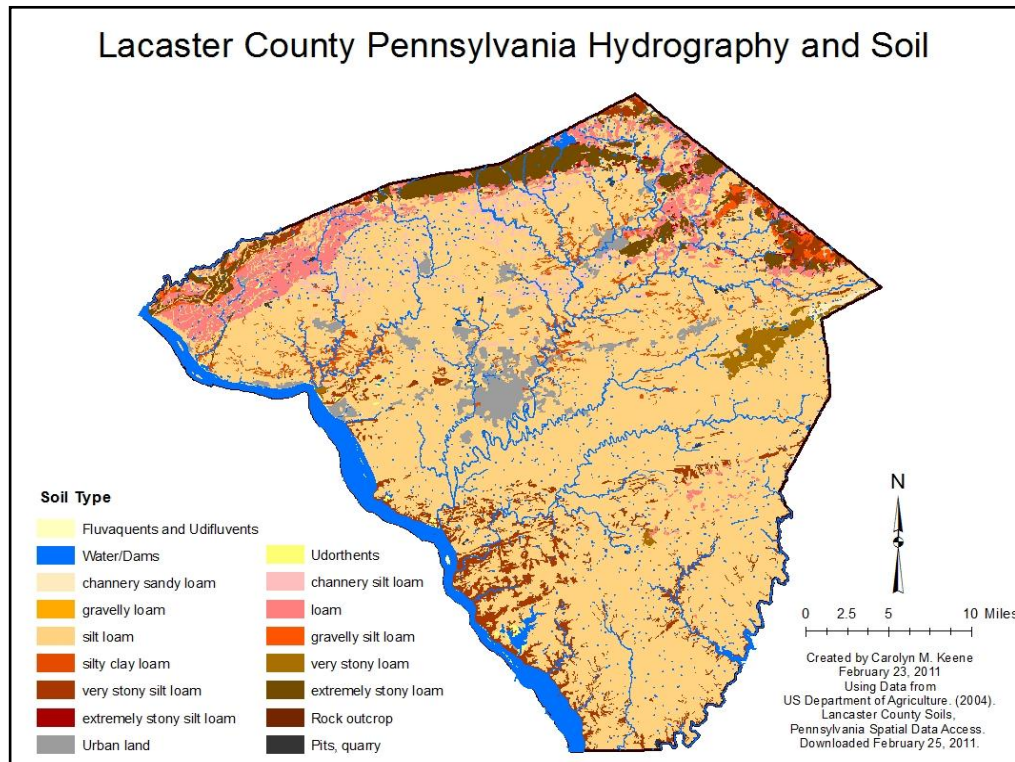


Physical Geography

Most of Lancaster County is located in the piedmont region, an area characterized by rolling hills and valleys (PA DCNR, 2010). The early landscape was mostly forested, with springs and streams that gave early inhabitants access to water (Lemon, 1966). The underlying limestone, shale and crystalline bedrock produced fertile soils. The most common

soil orders present are alfisols and ultisols; alfisols are very productive soils that form over carbonate rock in the valleys of the piedmont region (Geiger, 2005). Silt loam is the most prevalent soil type in Lancaster County (see Map 2). These soils provide good drainage, and are prime soils for farming. Indeed, the soil of Lancaster County ranks amongst the most productive in the nation (PA DEP, 2010).

Map 2.



Cultural Landscape

Native American tribes were the first to establish agriculture in this region (Smith, 2001). Colonials began farming this land when William Penn purchased the tract of land between the Delaware and Susquehanna Rivers in 1683, though the actual county was not established until May 10, 1729 (Loose, 2003). From 1722 to 1782 over 50% of Lancaster residents were of German descent; local religious groups included Mennonites, Quakers, Scotch-Irish Presbyterians, Welsh Anglicans, and German Lutherans (Lemon, 1966). The Amish, a subgroup of the Mennonite faith, also arrived in the area in the late 1720's and early 1730's. A large population of Amish and Mennonite still live in the region today and are an

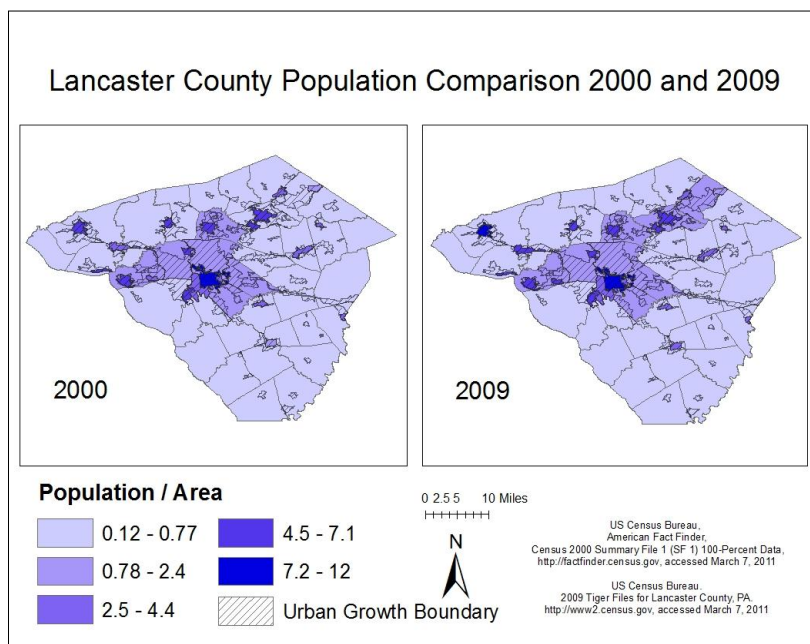
important element of the county's cultural landscape.

Lancaster continues its traditional farming traditions through its Amish population. Indeed, agriculture remains the number one land use in Lancaster County today, and 99% of the farms are family owned (EDC Lancaster, 2010). A whole tourism industry has been built around viewing the Amish culture. Every year over 10 million people travel to Lancaster County (Pennsylvania Dutch County Welcome Center, 2007). Their economic and cultural dependency on farming makes farmland preservation a fundamental issue.

Population Trends

The county has faced steady population pressure over recent years. They experienced a 7% growth rate since 2000 (US Census Bureau, 2011). In 2009, the total estimated population of Lancaster County was over 507,000 (see Map 3). The ages of Lancaster's current citizens are heavily distributed in the childbearing years, with a median age of 39.4. The population profile and trends makes continued growth more likely with a continued pressure for single family housing. Lancaster County projects that 53,259 new housing units will be need to accommodate growth between 2005-2030 (Lancaster County Planning Commission, 2007).

Map 3.



Lancaster County emerged as a leader in smart growth planning as it endeavoured to balance population growth without compromising their rich farmland and cultural heritage. Form-based development became an important part of this balance. The County's comprehensive plan outlines several initiatives for managing growth. Their goal is to direct eighty-five percent of new residential growth into the UGAs, allowing only 15% to occur in rural areas. The development density targets in UGAs is 7.5 dwelling units per acre. If fully implemented, it is projected that the area in the UGAs is large enough to sustain all expected growth within Lancaster County through 2030 (Lancaster County Planning Commission, 2007). Testament to the success of their growth management efforts, Lancaster County is ranked first in the percent of farmland preserved in the United States.

METHODS

This study seeks to add to previous empirical literature on form-based development by exploring the theoretical claim that form-based development is more efficient than conventional development in its use of infrastructure. Using neighborhood-level GIS data from existing residential communities in Lancaster County, the study compares actual sewer use between form-based and conventional neighborhoods. In contrast to other studies that have explored smart growth initiatives at a regional level, or form-based development at the scale of the individual housing unit, this study uses neighborhoods as the unit of analysis.

Data

Geo-referenced parcel data for the entire county was acquired from the Lancaster County planning department. Each parcel had a number of attributes including one indicating the neighborhood to which it belonged. The parcels were dissolved by neighborhood, thereby identifying discreet neighborhoods. Geo-referenced sewer-line data was obtained from the Lancaster Area Sewer Authority. Sewer line data was spatially joined to each neighborhood in order to determine the amount of sewer line used by each neighborhood.

Empirical Analysis

A model was developed to isolate the relationship between selected characteristics of the neighborhoods in relation to the amount of sewer needed to support the neighborhood. One dependent and three independent variables were initially identified. The dependent variable, sewer length per lot (SEWERPERLOT), was determined by dividing the total amount of sewer line serving the neighborhood by the total number of lots. The dependent variables included the density of the neighborhood in lots per acre (DENSITY), the average lot size in acres (AVGLOT), and the development form (FORM), as described below.

Accommodating higher development density (DENSITY) is often cited as one of the major tools of form-based development. Higher development densities concentrate development and thereby decrease sprawl and environmental degradation. Using GIS, the residential density of the community, expressed as lots per acre, was calculated by dividing the total number of lots in the neighborhood by the total area of the neighborhood. It was expected that communities with higher densities would experience a greater efficiency of infrastructure and thereby have an inverse relationship with the linear feet of sewer. That is, the higher the density, the less sewer required per lot.

Average lot size (AVGLOT) was selected as a second independent variable. Conventional development is often characterized by large minimum lot sizes. Form-based development, in contrast, relies on smaller average lot size to concentrate development in a smaller area. Using GIS, an average lot area for each neighborhood was calculated by dividing the total area of the neighborhood by the number of lots in the neighborhood. It was expected that neighborhoods with greater average lot sizes would utilize more infrastructure and therefore there would be a positive relationship between average lot size and sewer per lot.

Form (FORM) was included because it is the most basic principle in form-based

development. Defining a neighborhood as either conventional or form-based can be tricky; often it is convenient for developers, responding to market preferences and regulatory directives, to borrow from both approaches in designing developments. For this analysis, it was important to develop a framework to classify a neighborhood as form-based or conventional. Drawing from the literature on form-based design, six distinct development characteristics of form-based and conventional neighborhoods were chosen (see Table 1).

Table 1: Characteristics of Form-based vs. Conventional Development

Form-based Development	Conventional Development
Grid Street Pattern	Cul-de-sacs
Small Lot Size	Large Lot Size
Common Open Spaces	No Common Open Space
Mixed Use	Single Use
Mixed Sized Lots	Similar Sized Lots
Alleyways	No Alleyways

Grid streets are promoted in form-based communities as a way to reduce infrastructure costs, create connectivity within and between neighborhoods, allow for more dense development, and encourage walking and biking (Dill, 2003). Cul-de-sacs, on the other hand, are attributed to traffic congestion and discontinuous development. Presence of grid streets was determined by visual inspection of each neighborhood.

Small lot size is often associated with form-based development as a tool to meet housing needs while at the same time allowing for the protection of open space. Lots below .5 acre were considered small lots while lots above .5 acre were considered large lots. Lot size

was calculated with GIS.

The presence of common open space was a third criterion. The presence of open space is a key component of form-based developments and is typically used for active and passive recreation and to manage stormwater. The presence of common open space was determined by visual inspection of the neighborhoods.

The fourth criterion relates to the nature of the uses in each neighborhood. Mixing uses, such as neighborhood commercial with residential, is an important smart growth tool because it is said to decrease auto-dependence and aid in promoting a sense of place. Use was determined by mapping the zoning attribute of each parcel and identifying neighborhoods that contained commercial uses.

The fifth criterion relates to alleys. The presence of alleys allegedly provides for safer walking and biking as well as off street parking. Alleys were identified by visual inspection of each neighborhood.

The sixth criterion relates to the mix of residential uses. One of the goals of form-based development is to provide for a mix of housing types, to accommodate multiple housing needs. The presence of mixed residential lot sizes was determined by calculating the variance of lot sizes within ArcGIS.

Each neighborhood was assigned a one or a zero for each of the six characteristics. A one was assigned if the property that displayed the form-based indicator, and a zero if the property displayed the conventional design characteristic. If the property had three or more characteristics of form-based development it was classified as form-based.

Even with these rules in place, development hybrids which couldn't be classified still existed. For example, Figure 1 shows a neighborhood in the study area that borrows from both conventional and form-based design standards. It has both connected streets and cul-de-sacs, some mixing size lots but not mixed uses, small lots but no open space, and no

alleyways. Any similar neighborhood that couldn't be classified was removed from the data.

Figure 1. Hybrid Development



After classification there were 138 compact developments and 119 conventional developments. Fifty-eight neighborhoods were dropped from the study because they were unclassifiable. The expectation, based on the theoretical literature, was that form-based communities would exhibit a greater level of infrastructure efficiency than conventional communities.

Preliminary analysis of the data revealed a significant correlation between average lot size and density. The two independent variables were therefore considered as explaining the same variability (Shaw and Wheeler, 1994). Therefore, one of the variables – density – was dropped from the model.

Model Specification

A model was developed to test whether the incorporation of form-based elements in a residential neighborhood has an impact on required sewer. The model is specified below,

where Y represents a standardized measure of infrastructure in a neighborhood – sewer length per lot (SEWERPERLOT), X_I represents the neighborhood’s average lot area, and D represents a dichotomous (dummy) variable identifying a neighborhood’s design classification – conventional (0) and form-based (1). Pooling the observations under both characteristics, and assuming that the error terms are normally distributed with mean zero, the functional relationship between infrastructure and the various physical characteristics of the neighborhood can be written:

$$y = \alpha + b_1D + b_2X_i + b_3DX_i + e$$

In the equation, alpha is the intercept, b_1 is the difference intercept, b_2 is the slope coefficient that shows the unit change in linear feet of infrastructure that accompanies the unit change in average lots size, and b_3 is the difference coefficient – showing how much the slope coefficient of average lot area under the first circumstances (conventional neighborhood) differs from the slope coefficient of per capita income under the second circumstances (form-based neighborhood). The introduction of the dummy variable in the additive form (b_1) thus measures the difference (shift) in the intercepts of the two circumstances – form-based and conventional. The testable hypothesis in this case is that form-based communities utilize less infrastructure than conventional neighborhoods. In like manner, the dummy variable in the multiplicative (interaction) form (b_3) indicates the difference in the slope coefficients of the two distinct circumstances. The testable hypothesis in this case is that infrastructure use increases at a faster (or slower) rate in form-based neighborhoods than in conventional neighborhoods. The null hypothesis is that there is no difference in the rate of increase of linear feet of sewer line in form-based or conventional neighborhoods. A finding of significance would indicate that the slope and intercept differ between groups and therefore, there is a different effect in form-based areas than in conventionally designed areas.

The value of the dummy variable method in understanding the difference, if any, in

the functional relationship between variables given two circumstances lies in the estimated results for the coefficients b_1 and b_3 :

- If b_1 is not statistically significant, we do not reject the (null) hypothesis that the intercept for the two circumstances is the same. The estimated equation, then, is said to describe circumstances that are concurrent.
- If b_3 is not statistically significant, but b_1 is statistically significant, we do not reject the (null) hypothesis that the estimated regressions have the same slope. The estimated equation, then, is said to describe circumstances that are parallel.
- If the F-statistic, which tests the (null) hypothesis that $b_2 = b_3 = 0$, is not statistically significant, the estimated regression indicates that the functional relationship is coincident for the two circumstances.
- If both b_1 and b_3 are statistically significant, the estimate indicates that there is a structural change, or difference, in the functional relationship between the two circumstances. This is interpreted to mean that, for this research, both the level and the effect of lot size on infrastructure are different under the two circumstances — form-based and conventional neighborhoods.

There are two advantages to the dummy variable approach: only one regression need be run because individual regressions, one for each circumstance, can be easily deduced from the test, unlike the Chow test, which does not explicitly indicate which coefficient (intercept or slope) is different, the dummy variable method pinpoints the source of the/any difference (Gujarati 1995). Gujarati (1995) and Kennedy (1985) both note that the conclusions derived from a dummy variable approach and the Chow test are the same in any given application.

RESULTS

Ordinary least squares (OLS) multiple regression was used to estimate the model. The analysis is cross-sectional over the neighborhoods. A one-tailed test was used to test for

statistical significance, and the significance level was set at 0.05. A summary of the results of the regression analysis is presented in Table 2.

Table 2: Results

Dependent variable: SEWERPERLOT (Linear Feet of Sewer Line per lot)

Independent Variable	Coefficient (unstandardized)	t-value	p-value
Constant	53.802	11.899	.000
FORM	-44.635	-5.364	.000
AVGLOT	38.096	10.494	.000
INTERACTION	104.891	4.66	.000

$R^2 = 0.654$ (adjusted $R^2 = 0.646$)

N = 129

The estimated equation explains 65.4% of the variation in infrastructure. Each of the independent variables tested was found to be significant. The estimated coefficient for AVGLOT supports the hypothesis that an increase in average lot size in a neighborhood results in additional required sewer infrastructure per lot and therefore additional sewer infrastructure to service the neighborhood. This finding intuitively makes sense and is also supported by the theoretical development in the literature review. The estimation indicates that for every acre increase in the average lot size, the required amount of sewer infrastructure increases by 38 feet.

The dichotomous variable for development form (FORM) was also statistically significant. The null hypothesis (that there is no relationship between development form and required infrastructure) therefore can be rejected. This indicates that, from the sample studied, it can be statistically concluded that form-based developments use less sewer per lot than conventional developments. This is consistent with to the original expected result and the claims made in the literature. The empirical estimation indicates that, on average, form-based

developments require 44 less linear feet of sewer pipe per lot than in required for conventionally-designed communities.

The interaction term was also statistically significant. This indicates that the estimated equations between form-based neighborhoods and conventional neighborhoods in relation to sewer length and average lot size have different slopes. This can be interpreted to indicate that the circumstances between the two types of communities in regard to relationship between lot size and sewer provision are different. The magnitude of the coefficient came as a surprise, suggesting that infrastructure use increases more quickly as lot sizes increase in form-based communities than in conventional. Understanding the reason for this is beyond the scope of this research (indeed beyond the scope of the data) but is an important area for future inquiry.

CONCLUSION

Form-based development has received much attention in recent years as a way to improve the aesthetics of the built environment, enhance community and create more efficient development. Form-based development is implemented at the level of an individual site, yet there has been little analysis of the alleged benefits of form-based development at this scale. This study sought to quantify one of those claims; the efficiency in infrastructure, by assessing sewer use in neighborhoods. Consistent with the normative claims in the theoretical literature, the empirical analysis found that form-based based developments were more efficient in their use of sewer than conventional developments. These findings suggest that there are economies of scale in sewer provision related to the design of neighborhoods.

One has to be careful, however, in reading too much into the findings. A wide array of definitions and characteristics for form-based developments were found within the literature. The same benefits are claimed for all types of form-based development. This study demonstrated that coming up with an operational definition of form-based versus

conventional development is not straightforward. Based on the criteria that were established in this study, many developments were hybrids of both conventional and form-based types of development. Therefore it is hard to know which aspects of form yield the most benefits: further study needs to explore in finer detail which design characteristics result in greater economic efficiencies. This could be done by using the same methods employed in this study, using each indicator as an independent variable.

Another analytical limitation relates to using sewer length as a measure of efficiency. The true cost of sewer provision is based on a number of factors not necessarily related to linear feet of sewer including the nature of the topography and the nature of the surface geology. Further study using a more refined measure of sewer cost might yield more refined results. In addition, it may be instructive to analyze the selling prices of these developments to determine the economic impacts of sewer provision. While developments with certain features may have a higher infrastructure cost, these features may be capitalized into higher prices. These findings nonetheless provide important insights for developers of residential communities and the municipalities that plan and regulate development. Form-based approaches have the potential to provide infrastructure efficiencies at the neighborhood scale. A more refined analysis might better identify aspects of form produce the greatest efficiencies, but form-based approaches should be encouraged for better use of infrastructure.

Empirical investigation of the impacts of form-based development is very much in its early stages. Until recently, there have not been a large number of completed communities to utilize in doing any hard analysis. Today these communities exist and there is great opportunity for future research in this area. With the advent of GIS technologies and the local data that is increasingly available, it is important to continue to investigate and determine the potential positive and negative impacts of development form as an alternative to conventional development patterns.

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