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Cost of Providing Government Services to Alternative Residential Patterns

Chesapeake Bay Program

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Cost of Providing Government Services to Alternative Residential Patterns

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Study Context

The Subcommittee on Population Growth and Development (the Subcommittee) was established to assist in the implementation of one of the seven goals of the 1987 Chesapeake Bay Agreement which reads "Plan for and manage the adverse environmental effect of human population growth and land development in the Chesapeake Bay watershed."

An important precursor to the work of the Subcommittee was a panel established by the 1987 agreement, known as the year 2020 Panel. The Panel's report, *Population Growth and Development in the Chesapeake Bay Watershed to the Year 2020*, known as *The 2020 Report*, contained a number of significant findings, including:

- A total of 1,716,418 new housing units will be constructed between 1990 and 2020; within the Chesapeake Bay watershed; if current development trends continue, 80 percent of these units will be located on one-third of the land converted to residential use. The remaining 20 percent of the dwelling units, consisting of large lot residential development, will be built on two-thirds of the land converted to residential uses.

- "It is unlikely that the roads, sewers, and other public facilities needed to fully support growth could be built, if growth continues in present patterns and densities (p. 33)."

- "Sprawl is an ineffective use of the land, difficult to service with infrastructure and transportation, requiring extensive use of automobiles, and consuming large land areas (p. 36)."

The 2020 Report noted that "the low density residential alternative produces environmental effects and infrastructure demands that are more expensive to remedy than medium and high densities" (p. 38). All of the above and other findings contained in the report have led the Subcommittee to seek additional information regarding the environmental and economic costs of low density residential development, often referred to as "sprawl" development to provide vital information to those making land use decisions within the Chesapeake Bay watershed.

In this report, "sprawl" is defined as residential development at a density of less than 3 dwelling units per acre, which does not have a locational component. That is, sprawl can occur either as leapfrog development located outside of existing service areas or as a development located in or adjacent to existing service areas.

Objective

As a result of these concerns, the Subcommittee established a two step process to begin to analyze the environmental and economic impacts of residential development. Its objective is to determine if there are significantly different economic and environmental costs that can be attributed to different types, forms, and locations of residential development. While the Subcommittee's objectives are set within the overall environmental context of the Chesapeake Bay Agreement, its initial focus is to assess the economic impacts of different types of residential growth. In particular, the Subcommittee has decided to investigate how the capital cost per dwelling unit of providing services and infrastructure, specifically public services and infrastructure, varies according to type, form, and location of new residential development.

As a next step, the Subcommittee will be investigating the specific water-quality impacts of various forms and patterns of development. With detailed analysis of both the economic and ecologic issues in place, the Subcommittee will be able to fully inform the Chesapeake Bay Program, the policy-makers of the region, and the development community regarding these issues.

The Subcommittee retained CH2M HILL to perform a comprehensive review of the literature dealing with how the capital cost of providing services and infrastructure varies according to the characteristics of residential development. The consultant's charge is to present the findings from the literature and draw conclusions where appropriate. The information in the study will then be one of many sources to be used by the Subcommittee in fulfilling its responsibility to "Plan for and manage the adverse environmental effect of human population growth and land development in the Chesapeake Bay watershed".

This first study has the following specific objectives:

- Provide an in-depth review of the current cost of development literature and other studies that address the cost of providing public services and infrastructure to different residential developments

- Describe the methods, approaches, and assumptions of the studies, and describe the applicability of their conclusions to the Subcommittee's mission and to the Chesapeake Bay watershed

- Identify factors that affect the capital cost of providing services and infrastructure to residential development

- Present data and conclusions from relevant studies concerning variations in the capital cost per dwelling unit of providing services and infrastructure, specifically for providing public services

The objective of the second study will be to examine the relationship between different arms of development and their affects on surface and groundwater quality. The study will attempt to concentrate on the effects of different residential patterns, and will explain the processes through which water quality is affected. Where they exist, recent and current watershed-wide studies in the Chesapeake Bay watershed will be examined. the results of the study will help local planning officials to better understand the water quality impacts of the different development terms they are faced with deciding upon at the local level.

Activities

CH2M HILL performed a comprehensive survey of the literature on cost of development studies (that is, those such as *The Costs of Sprawl* that had calculated variations in capital and annual service costs for different types of dwelling units), and other related planning studies. According to the Subcommittee's wishes, this search was primarily focused on identifying studies whose results would be the most applicable to the Chesapeake Bay watershed. The review encompassed a broad range of studies that had been performed throughout the country. The consultant contacted planning agencies within the watershed to obtain relevant studies. A number of planning agencies and non-profit organizations (such as the American Planning Association, Lincoln Land Institute, universities, trade organizations, etc.) were also contacted. A list of the organizations and individuals contacted is presented on pages G1 through G-4 following Chapter 5.

Organization

The literature review appears in Appendices A and B. Appendix A contains the more relevant studies that provided information about the costs of serving different types of residential developments. Each review describes the methodology and results, and presents a summary of the applicability of the results. Appendix B contains reviews of less directly applicable but interesting studies.

The report begins with Chapter 1 which presents the context of this study within the context of the mission of the Subcommittee and the Chesapeake Bay Program. Chapter 2 presents a review of the general approaches used in cost of development studies, based primarily on the material in Appendix A. Chapter 2 also identifies three types of public services based on the service characteristics and identifies factors that effect the capital cost of the different types of services. Chapter 3 describes the relationship between the cost factors and the capital costs of different types of services. Summary tables presented in Chapter 3 are supported by more detailed tables contained in Appendix C. Chapter 4 presents information from the literature about the capital costs per dwelling unit for providing infrastructure to different types and forms of residential development. Chapter 5 presents conclusions.

General Approaches Used in Cost of Development Studies

Chapter 2 contains an analysis of the methods and assumptions used in the reports analyzed for this study.

Types of Developments Analyzed

Most cost of development studies, such as *The Costs of Sprawl* and a number of others identified in Frank's *The Costs of Alternative Development Patterns*, defined prototype communities to control as many variables as possible, and to focus on cost variations due to differences in density, lot size, type of dwelling unit, and proximity to service areas. These studies usually use different mixes and densities of dwellings units for different prototypes with the same total number of dwellings units and the same total area. The distribution of dwellings units and density is not uniform across the prototypes.

Cost Approaches

The two approaches used in estimating capital costs produced by new residential development are the per capita and the marginal cost approach. The marginal cost is defined as the true cost incurred by a local government in supplying service or infrastructure to a new increment of residential demand, such as a subdivision. Marginal cost is the preferred approach and is used in project-specific studies. The definition of prototypical communities, used in such studies as *The Costs of Sprawl*, is an attempt to estimate marginal capital costs.

The per capita approach is more commonly found in county-wide fiscal impact models. This approach will be accurate where capacity utilization is high but not where it is in over-capacity, so that the average cost is close to the marginal cost. In situations where this is not true (that is, there are large amounts of current excess capacity), this approach will not be as accurate because the marginal costs of serving new development will be low.

Allocating Costs

One issue that confronts many studies is how to accurately allocate the true costs for new services and infrastructure to different types of land use, such as new residential development. This is relatively easy to do for infrastructure, such as water distribution pipes, sidewalks, streetlights, sewer collector pipes, and local streets, required within a new subdivision. Allocating costs is harder to do for other types of services and infrastructure, such as police, fire, recreation centers, libraries, and general government. Accurate allocation is particularly important for studies employing the per capita cost approach.

The most common approach is to allocate costs based on the residential proportion of the jurisdiction's total assessed valuation. This ratio is sometimes modified by also considering the ratio of the number of residential taxable parcels to the total number of taxable parcels, and by considering the average size of residential parcels to the average size of all taxable parcels. Allocation of costs can be done at a department level by examining service and use statistics, such as the distribution of police and fire calls, and solid waste flow records.

Classification of Services

Chapter 2 presents a classification of services based on their characteristics, including capital intensity (ratio of annual capital cost to total annual costs - defined as annual capital plus annual operating and maintenance costs); form (linear vs point), spatial arrangement, and the size of the service area (within a subdivision or neighborhood vs county or region). Four classes of services were identified:

- **Onsite.** These are the capital facilities on the lot that connect the dwelling unit to nearby, offsite public systems and right-of-ways

- **Intraneighborhood.** These services are provided to individual dwelling units within distinct residential developments, such as subdivisions or neighborhoods

- **Interneighborhood.** These services are provided over a larger service territory that covers a subarea of an entire municipality that contains many separate neighborhoods or residential developments. The services are provided to a group of neighborhoods and consist of the capital facilities connecting them.

- **Regional.** These services are provided to an entire municipality or to a larger region consisting of a number of municipalities

This study addresses only three types of off-site services: intraneighborhood, interneighborhood, and regional. This study does not address on-site services because these are almost always incurred by the property owner.

Services were classified as follows:

Intraneighborhood

- Sewer collector lines
- Water distribution lines
- Stormwater collector lines
- Collector streets, including subcollectors, loops, and cul-de-sacs
- Streetlighting
- Stormwater and drainage improvements, excluding the collector lines

Interneighborhood

- Capital-intensive
  - Sanitary sewer trunk or collector lines, and interceptors
  - Stormwater trunk or collector lines
  - Water trunk or distribution lines, and supply mains
  - Parks and recreation
  - Arterial streets

- Labor-intensive
  - Police
  - Fire
  - Solid waste collection
  - Emergency medical
  - Education, particularly elementary and possibly junior high/middle schools

Regional

- High schools
- Wastewater treatment plants
- Water treatment plants
- Water supply reservoirs
- Solid waste disposal facilities
- Highways
- General government administrative buildings

Chapter 2 describes the attributes of these services, noting their level of capital intensity, size of the service area, ability to allocate costs to residential uses, form, and arrangement.

Factors That Influence the Cost of Providing Service

Chapter 2 also presents a list of factors that influence the costs of providing services to new residential development. The primary focus is on the capital cost. The effect of the following factors is described below:

Attributes of the Service

- Capital intensity
- Form
- Spatial arrangement

Development Density

- Gross density
- Net density

Characteristics of the Development

- Lot size and shape
- Type of dwelling unit

Population Characteristics

- Total population served
- Population density
- Number of school-age children

Locational Attributes

- Proximity to existing service areas
- Proximity to employment
- Proximity to community facilities

Service Characteristics

- Capacity utilization
- Service and design standards
- Regulatory standards
- Shape of service area

Chapter 2 describes how these factors affect service costs, noting how variations in these factors affect the demand for and the cost of providing services.

Sensitivity of Capital Costs for Different Service Classes

Chapter 3 describes the sensitivity of capital costs for individual services within each of the three classes of off-site services (listed above) to the different factors. For example, for intraneighborhood services, the sensitivity of the capital costs of sewer collector pipes to the various factors is described in qualitative terms; for interneighborhood services, the sensitivity of the capital costs of elementary and middle schools to the same set of factors is presented.

A summary table for each class of service is presented in Chapter 3. It presents an ordinal ranking of capital cost sensitivity using the following scale:

- Highly Sensitive: a factor has a strong, direct effect on the capital cost of a service

- Sensitive: a factor has a direct, but not overly strong effect on the capital cost of a service

- Moderately Sensitive: a factor has a weak effect on the capital cost of service

- Minimally Sensitive: a factor has little or no affect on the capital cost of a service

Appendix C contains a set of tables that describes, in more detail, the capital sensitivity relationship between an individual service and each of the cost factors.

This scale expresses the sensitivity of the capital cost of a specific service to various factors. The determinations of capital cost sensitivity were made by CH2M HILL based on the literature reviewed for this study, on our experience in conducting planning studies, and on our engineering and design experience in preparing designs for different types of infrastructure.

The following trends can be observed in Tables 3-2, 3-4, and 3-6:

- The capital costs of intraneighborhood services are, for the most part, most sensitive to net density and lot size. These capital costs are also effected by service and design standards. Population and locational factors have moderate to minimal affects on the capital costs of intraneighborhood services.

- The capital costs of interneighborhood services tend to be, depending on their level of capital intensity, highly sensitive and sensitive to gross development density (for trunk lines and arterial streets), and highly sensitive to the population to be served (for labor intensive services). For the capital-intensive services, net density and lot size have less of an effect. Capital costs are also sensitive to service standards. Locational attributes have, with the exception of arterials, a minimal effect on capital costs.

- The capital cost of regional services is most sensitive to the total population to be served, and is only slightly less sensitive to capacity utilization and to design and service standards. The type of dwelling unit affects the capital cost for some services, such as high schools, water supply and water treatment, and highways. The cost of regional services is not sensitive to development density or to lot size.

Relationship of Capital Cost to Annual Cost

While the focus of this report is on the capital costs per dwelling unit, the annual capital costs required to provide services and infrastructure to a new dwelling unit comprise a minority of the total annual costs (annual capital plus annual operating and maintenance costs) incurred by local governments. Three studies indicate that annual capital costs per dwelling unit are probably between 20 to 30 percent of total annual costs per dwelling unit. This assumes that public water and sewer are provided and that the bundles and levels of services provided are comparable to those supplied in most suburban counties located in metropolitan areas within the Chesapeake Bay watershed.

This proportion would be near or below the low end of this range when impact fees and proffer charges require property owners to pay the full marginal capital cost of providing services and infrastructure, particularly if some of the marginal capital costs of interneighborhood and regional services are incurred by property owners. The actual proportion could be higher where service levels are high or where high public capital costs are incurred in providing interneighborhood and regional services, such as water and sewer trunk lines, new water and wastewater plant treatment capacity, and school expansions.

The Cost of Development

Chapter 4 presents data on the capital costs per dwelling unit for different types of density of housing. The two main sources were *The Costs of Alternative Development Patterns* and *The Costs of Sprawl*. This chapter provides readers with estimates of the capital cost per dwelling unit that are contained in the literature. The estimates are presented in Tables 4-1, 4-2, and 4-3. The information in these studies was modified to correspond to the classes of services identified in this study, although it was impossible for the information to correspond exactly.

Chapter 4 notes how difficult it is to develop capital cost estimates and to precisely measure the influence of different factors, such as density, lot size, location, service levels, etc. Chapter 4 presents a caveat concerning the complexity of the relationship between capital costs per dwelling unit and the factors identified in this study. This caveat is worth noting here:

> "Distinctions among alternative development factors form the experimental variables that are manipulated to observe the extent to which development costs change concurrently. The crucial terms are density and lot size or lot width, municipal improvement standards, characteristics of the occupants, contiguity of development, distance to central facilities, and size of the urban area. Each one, when allowed to vary, has a discernible effect on development costs, but when they are all allowed to vary at the same time, the independent effect of each is difficult to measure because of simultaneous effects" (Frank, p. 37).

Two important points are worth noting. First, there are factors that affect the capital costs per dwelling unit in addition to density and lot size; the list Frank identified corresponds to the list of factors identified in Chapter 2. Second, it is difficult to precisely isolate the effect of the different factors on the cost of providing public services to residential development.

Capital Costs of Intraneighborhood Services

Table 4-1 contains capital cost estimates for densities of 1 dwelling unit per acre or greater, and compares the cost of neighborhood services (updated to account for escalation) in *The Costs of Alternative Development Patterns* with intraneighborhood services as defined in this study. The figures in Table 4-1 show a decline in capital costs per dwelling unit as density increases. This should not be interpreted as density being the only factor causing such a decline in capital costs. Frank's caution presented above should be kept in mind. An examination of Table 3-2 indicates that factors other than density and lot size, such as service standards and the type of dwelling unit, affect intraneighborhood capital costs.

The capital cost per dwelling unit of intraneighborhood services for residential development at a density of 1 dwelling unit per acre or greater declines on a per dwelling unit basis as density increases. While such a decline may be due primarily to development density and lot size, other factors also have an effect.

Capital Cost of Interneighborhood and Regional Services

Attempts at estimating the capital costs for interneighborhood services have been made in several studies while few attempts have been made at estimating the capital costs of regional services, with the exception of high schools. *The Costs of Sprawl* paid only limited attention to the capital costs for other interneighborhood services that are external to a residential development. As Frank has noted, even where interneighborhood capital costs, such as water and sewer trunk lines connecting treatment plants to leapfrog residential development, have been estimated, the estimate has been flawed.

Table 4-2 presents a partial estimate of the capital cost for providing both interneighborhood services and some regional services. This table includes the costs for sewer, water, and storm sewer trunk lines; all schools; solid waste collection and disposal; police, fire, parks and recreation; general government; and arterial streets. The table excludes the cost of constructing new wastewater and water treatment plants, and a new water supply facility. Capital costs are presented for 5-mile and 10-mile distances between the residential development and employment centers, water and wastewater treatment plants, and a receiving body of water.

The data for interneighborhood and regional services show that the capital costs per dwelling unit of inter-regional and some regional costs decline relatively little as density increases. Other factors, such as proximity to the service area (for sewer and water trunk lines), population (for labor intensive interneighborhood services, water and sewer treatment plants), and locational attributes (for arterial streets and highways) have more of an effect on capital costs than does lot size or density.

Table 4-3 combines the figures from Tables 4-1 and 4-2 and presents the capital costs per dwelling unit for intraneighborhood, interneighborhood, and some regional services. The total capital cost per dwelling unit of facilities needed to service new residential development declines as development density increases. Such a decline is due to many factors other than density and lot size, particularly for interneighborhood and regional services. The decline in capital costs per dwelling unit occurs primarily for intraneighborhood services, assuming these are publicly funded–not incurred by property owners through impact fees and proffer charges.

The caveats contained in the literature, and the complexity of the relationship that determines the capital cost of providing services and infrastructure to residential development, make it virtually impossible to precisely specify the effect contributed by any one factor. For example, it would be inaccurate to interpret that these tables show that density is the most important factor. Density is clearly not the only factor in reducing capital costs per dwelling unit in providing public services and infrastructure. When looking individually at the three classes of service and assuming that the capital costs of the full bundle of services is incurred by local jurisdictions, some conclusions can be drawn about 15 dwelling units per acre, according to the literature.

The capital cost per dwelling unit of providing intraneighborhood services declines as density increases, primarily because of the spatial effects noted in this study that increase the length of collector and distribution pipe, and local streets per parcel. High density, compact residential developments are cheaper to service, on a dwelling unit basis, up to about 15 dwelling units per acre, according to the literature. Above a certain point, for example for high rise apartments, the capital costs per dwelling unit begin to increase over the costs for attached housing, such as townhouses. The decrease in intraneighborhood capital costs per dwelling unit observed as density increases is due to density and lot size, and other factors, such as the service standard.

Conclusions

Presented below are the conclusions that can be made from the literature reviewed for this study:

Conclusion 1: The capital cost per dwelling unit of intraneighborhood services declines as density increases and lot size diminishes; although the decline is due primarily to development density and lot size, other factors also have an effect.

Conclusion 2: An increasing proportion of the marginal capital costs per dwelling unit, particularly for capital-intensive intraneighborhood services, are being incurred by the homeowners through the imposition of impact fees and proffer charges.

Conclusion 3: Density and lot size are not the only factors that determine the capital cost of providing intraneighborhood services. Service and design standards also affect capital costs.

Conclusion 4: The precise contribution of cost factors in determining the total capital cost per dwelling unit remains unclear, particularly for interneighborhood and regional services, but some idea of relative effects can be ascertained.

Conclusion 5: The greatest reduction in total capital costs per dwelling unit through the use of higher density residential development is achieved in intraneighborhood services. The reduction in capital cost per dwelling unit from more efficient development forms is greater at the subdivision or neighborhood level and is smaller at the municipal, county, or regional level.

Conclusion 6: The use of compact, higher density residential development forms produces a small percentage savings in capital cost at the regional or statewide levels.

Conclusion 7: Infill development or contiguous development will minimize marginal capital costs for interneighborhood services and, to a lesser extent, for regional services.

Conclusion 8: Increases in the population growth rate and population density produce increases in local per capita annual operating and maintenance expenditures and, to a lesser extent, in annual per capita capital spending.

Conclusion 9: The capital cost per dwelling unit of providing services is only a minor proportion of the total annual costs per dwelling unit (annual operating and maintenance cost plus annualized capital cost).

Conclusion 10: Not all local jurisdictions provide comparable bundles of services, either in terms of the types provided or service levels. This complicates comparing the cost of providing services to dwellings units located in rural areas to that of suburban areas.

Conclusion 11: Demographic characteristics of the occupants of dwellings units to be served are a major factor in determining the demand for and resulting cost of providing labor-intensive services to new residential development.

Conclusion 12: The cost of providing education services, both capital and operating, is the largest cost per dwelling unit expense in most local budgets. Education costs are only minimally sensitive to development density and lot size, and, to a lesser extent, to the location of new development.

Presented below are conclusions about capital cost for each of the three types of services considered by this study.

Intraneighborhood Services

Because of their linear, capital-intensive nature, the capital costs of intraneighborhood services are the most sensitive to the form and development density of residential development. These services have the greatest potential for shifting capital costs from local governments to property owners through the use of impact fees.

- The capital cost of all intraneighborhood services, except stormwater structures, is highly sensitive to lot size and net development density. Both factors interact to determine the spacing between dwelling units; frontage length of pipe, streets, street lighting, and sidewalks required per residential lot; and, ultimately, capital cost.

- Intraneighborhood capital costs are sensitive to gross density. Where gross and net densities are nearly equal (as in standard subdivisions where there is no clustering), capital costs are highly sensitive to gross density.

- Intraneighborhood services can be provided most efficiently (cost per dwelling unit) for high-density, compact, residential developments, although density and lot size are not the only important factors. As shown in Table 3-2, intraneighborhood capital costs vary in sensitivity to service and design standards.

- The marginal capital cost of providing intraneighborhood facilities to new residential development is much lower when density is increased or infill development occurs than it is when the new development is built in unserved areas in a leapfrog or scattered form. Changes in density and flow coming from within a given residential area produce relatively small changes in the capital cost of intraneighborhood and interneighborhood facilities, particularly water and sewer pipes.

Interneighborhood Services

The capital cost of interneighborhood services are, in general, less sensitive to lot size and net density, and are more sensitive to gross density and to the size of the population to be served. Major conclusions about interneighborhood services are presented below:

- The capital cost of interneighborhood services is less sensitive than that of intraneighborhood services to the development density and lot size of the residential areas being served, and is more sensitive to population density within the service area and to locational factors

- The cost of linear, interneighborhood services, such as water, sewer, and stormwater trunk lines, and roads, are highly sensitive to the gross development density of the service area. This determines the total length of the network that connects demand centers, such as neighborhood and subdivisions, with interceptors or central treatment facilities.

- The most expensive residential land use pattern in capital costs per dwelling unit consists of scattered, noncontiguous neighborhoods and subdivisions, which results in low service area gross density

- The capital cost of interneighborhood services, with the exception of education, is a much smaller proportion of total capital costs per dwelling unit than that of intraneighborhood services

- Locating new residential development at the edge of existing service areas decreases the capital and annual costs of providing interneighborhood services. The capital cost of providing the linear capital facilities that connect a new development to the existing infrastructure systems is minimized. A contiguous location also allows for more cost-effective capital facilities that support such labor-intensive interneighborhood services as solid waste, police, fire, and emergency medical.

Regional Services

In general, the capital costs for providing regional services are most sensitive to the population factors and service standards, and are less sensitive to the development density, type, and location of the new residential development. Regional services, with the exception of general government, generally are provided in large increments of capacity, have long service lives, and often enable economies of scale in unit capital and operating and maintenance costs to be obtained.

- The capital costs of water and wastewater treatment, water supply facilities, and solid waste disposal facilities are highly sensitive to the number of persons to be served, which includes the current and projected populations. Often, these facilities must be designed with substantial initial excess capacity to accommodate future development.

- The capital cost of most regional services are sensitive to service characteristics, specifically service standards and capacity utilization. Design standards determine the capital cost of regional facilities through engineering standards and regulations that may specify treatment methods. Underutilized regional facilities, particularly water and wastewater treatment plants, highways, and water supply facilities, can impose high initial marginal costs on existing residents.

Chapter 1
Introduction

Purpose

The significant population growth and development that occurred within the Chesapeake Bay watershed from the 1970s through the mid-1980s concerned the citizens and public officials. Specifically, they were concerned that the environmental and economic vitality of the region was increasingly threatened. Unmanaged growth was creating pollution and traffic congestion, farmland and forest lands were being converted to residential uses through the outward expansion of low density housing, and the environmental quality of the Chesapeake Bay was declining. In response to these concerns, in 1987, the Chesapeake Bay Agreement was developed to promote intergovernmental cooperation to help restore the environmental and economic health of the watershed. Signers of the agreement included: the Governors of Maryland, Pennsylvania, and Virginia; the Mayor of the District of Columbia; the Chairman of the Chesapeake Bay Commission; and the Administrator of the U.S. Environmental Protection Agency.

The agreement included goals and commitments for seven areas, including the following goal for population growth and development:

> "Plan for and manage the adverse environmental effects of human population growth and land development in the Chesapeake Bay watershed."

To achieve this goal, a 12-member panel was commissioned to report by December 1988 about anticipated growth and related issues through 2020. The panel's specific charge was to report about the following items:

- "Anticipated population growth and land development patterns in the Bay region through the year 2020."
- "Infrastructure requirements necessary to serve growth and development."
- "Environmental programs needed to improve Bay resources while accommodating growth."
- "Alternative means of managing and directing growth."
- "Alternative mechanisms for financing government services and environmental controls."

The 12-member panel published its report, *Population Growth and Development in the Chesapeake Bay Watershed to the Year 2020 (The 2020 Report)* in December 1988. This report contained the following projections about future development patterns anticipated in the watershed:

- Population within the Pennsylvania, Maryland, and Virginia portions of the watershed would grow by 2.6 million people (from 13.6 million in 1990 to 16.2 million by 2020); an increase of 19 percent. The highest percentage increase in population was forecast for Virginia, followed by Maryland and Pennsylvania.

- The growth will not be uniformly distributed but will be concentrated in metropolitan areas and near shore areas located in the southern part of the watershed, adjacent to the Bay

- Land consumption for developed uses was projected to continue to increase faster than the rate of population growth. Between 1970 and 1980, the population in Maryland grew by 7.5 percent but developed acreage increased by 16.5 percent. Within the entire basin, population grew almost 50 percent between 1950 and 1980, while the amount of land used for commercial and residential purposes grew by 180 percent. The report forecast that developed land, which comprised 10 percent of the land area within the watershed, will increase to 16 percent by 2020.

- A total of 1,716,418 new housing units will be constructed between 1990 and 2020, consuming a total of 636,360 acres (gross density of 2.7 dwelling units per acre), including an allowance for the area required by new roads. Most of this development will occur through the conversion of farmlands and forestlands.

- Eighty percent of new housing units will be built on only one-third of the land area being converted to residential uses, most of this occurring within sewer service areas. In contrast, 20 percent of the new housing units will consume two-thirds of the land converted to residential uses. Most of this development will occur on large lots located outside water and sewer service areas. Future land consumption per new dwelling unit could decrease because of a variety of factors, including higher land costs, higher energy costs, and decreased household size.

The 2020 Report described recent trends and forecast the impact of these future growth patterns on key resources within the watershed:

- Between the mid-1950s and the late 1970s, approximately 2,800 acres of wetlands were lost annually to new development. During this period, Maryland lost about 5 percent of its total wetlands, while Pennsylvania and Virginia lost about 6 percent each. Inland wetlands disappeared at a faster rate than coastal wetlands.

- By 2020, an additional 260 million gallons of wastewater per day will be generated within the watershed, requiring a substantial investment in sewer collection and treatment infrastructure.

The 2020 Report noted that the infrastructure cost impacts associated with the new residential development, particularly low-density development, could be significant to both state and local governments:

- Eighty percent of the variation in on-site capital costs is attributable to variations in density and lot size. Most of these capital costs are incurred by the home buyer. Off-site costs for roads, water, sewer, and schools, usually incurred by local or state governments, could be significant.

- It is unlikely that the roads, sewers, and other public facilities needed to fully support growth could be built, if growth continues in present patterns and densities

- Sprawl is an ineffective use of the land, is difficult to service with infrastructure and transportation, requires extensive use of automobiles, and consumes large land areas

These findings all confirm the Subcommittee's continuing concern with both the environmental and economic impacts produced by continued low density residential development.

The term "sprawl" is used often to describe the extension of new, low-density residential development beyond the existing edge of suburban development. "Sprawl" is one of those terms everyone seems to know but has no standard definition. In *The Costs of Sprawl* (Real Estate Research Corporation; 1974), "sprawl" at the neighborhood or subdivision level was defined as standard single family detached dwelling units at a gross residential density of two dwelling units per acre. Based on definitions used in other studies, such as *The Costs of Alternative Development Patterns*, "sprawl" used in our study will refer to residential development at a density of less than three dwelling units per acre. This definition does not have a locational component, although many people often infer that sprawl applies only to "leapfrog" residential development located beyond the edge of development and public service areas.

Regardless of its location (suburban or rural), sprawl is a land-consumptive form of residential development and, when combined with other locational factors, such as "leapfrog" or "scattered" development, may result in inefficiencies in providing government services.

The concern about the continuation of residential sprawl development includes the density of the new development and its location within a metropolitan region. Several other terms also apply to the spatial pattern of new residential development, including "leapfrog", "contiguous", and "scattered". The first term, described above, results in vacant land between the development and the suburban fringe, which is often the edge of the service area for water, wastewater, and other local government services. The second term refers to new development that is located at the edge of the suburban fringe. The third term refers to separate new residential developments (all of which are leapfrog) that are dotted throughout rural or agricultural areas and are surrounded by undeveloped land. Depending upon its density, scattered developments may not necessarily be "sprawl" but its locational attributes, as explained in Chapter 4, do affect the capital cost of providing public services.

The Subcommittee is concerned that the continuation of the recent trends of residential development that have occurred within the Chesapeake Bay watershed, be they sprawl, leapfrog, or scattered, may have significant environmental and economic impacts within the watershed. In economic effects, a primary concern is that sprawl development, along with leapfrog or scattered residential development patterns, may impose high costs on local governments and their taxpayers (the capital costs of supplying the local government services, particularly infrastructure, such as roads, water, sewer, storm sewers, and schools). Sprawl development can also have wildlife negative environmental consequences such as the elimination of habitat conversion of agricultural soils, loss of wetlands, and encroachment of development into water supply areas. The specific question for this study is whether higher public service capital costs per dwelling unit are incurred in servicing residential development that is sprawl, leapfrog, or scattered.

This study examines the literature that estimated the capital costs of providing local public services to alternative residential forms that vary according to their density, lot size, location, type of dwelling unit, and other characteristics. The primary emphasis is on capital costs because this type of cost impacts a local government's long-term financing, although annual operating and maintenance costs also are discussed, where appropriate. However, in Chapter 4, both total capital and annual capital costs examined for their proportion of total local annual cost per dwelling unit (annual capital and annual operating costs).

CH2M HILL reviewed the literature and analyzed it to accomplish the following:

- Describe the methodologies used in the study
- Indicate the applicability of each study's findings to the Chesapeake Bay watershed
- Classify local government services based on characteristics that determine their capital costs, such as size of service area, degree of capital, labor intensity, form, and spatial arrangement
- Identify those factors that affect the capital cost of providing local government services and describe how their impacts vary by the type and characteristics of the service being considered

- Present estimates from the literature about the capital cost per dwelling unit for different forms of residential development

- Present conclusions drawn from the literature on how capital costs per dwelling unit for different types of services are affected by different cost factors

This report concentrates on the capital costs of providing the full bundle of local government services to new residential development. The emphasis here is on costs that would be incurred by public jurisdictions. However, through the growing use of proffer charges and impact fees, an increasing share of the cost of capital facilities required to serve new residential development is being incurred by the property owners.

Organization

Chapter 2 identifies the factors that affect the cost of providing local government services to residential development. This is done in three steps:

- Describe the approaches used in cost of development studies

- Classify local government services according to their characteristics

- Identify the factors that affect the capital cost of providing the different types of services

Chapter 2 gives the reader an understanding of the full range of factors that affect the capital costs of providing local government services. These factors include the characteristics of the service, locational considerations, and regulations, as well as the characteristics of the residential development, such as development density.

Chapters 3 and 4 synthesize the results of the two preceding chapters. Chapter 3 describes how the sensitivity of the capital cost for the different types of service varies according to the different cost factors. Summary tables describe the relationship between cost and a service's capital cost sensitivity. Chapter 4 presents figures from the literature about how capital cost per dwelling unit varies for different types of residential development.

Chapter 5 presents a summary of the results of the study, focusing on the material presented in Chapters 2 and 3.

Appendix A presents summaries of the studies and the findings that are most applicable to the objectives of the Subcommittee. This material was used in preparing Chapter 2. Appendix B presents summaries of additional studies. Appendix C displays the detailed tables and information that were used as a basis for the summary tables found in Chapter 3.

CH2M HILL conducted a comprehensive literature search to identify the most recent studies by performing the following activities:

- Performing a computerized literature search to identify studies and journal articles

- Contacting national planning organizations, such as the American Planning Association, Lincoln Land Institute, and the International City County Managers Association, to obtain relevant studies

- Contacting state, county, and local planning organizations throughout the Chesapeake Bay watershed to obtain relevant studies and to identify case study developments

Assumptions

This study analyzes the capital cost of providing the full bundle of local government services to new residential development located in suburban areas. The complete list of services considered is presented in Chapter 2 and this list includes public water and sewer, plus the other services noted in Chapter 2. The service bundle does not include local social services that are often incurred by city governments, nor does it consider the smaller bundle of services provided to residential development in rural areas (which usually excludes public water and sewer waste collection, and includes the use of unimproved local roads). This study considers capital costs that will be incurred by public jurisdictions, such as a municipality, township, county, or state government; or a utility authority.

Chapter 2
General Approaches Used in Cost of Development Studies

Purpose

This chapter presents the general approaches that were used in the studies described in Appendices A and B. Before analyzing how different factors affect the capital costs of providing services (the topic of Chapter 3) it is useful to identify what methods, data, and assumptions were used in the various studies. (It is important that local policy makers understand how the literature approached the analysis of the cost of development, particularly in assumptions and methods employed. This is particularly true where local planning officials may be evaluating the costs of new residential development.) The items discussed in this chapter include the methodology used, the types of services, and cost approaches used. Following this section, a classification of service types is presented, based on the geographic area they serve.

One important finding from the literature is worth noting now. The density and location of a residential development were not the only factors that were important in determining the capital costs of providing local government services. Other factors included the characteristic of the service (that is, capital intensity), the characteristics of the residents, and the service standard. A secondary objective of this chapter is to identify those factors that affect the capital cost of providing services.

Methodology

This subsection describes the major methodologies used in performing cost-of-development strategies. This subsection covers the analytical basis for the developments that were evaluated, the economic approaches, and the allocation of costs.

Type of Development Analyzed

There were two analytical approaches that were used in cost-of-development studies:

- Use a hypothetical residential subdivision or community that contains assumptions about type and mix of dwelling units, gross and net density, lot size, demographics, distance to work and community facilities, etc. The assumptions are used to define, in detail, the demand for services and infrastructure produced by a dwelling unit.

- Analyze existing residential patterns of either the entire residential land use sector within a local government or an individual residential development, such as a subdivision (that is, the case study approach). This empirical approach uses data on the existing costs and revenues in the jurisdiction being studied and allocates them to the residential sector.

Hypothetical Residential Pattern

The use of a hypothetical development pattern required that a number of characteristics and design standards be described and defined to determine the demand for services and infrastructure produced by a dwelling unit. Some of the characteristics requiring definition included the following items:

- Development characteristics, including dwelling unit mix, density (both net and gross), and lot size
- Locational assumptions, such as proximity to water and sewer treatment plants, journey to work, proximity to schools, etc.
- Dwelling unit characteristics, such as floor area, cost, number of bedrooms, and real and assessed market value
- Demographic parameters, such as persons and school children per household
- Service standard levels, such as the number of persons served by a park, number of fire stations, or number of children per classroom
- Design standards, such as road cartway width
- Unit demands for service, such as water consumption per capita, wastewater generated per capita, and solid waste generated per capita
- Unit infrastructure amounts, such as length of sewer, water, and roads per dwelling unit or inhabitant
- Costs borne by the home buyer vs those incurred by the government jurisdiction
- Characteristics of inhabitants, including income levels and age of inhabitants
- Transportation characteristics, such as number of trips per dwelling unit and trip length by type

Information used to define these variables came from a variety of local, empirical sources and from published literature.

Once the demand was estimated, cost data were developed and used to estimate capital and total annual costs. This cost data included unit capital costs for infrastructure and per capita costs for annual services. The cost data came from either local empirical sources, such as budgets and capital improvement plans, or from the published literature, such as unit costs for infrastructure. Most of the studies using hypothetical development patterns evaluated the costs of new "greenfield" residential developments located at (that is, contiguous) or beyond (that is, leapfrog) the existing edge of services and for which a complete set of new services and infrastructure would be required.

The most well-known example of the use of hypothetical development patterns is *The Costs of Sprawl,* which analyzed residential development patterns at both the neighborhood (that is, 1,000 dwelling units of the same type) and community (that is, 10,000 dwelling units consisting of a mix of dwelling unit types). James Frank's review of cost-of-development studies, *The Costs of Alternative Development Patterns,* prepared for the Urban Land Institute in 1989, identified five other studies (Wheaton and Schussheim, 1955; Isard and Coughlin, 1957; Urban Land Institute, 1958; Stone, 1973; and Downing and Gustely, 1977) that used a hypothetical subdivision as a basis for analysis. More recently, the Maryland Department of State Planning's *Environmental and Economic Impacts of Lot Size and Other Development Standards* also used different hypothetical subdivision arrangements.

Advantages. There were some significant advantages in using a hypothetical residential development pattern:

- The marginal costs directly attributable to a new development could be more accurately measured. The level of services and amount of infrastructure required for the new dwelling units could be precisely defined, permitting costs to be determined more accurately. For example, explicit assumptions concerning the level of service, length of water and sewer mains (or roads) required per dwelling unit, or the size of the population being served could be defined and accurate costs developed from them.

- The use of current cost data and assumptions enabled the actual service costs that would be incurred to be more accurately estimated.

- The effect of an individual factor (for example, density, lot size, or number of bedrooms) on demand and on costs could be more easily determined. This could be done by using a sensitivity analysis in which the values for one factor, such as lot size or number of persons per household, was changed while holding all the other factors constant.

- A hypothetical development may have more accurately reflected the service costs that actually would have been incurred under the existing master plan and zoning ordinance. (A study of an existing development unavoidably incorporates the zoning regulations and service levels that prevailed when the development was built, and may produce costs and revenue estimates that will not accurately represent those that will be incurred.)

Disadvantages. There were disadvantages in using a hypothetical community:

- The studies required a large amount of data to define all the factors determining demand and to provide the necessary cost assumptions. These studies can be costly and time consuming to prepare.

- The hypothetical community may not have accurately reflect current conditions, if it was too abstract. It may, in fact, have represented an idealized development pattern as opposed to an actual pattern that would have occurred under the zoning ordinance.

- The results were highly dependent upon the assumptions used in constructing the prototype.

- When comparing different forms of development, occupying the same land area and containing the same total population, the high density alternative consisted of a cluster of high density development surrounded by open space in comparison to the low density alternative that is usually uniformly distributed. High density development may have not necessarily occurred in this way, except in a planned community, so the results may be limited in applicability.

Existing Residential Land Uses

Existing residential developments or the entire residential land use sector of a municipality are used less frequently in cost of development studies, and more often in fiscal impact studies (American Farmland Trust, Loudon County, 1992). Existing residential land uses were assessed in two ways:

- The entire residential sector of the jurisdiction being studied was evaluated. This sector consisted of all parcels classified by a tax assessor as being in residential use. This was commonly done when using fiscal impact models to assess the impacts of alternative future development scenarios (Loudon County, 1990).

- An individual residential project is analyzed. This project can be either a new individual subdivision, when assessing leapfrog growth, or a spatially, well- defined neighborhood, when assessing infill developments.

The cost and revenue estimates were obtained from local data sources, such as municipal budgets, capital improvement plans, and state level documents that provided financial data by service category. Heads of local agencies were also contacted to determine capacity utilization levels, plans for expansion, and average and marginal costs of services. Other published data sources, such as census information, were also used. This information was often supplemented by other data, such as unit cost estimates, socioeconomic assumptions, and generally accepted values that have been published.

Advantages. There were four advantages in using an existing development as the basis for an analysis:

- Costs specific to the host locality providing the service were used. This ensured that costs accurately reflecting conditions prevailing in the study area were used.

- Information was readily obtainable and the studies could be performed more quickly and cheaply

- The development, if very recent, reflected the type of projects allowed by the master plan, zoning ordinance, and site plan ordinance

- Enabled marginal costs to be more accurately considered, particularly when accompanied by discussions with local service providers to determine actual marginal costs to be incurred

Disadvantages. There were four disadvantages in using an existing development as the basis for an analysis:

- It was difficult to determine and allocate the proportion of total local service and infrastructure costs to the residential sector that accurately reflected its demands. Costs were usually allocated based on some combination of the residential sector's proportion of total municipality-wide assessed value, taxable acreage, and average parcel size.

- It was hard to determine the effect on total service costs attributable to one specific factor (that is, conduct a sensitivity analysis), such as density, lot size, floor area, or population

- It was primarily an average cost approach as opposed to a marginal cost approach (see below for an explanation of the difference)

- It may have been hard to determine the allocation of total annual costs among annual capital and O&M costs

Cost Approaches

There were two methods used in determining the total costs of service and infrastructure produced by the demands generated by a residential development:

- The average or per capita cost approach
- The marginal cost approach

Many cost of development studies determine the true marginal cost of providing services and infrastructure to a new residential development. In some cases, the use of average costs accurately measures these costs; in other cases, it does not.

Average or Per Capita Cost Approach

Average cost is the total cost for providing services or infrastructure divided by the number of persons (or dwelling units or school-age children) served. Average cost factors are usually calculated for an entire municipality or service area. The average cost approach is the most commonly applied and is heavily used in municipality-wide fiscal impact studies.

There were several assumptions implied in using per capita multipliers:

- The true cost of serving a new dwelling unit or person (that is, the marginal cost) was the prevailing average cost. This tended to be true where existing systems were utilized close to their full capacity, having neither significant excess capacity nor operating at or above current capacity. In these situations, the cost of extending service to one more unit of demand was at or close to the average cost.

- The current level of utilization for a service system was used in estimating the average cost. Thus, a system with a high level of capacity utilization tended to have lower per capita costs, and vice versa.

- The current cost situation would prevail in the future. This may not be true if service standards are different in the future (that is, capital costs/service unit would change), or if technological innovations or new regulations change the cost of providing a service. Even if the current average cost accurately measured marginal cost, it was not necessarily true that the average cost would prevail in the future.

- The current level of service would prevail into the future

- It assumed that the increment of demand was a small proportion of the total system capacity. If this was not true, marginal costs could be high as a capacity expansion could be required.

The average cost approach was most applicable to infill projects or those located at the edge of a current service boundary. This approach could be accurately applied to fully developed municipalities where the service and infrastructure systems have been installed and have a high capacity utilization factor. The average cost approach was also applicable where the incremental increase in demand was a small percent of the total service system capacity, assuming, of course, that the system has a high, but not a 100 percent, capacity utilization factor. In these situations, the increase in demand was not likely to be large enough to require an increase in system capacity, which would impose a high marginal capital cost because of the excess capacity.

Another issue of concern in applying the current average cost to future developments was whether the applicable average cost should be that which prevails now at the current capacity utilization rate, or that which will result in the future once the new development begins receiving service. In general, as the size of the population served by a system increases when it has sufficient excess capacity to accept them without needing a physical expansion (that is, no new capital expenditures are required), the average cost declines. This was particularly true for capital-intensive services, like water and sewer, and was less so for labor-intensive services, like police, fire, and education. The marginal cost was less than the average cost because of the excess capacity.

Advantages. There were number of advantages to using the average cost approach:

- It is the most widely applied methodology
- It is applied easily and quickly
- Existing information could be used, such as revenue and expense data from local budgets
- It was most accurate where utilization was at or near capacity and where the incremental increase in demand was small

Small increments of demand (that is, one or two new students in a classroom) may be absorbed with little or no marginal costs, so analysts had to examine the current capacity utilization. Small increments of demand, relative to current capacity utilization of the entire system, were less likely to require large capacity expansions.

Disadvantages. There were some significant disadvantages to using the average cost approach:

- It is an average cost method. The true marginal cost of providing services or infrastructure to a residential development may not be accurately measured.
- It measured costs at one point in time. As technology, service standards, and preferences of residents change, the average cost can change over time.
- Its applicability was limited to those situations where the marginal cost equals the average cost.
- It tended to make demographic factors (for example, persons and school-age children per household) the most important factors in the cost of providing services, particularly labor-intensive services, to residential developments. For forecasting future impacts, it placed a premium on having accurate forecasts.
- It assumed that current capacity utilization levels and service standards prevail in the future

Marginal Cost Approach

The marginal cost is defined as the true cost incurred by a local government in supplying service to a new increment of demand, such as a new subdivision. Marginal costs consist of the actual expenditures that the local government would otherwise not have made to supply services that are directly attributable to the demands of a new development. The marginal cost approach was most applicable where current systems have either significant excess capacity, or are operating at or over capacity, and was most applicable for leapfrog developments located beyond current service boundaries. In both cases, the marginal cost of servicing new dwelling units would not be accurately reflected by the average cost.

Marginal costs can vary significantly from average costs depending on capacity utilization and other factors. The average cost of educating a student is the total annual educational expenses divided by the number of students, usually a figure of around $4,000 to $8,000 for most suburban school districts. The marginal cost of accommodating a student from a new home would be very low, if the nearest school had sufficient capacity. In situations where there is room in individual classrooms for new students, the marginal cost for adding a single student, or even a small number of students to classrooms would be very low. No new teachers would have to be hired and the building would not need to be expanded. The marginal cost would consist of the cost of providing the student with books, materials, other services, and possibly transportation. The marginal cost would certainly be much less than the average cost. The reverse would be true where the development of a large subdivision would produce a large enough increase in enrollment such that a new school would have to be constructed. In this case, the marginal costs would exceed the current average costs.

Marginal costs were determined by examining the current and future capacity utilization levels in the services that would be demanded by a new residential development. The key issue was what additional resources will be required to accommodate the new units of demand. Managers of local service systems should be interviewed to determine capacity utilization levels before and after the new development was being served, and to obtain their judgement about the additional resources that they will have to commit to accommodate the new demands. This is the case study approach as defined by Burchell and Listokin in *The Fiscal Impact Handbook.*

The marginal cost approach was the most theoretically correct approach to apply in estimating the cost of development studies, and offered the following advantages and disadvantages.

Advantages. The advantages to the marginal cost approach included the following:

- It measured the actual incremental costs to service a new residential development. Thus, it was the most methodologically correct approach.

- It considered existing and projected capacity utilization in developing cost estimates

- It can consider situations where there was either excess capacity, or a shortage of capacity, and where development would result in a large proportional increase over current levels

Disadvantages. There were some disadvantages to using the marginal cost approach:

- Defining the true marginal cost was difficult, and required a large amount of information and time

- It has been applied only in a few studies

- It required an in-depth understanding of the functioning of current service systems to determine the incremental costs that would actually be incurred

Full Capital Costs vs Precipitated Capital Costs

One of the early cost-of-development studies (Wheaton and Schussheim, 1955; as summarized in Frank, 1989) made a valuable distinction between full capital costs and precipitated capital costs that relies on the concept of average vs marginal cost. Most developments will not require the local municipality or authority to install capital improvements for all of the services they provide. The marginal capital costs will be very low or possibly zero for some service categories (that is, no additional classroom space is needed to accommodate a new student), and high for others. This study offered the following definitions:

- Precipitated capital costs are for those improvements, either new facilities, upgrades, or expansions in capacity, that must be made to meet the service demands generated by a new development

- Full capital costs are those incurred for providing the full range of services provided to a new development, including the per capita portion of existing services

- Where there is existing capacity in infrastructure or service systems, there may be no precipitated capital costs, although some annual operating and maintenance costs may be incurred. In this instance, the marginal annual costs (including capital and O&M) are very low.

The concept of precipitated capital costs is important because when new residential development imposes full capital costs for a full range of services, the total costs begin to be unacceptable to existing taxpayers and the new residents being served. One objective in managing new residential developments could be to minimize precipitated capital costs.

Statistical Approach

A small number of studies also applied statistical methods in estimating the costs of providing services as a function of the type of development. This more empirical approach was best suited for analyzing general, community-wide development questions.

Statistical studies first developed a historical time series containing cost, revenue, demographic, and development data from a municipality. Multiple regression analysis was used to identify significant relationships between a dependent variable and a number of independent variables. The result was a series of equations that explained past relationships between service costs (the dependent variable) and a set of independent variables.

The dependent variables usually consisted of cost and revenues, often by major service category, or by household or per capita, and tax rates. The independent variables were usually development and demographic indicators (that is, proxy indicators of demand for services) such as land use, assessed valuation, development measures (that is, residential building permits, floor area of non-residential buildings), density, and demographic assumptions.

The equations then projected service costs and revenues based on changes in the dependent variables. The statistical approach was explained in Borgos (1979) and Johnson (1990).

Advantages. A statistical approach offered the following advantages:

- It may be more accurate in predicting future costs and revenues than other methods because it used a historical time series in developing equations. This assumes, of course, that the conditions that prevailed during the time series period prevailed into the future.
- It focused on the broad relationships between local government costs and revenues, and between development and land use patterns as opposed to attempting to model all the variables that determine the cost of providing services to individual developments. The statistical approach was highly suitable for answering broader, community-wide land use policy questions.
- It could measure the incremental or marginal costs and revenues associated with changes in land use at a community-wide level because it was not based on average costs.
- It could measure all of the relevant factors that affected the cost of a service by including the correct independent variables in the regression equation
- It analyzed an entire municipality, county, etc., as opposed to an individual subdivision

Disadvantages. There were several disadvantages to using a statistical approach:

- It was not useful for assessing the impacts of an individual development project, primarily because data will not be available in a sufficient time series form or at the proper level of detail
- A statistical relationship or correlation did not necessarily imply a cause-and-effect relationship, so it may not have precisely captured or identified a cause-and-effect relationship between changes in independent variables and changes in service cost

Allocating Costs

One of the crucial methodological steps in performing cost-of-development studies, particularly when analyzing existing development and using municipality-wide data, was allocating the total costs for a service category to residential and non-residential land uses. Other issues were allocating costs over time for new capital facilities and allocating the burden for repaying them through user fees. This was particularly important when new capital facilities, such as a sewer trunk line, may have had a low capacity utilization during the early years of its operating life, and thus had high marginal costs per user served.

Allocating by Land Use Type

It was difficult to allocate costs properly between residential and non-residential sectors based on their demands for services. These sectors differed in terms of the type and amount of services they required based on their direct demands. For example, residential uses had obvious high direct demands for schools, recreation facilities, libraries, and emergency medical, while non-residential uses produced little direct demand for these services. Some studies have suggested that, over time, non-residential development will produce demands for these services as persons desire to live near their places of employment. In contrast, other services, such as water, wastewater, police, fire, and solid waste were required by both residential and non-residential land uses. Non-residential uses could place high demands for transportation services and infrastructure.

The most common method for allocating costs between residential and non-residential sectors encountered in fiscal impact studies is on the basis of the proportion of the total real property tax base that was classified as residential. Under this approach, total municipal costs and revenues for service categories were allocated to residential and non-residential land uses based on one or a combination of the following factors:

- The proportion of total residential assessed valuation to the jurisdiction's total assessed valuation

- The proportion of the total number of taxable residential parcels to a jurisdiction's total number of taxable parcels that is classified as residential.

- The average size of all residential parcels compared to the average size of all non-residential taxable parcels.

In some cases, equalized valuations as opposed to assessed valuations were used to better approximate the total market value of taxable parcels. Burchell and Listokin, in their *Fiscal Impact Assessment Guide,* defined this as the proportional valuation method. A number of studies have used this approach including *The Cost of Community Services in Three Pioneer Valley Towns* (American Farmland Trust); and *Development in Wright County* (Gray).

Burchell and Listokin incorporated the varying demands for different categories of service between the residential and non-residential sectors. This was done by allocating all or nearly all of the annual costs for certain service categories to residential land uses, such as education and recreation, and by allocating the costs for other service categories based on proportional valuation. The allocation of costs was also based on interviews with service providers.

There was no obvious cause-and-effect relationship that would indicate that the proportion of total service costs within a category demanded by residential land uses was precisely equal to the residential proportion of total local assessed valuation or the ratio of average lot sizes. However, to determine accurately the residential demand proportion for each service category was very difficult and may in fact be indeterminant. One alternative was a case study method where the local heads of service departments were interviewed to obtain their judgement about the proper demand proportion. Another was the comparable city method where the distribution of costs from similar cities was used to estimate the distribution in the city being analyzed.

As noted by one of the reviewers (Avin, 1993), this approach could introduce distortions in the allocation of costs and revenues that did not align with the service costs they demanded or the revenues they produced. Capital-intensive industrial and commercial land uses with high taxable values and few employees may have been allocated a higher share of costs than they actually required. Labor-intensive uses, such as retail and office commercial, may have demanded more in services than the proportion of the tax base they represented.

The proportional allocation method could be complemented by asking actual service providers to estimate the proportion of their services and costs that went to different land use types. Data, such as the number of police, fire, and emergency medical calls made to residential vs non-residential uses; solid waste collection statistics; or sewer and water metering data for residential and non-residential customers, may be available to help in allocating cost. Another approach was to examine the proportion of residents vs employees working within a jurisdiction.

Allocating Over Time

Another difficult to resolve methodological issue encountered in many of the studies was properly allocating the marginal costs for providing new services and infrastructure over time. This issue was also a concern in estimating and equitably applying impact fees. When capital facilities were expanded to meet new increments of demand, the amount of capacity provided was often much larger than the initial demand increment that precipitated the need to increase capacity. There were sound, long-term economic reasons for doing this. There were usually economies of scale in capital costs achieved by constructing larger capacity facilities, such as water and wastewater treatment plants, water and sewer trunk lines and collectors, and highways. In addition, long-term total unit costs may be minimized by constructing one large, new capital facility with a large increment in capacity instead of constructing several smaller facilities over time.

The potential, short-term adverse effect of constructing a new capital facility with a large capacity was that, initially, it may have served only a few users and thus resulted in very high marginal capital and total costs per capita for the new service population. The classic example is a sewer or water line extended to a leapfrog development with the capacity to accommodate significant, future infill development along the line. When the line is underutilized early in its operating life, early users may bear a high cost, if only those benefitting from the improvement are paying for it. This would be a subsidy of the future users. The excess capacity also creates an incentive for local government officials to permit growth along the line to finance it, and to lessen the cost burden on current residents. Over time, as utilization increases, the future and current users will incur lower costs as capacity utilization increases.

Under this scenario, the key question was what are the true marginal costs that should be allocated to the first and future users of the improvement? Clearly, assigning the current average costs based on the utilization of existing systems would understate the true marginal costs of serving the initial users of the new facility. On the other hand, should the initial beneficiaries of the capital facility incur very high marginal costs, particularly when the long-term costs will decline as capacity utilization increases? These issues have obvious corollaries in the application of the rational nexus test in determining how and to whom impact fees should be allocated.

Classification of Services

Services provided by local governments to residential land uses could be grouped into four classes based on the size of the area they served and to a lesser extent, on their characteristics. This classification was based on those found in the literature, specifically Frank's monograph (Frank) and several of the previous studies he reviewed. A classification of services is important because different factors operate within each class to determine the costs of providing the service. The four classes are comprised of the following:

- **On-Lot or onsite.** These are the capital facilities on the lot that connect the dwelling unit to nearby, offsite public systems and ROWs

- **Intraneighborhood.** These are services provided to individual dwelling units within distinct residential developments, such as subdivisions or neighborhoods

- **Interneighborhood.** These are services provided for a larger service territory that covers a subarea of an entire municipality that contains many separate neighborhoods or residential developments. The services are provided to a group of neighborhoods and consist of the capital facilities connecting the services and neighborhoods

- **Regional.** These services are provided to an entire municipality or a larger region consisting of a number of municipalities

This study addressed only the three types of off-site services: intraneighborhood, interneighborhood, and regional. This study did not address on-site services because these are almost always incurred by the property owner. These costs have also been addressed in a number of other studies, such as *Cost Effective Site Planning* (National Association of Home Builders). Increasingly, through the use of proffer charges and impact fees (primarily in Maryland and Virginia as opposed to Pennsylvania), the capital costs for the intraneighborhood and some interneighborhood services are being incurred by the property owner. The local government often will assume maintenance responsibility for these improvements, so even if it did not incur the initial capital cost, it will incur maintenance costs.

The characteristics of the services in each class differed significantly. For example, intraneighborhood services were capital intensive and consisted primarily of linear capital facilities (that is, sewer, water, and stormwater pipes; and roads) laid out in a fine-grained network required to provide services to individual dwellings. In contrast, interneighborhood services consisted of a mix of linear and point capital facilities (that is, schools, police and fire stations, parks, etc). Some of these were highly capital intensive, such as sewer and water collector lines, while others were more labor intensive.

The classification of services was also important in terms of who pays directly for the services. The cost of providing onsite services, such as stormwater improvements, water and sewer connections between the house and the street, driveways, and curbs, are incurred directly by the homeowners and were included in the cost of home. To a lesser extent, the costs of intraneighborhood services may also be borne by home buyers. In contrast, the cost for the other classes of services were incurred by the local government or utility authority, and were then recovered from consumers through taxes or user fees. Many studies have evaluated the cost of onsite services as a function of residential form (*Cost Effective Site Planning* and *Affordable Residential Land Development*).

One observation about the cost of onsite services is worth making. There was concern in some of the literature that minimizing environmental impacts at the individual dwelling unit level through innovative site planning and use of large lots, coupled with stringent local environmental regulations, increased the price of housing. This had a short-term equity impact of making housing less affordable and of limiting the purchase of such housing to more affluent households, particularly where large lot sizes and on-lot septic systems are used. The concern was that achieving environmental benefits in developing new housing may have offsetting social and economic effects that need to be considered.

Intraneighborhood Services

Intraneighborhood services provided services to an individual dwelling unit or residential structure. They consisted of infrastructure that extended up to the lot line and distributed service within discrete neighborhoods and subdivisions. The characteristics of intraneighborhood services are comprised of the following:

- Primarily capital facilities, usually linear in form

- Capital intensive (have a high ratio of annual capital to total annual costs)

- Cost of the service was closely linked to demand coming from within the service area

- Linear facilities, usually located in the public ROW fronting the lot

- The network pattern spatial pattern

- Designed for a high level of capacity utilization (little, if any, future development will occur within a neighborhood)

The types of intraneighborhood services included the following:

- Sewer collector lines
- Water distribution lines
- Stormwater collector lines
- Collector streets, including subcollectors, loops, and cul-de-sacs
- Streetlighting
- Stormwater and drainage improvements, excluding the collector lines

Interneighborhood Services

Interneighborhood services were provided to a larger area covering a group of distinct neighborhoods or a portion of a municipality. They consisted of the facilities and personnel needed to distribute services to a group of neighborhoods, or consisted of the facilities needed to link distinct neighborhoods. The services were delivered to the edge of a neighborhood or subdivision, instead of to individual dwelling units.

The characteristics of interneighborhood services included the following:

- Service area covered a portion of a municipality containing multiple neighborhoods

- Consisted of a mix of:
  - Linear, capital intensive services
  - Labor-intensive services provided from centrally located facilities

- Usually designed with initial excess capacity to accommodate future growth

- Costs could be allocated primarily to the residential demands originating in the neighborhoods being served, although the nonresidential sector in these areas also was served

- Linear facilities were arrayed in a coarse network

There were two types of interneighborhood services:

- Capital-intensive:
  - Sanitary sewer trunk or collector lines, and interceptors
  - Stormwater trunk or collector lines
  - Water trunk or distribution lines, and supply mains
  - Parks and recreation
  - Arterial streets

- Labor-intensive:
  - Police
  - Fire
  - Solid waste collection
  - Emergency medical
  - Education, particularly elementary and possibly junior high/middle schools

Regional Services

Regional services were provided to an area usually covering at least a single municipality, but may often have served a county or a metropolitan region. The characteristics of regional services are listed below:

- Centrally located facilities

- Service area was an entire municipality, several municipalities, county, or region

- Costs of these facilities were allocated over the entire community, which included both the residential and nonresidential sectors

- There were often economies of scale by constructing larger capacity treatment or service centers. These economies could offset the costs for constructing the distribution infrastructure that covered the service territory.

- Usually designed with substantial, initial excess capacity to accommodate future growth

- Variable capital intensity. High schools and general government are labor-intensive, while highways and water supply facilities are capital-intensive.

Annual capital costs for wastewater treatment plants are a majority of total annual costs.

The types of regional services are listed below:

- High schools
- Wastewater treatment plants
- Water treatment plants
- Water supply reservoirs
- Solid waste disposal facilities
- Highways
- General government administrative buildings

Factors That Influence the Cost of Providing Services

There are many factors that determined the cost of providing services to residential developments. They varied in importance for the three types of off-lot services being considered in this study. Some of the factors were clearly related to residential development form, while others were a function of locational characteristics and design criteria. The purpose of this section is to identify these factors. (Chapter 3 describes how the factors determine the cost of providing the different services.)

Attributes of the Service

The physical characteristics of the system required to provide a service was a major determinant of the cost of providing it, and of the proportion of total annual costs allocated to annual capital and O&M costs. In some cases, the characteristic of service was independent of residential development form, while in other cases, it was directly related to it.

Capital Intensity

Capital intensity is defined as the ratio of annual capital to total annual costs. The annual total costs of a capital-intensive service, such as a water or sewer collection system, consisted primarily of levelized capital cost, with relatively low annual O&M costs. In contrast, the annual total costs of labor-intensive services such as police, fire, and education consisted primarily of labor, vehicle operation, supplies and equipment, as opposed to annual capital costs.

A recent study in Florida (James Duncan et al., 1989) estimated the capital intensity of major service categories. They are presented in the Table 2-1.

Table 2-1 Capital Intensity of Service Types	
Service Category	**Percentage of Annual Costs That are Annual Capital Cost**
Roads	92.1
Water	42.9
Wastewater	33.6
Parks	21.1
Education	16.3
Solid Waste	10.2
Fire/Rescue	4.4
Police	2.2
ALL SERVICES	23.5
Source: *The Search For Efficient Urban Growth Patterns*. James Duncan and Associates, et al., 1989.	

These costs were compiled for eight existing detailed service areas that encompassed a variety of different development forms ranging from low-density scattered or leapfrog developments to urban infill projects.

Because the costs are for developments in Florida, the relative rankings in terms of capital intensity will be somewhat different in the Chesapeake Bay region. Some differences are that road O&M costs would be higher in The Chesapeake Bay region because of winter plowing and repairing freeze and thaw cracks produced by the use of road salt, and because parks and recreation centers would be open only part of the year. The capital intensity of road would be lower than shown above, but it would still be high. Finally, the proportion of annual capital costs for water and sewer treatments, will be higher in the Chesapeake Bay region due to climate effects and higher construction costs.

The capital intensity and spatial form of a service's infrastructure were significant determinants of how sensitive capital costs would be to residential development patterns.

Form

Another important characteristic was the spatial form of the infrastructure and capital facilities required to provide or convey a service. There were two basic forms:

- Linear, where capital facilities, such as water and sewer pipe, comprised a network within a service area

- Point form, consisting of centrally located facilities at which either service was provided (that is, a school, park, general government, police, or fire or recreation center), or at which material was either conveyed to or received from a service area (that is, wastewater treatment plant, water treatment plant, or solid waste disposal plant)

Some services with a linear form were very capital intensive, such as water and sewer pipe. In contrast, the capital intensity of point forms can vary widely. Water and sewer treatment facilities were capital intensive while others, such as a school or recreation centers, were more labor intensive.

Spatial Arrangement

The spatial arrangement of a system's capital facilities, particularly those with a linear form, was also a major determinant of capital cost. Interneighborhood facilities, such as water and sewer collector pipes, comprised a detailed network that was contained in virtually all subcollector and collector streets. Intraneighborhood services provided service to individual dwelling units. Other services comprised a coarser network because they were farther up the service hierarchy and were fed by collector facilities. These facilities included arterial roads, and water distribution and wastewater collection lines. Regional capital facilities, such as sewer interceptors, did not comprise a network but instead comprised a corridor or "highway" connecting a centrally located treatment or service facility to the distribution facilities.

Point facilities also had some differences in how their services were provided spatially. Solid waste collection was provided over the most detailed network as collections were made at individual dwelling units. Schools must cover a similar network, although some proportion of students walked to school instead of taking a bus. Schools were also arranged in a hierarchy with scattered elementary schools and more centralized high schools. Police and fire services needed to be able to respond to any location within their service areas, even though emergency vehicles do not have to make stops at all locations on a regular basis.

Development Density

Development density measures the number of dwelling units per unit of area. Because the size of a service area and the amount of demand for most services correlated closely with the number and spacing of dwelling units, it was an important characteristic of a residential development form.

There are two ways to measure development density: gross and net. Each type had differing impacts on service costs, depending on the type of service being considered. It is important to understand the difference between these two measures within the service areas for the three types of services, particularly for intraneighborhood services.

Gross Density

Gross density is defined as the number of dwelling units divided by the total area of residential land use. The total residential area included land area in all the individual lots plus any common open space; interior street and road ROWs for collectors, sub collectors, loops, and cul-de-sacs; undevelopable areas; and areas for public facilities such schools, stormwater improvements, etc. For example, a subdivision covering 100 acres and containing 75 homes would have a gross density of 0.75 dwelling unit per acre (du/acre).

The significance of gross density was that it indicated the average distribution or spacing of dwelling units within an area of residential land use, although not necessarily the spacing between individual dwelling units. While gross density depended on minimum lot size, it also depended on other factors, such as the width of road ROWs, proportion of undevelopable land, and land dedicated to other public uses. Gross density is an accurate indicator of the length of the network required for interneighborhood services.

Net Density

Net density is defined as the number of dwelling units divided by the developed residential area, excluding area for streets, undevelopable land, and other non-residential uses. Net density is determined primarily by the minimum lot size. In a residential cluster, net density is the number of dwelling units within the entire subdivided lot divided only by the parcels occupied by the dwelling units (that is, the developed residential area, excluding common open space). In the example above, if residential clustering were used and the 75 homes were clustered within 25 acres, the net density would be 3 dus/acre, while the gross density for the subdivision would remain at 0.75 du/acre.

Net density more accurately represented the actual concentration of demand (in terms of dwellings units, household, or population per area) by considering only the amount of residential area. Net density accurately indicated the spacing between individual dwellings units and the amount of intraneighborhood infrastructure that may be required (that is, sewer, water or road frontage along each lot or per dwelling units served). Net density would also indicate the concentration of service demand coming from within a residentially developed area (that is, total gallons of water required or wastewater generated per area of development), which, in turn, could be used to size the infrastructure (that is, the diameter of the pipe).

Character of the Development

Lot Size and Shape

The size and shape of the lots within a development determined both the gross and net development densities, and therefore determined the amount of linear facilities, such as water and sewer collector pipe, and streets, that would be required per dwelling unit. Even within the single-family detached residential form, lot size and configuration, and site planning principles could be used to reduce service costs. These would increase net densities while holding gross density constant. Net density is an accurate surrogate for lot size and shape and examples include the use of clustering, reducing lot frontages through the use of "Z" lots, zero lot lines, reducing setbacks, and minimizing right-of-way widths.

Type of Dwelling Unit

The type of the dwelling unit was a major factor in determining the demand for labor-intensive services. The type of dwelling unit determined the number and the characteristics of the people residing in them. Single-family dwelling units had more bedrooms per dwelling unit, and more persons and school age-children per dwelling unit than other forms of residential housing that had the same floor area. Single-family dwelling units had higher populations and they generated greater demands for labor-intensive services, such as education, police, fire, solid waste, emergency medical, and general government. The demand for these services depended more on the number of persons being served and less on the location of the services.

There were also activities that were unique to single-family dwelling units that created greater service demands. These included greater generation of yard wastes as a part of municipal solid waste and greater per capita consumption of water for watering lawns and gardens. Trip generation rate data (ITEE, 1990) showed that single-family detached homes generated more automobile trips per dwellings unit than other residential types, resulting in a higher need for street and road capacity.

One reviewer (Valenza, 1993) noted that the incidence of police and fire calls was highly correlated with the type of dwelling unit, among other factors. The incidence of both types of calls was higher for multifamily housing units that it was for single family detached units. The capital cost savings in infrastructure that could be gained by constructing multifamily dwelling units may be offset, to some extent, by higher annual operating costs for police and fire services, and, in more urban areas, by higher social services costs. The income of the residents could also have been a factor with a higher incidence of calls found in multifamily housing whose residents have lower incomes.

The type of dwelling unit also had a direct effect on the cost of providing capital-intensive intraneighborhood services. Single-family detached dwelling units were more likely to be located on larger lots, had lower gross and net development densities, and therefore require longer lengths of water and sewer collector pipe, streets, and streetlighting per dwelling unit served than were attached residential forms. Attached dwelling units offered significant efficiencies in providing both capital-intensive and labor-intensive services because they required shorter lengths of linear capital facilities per dwelling unit served, while they also offered efficiencies in providing labor-intensive services.

Population Characteristics

Two aspects of population, the total size and density, were major determinants of the aggregate demand for and the cost of providing local government services.

Total Population Served

The demand for local government services and, for the most part, the cost of providing them, was determined largely by the number of persons to be served. The cost of providing labor-intensive services, such as police, fire, emergency medical, and education, was particularly sensitive to the size of the population or to the number of school-age children to be served. The demand other services, such as water and wastewater, also depended on total population because the number of persons determined the daily flows of water consumed, wastewater to be treated, or solid waste to be collected. The number of persons correlated closely with the type of the dwelling unit and with the number of bedrooms.

Population Density

Population density measures the number of persons present per unit of area, and therefore, the spatial concentration of demand for services. There were cost efficiencies in providing most types of services to a more concentrated population occupying a smaller developed area. Even though a larger diameter sewer or water pipe was required to accommodate a larger total flow coming from a densely populated development, the capital costs per dwelling unit or person served would be lower in suburban and new development situations. These costs could increase in urban situations, where the cost of construction and acquiring rights-of-ways becomes very high, but the urban setting was outside of the scope of this report.

At the intraneighborhood level, population density correlated closely with net development density and with lot size. Net development density focused on the developed residential area, or the area where the residents are located. At the larger interneighborhood or regional service areas, population density correlated more closely with gross development density. Gross density included within its area all types of areas, including both the developed residential areas plus the area occupied by streets, undeveloped areas, open space, etc. Population density for a municipality was calculated as total land area divided by total population.

Number of School-Age Children

The number of school-age children determined the demand for educational services at all levels. A lesser, but highly variable factor, was the number of school-age children that actually attended public schools. The proportion not attending public schools could be quite large (that is, approaching 30 or 40 percent) in areas where there are a large number of parochial schools and other nonreligious private schools, and where residents have high incomes. The service standard would also be a major determinant of education costs, reflected in average classroom size demanded by parents, teacher salaries (a function of the value of the tax base and residents' incomes), income and educational attainment characteristics of parents, and state regulations.

Variations in Population and Number of School-Age Children by Type of Dwelling Unit

An interesting question was the extent to which the number of persons and the number of school-age children varied by the type of dwelling unit, number of bedrooms, or both (that is, was there a difference between a single-family dwelling unit and a townhouse with 3 bedrooms each in terms of either the number of persons or number of school-age children per dwelling unit?). Tables 2-2 and 2-3 present data from the 1980 Census of Population as presented in Burchell and Listokin's update to the *Fiscal Impact Assessment Guide* for the South Atlantic states, which included Maryland, Delaware, and Virginia. (The data from the 1990 census presenting this information from the STF3 tapes will not be available until the end of 1992.) The figures in each cell were averages for that particular cross tabulation.

As expected, single-family dwelling units had, on average, higher population and more school-age children per dwelling unit than did that of other housing types as shown in Table 2-2. Single-family dwelling units were the only dwelling unit type with a significant number of 4- and 5-bedroom units. The type of dwelling unit was significant when considering 2- and 3-bedroom units:

- For 2-bedroom dwelling units, there was some variation in population per dwelling unit by type of dwelling unit. The variation from the low to the high value was only 20 percent.

- There was more variation among 3-bedroom dwelling units. Three-bedroom single-family, garden apartments, and duplexes/triplexes had similar figures. Mobile homes had the highest population per dwelling unit. Single-family dwelling units had the lowest population per dwelling unit among these four types. All four types had a significantly higher population/dwelling unit than did 3-bedroom townhouses. The variation from the low to the high value is 31 percent.

- There was more variation in the number of school-age children by type of dwelling unit when considering both 2- and 3-bedroom units, as shown in Table 2-3. The variation from the low to the high value (excluding high rise apartments) within 2-bedroom units was 32 percent, and 98 percent for 3-bedroom units. Excluding high-rise apartments, townhouses had the lowest figure and mobile homes had the highest figure.

Two other key variables that could affect local service expenditures were associated with different types of dwelling units. These key valuables were income and age, and they sometimes reinforce or even offset the demographic figures presented above. Wealthier

Table 2-2 Persons/du by Type of du and Number of Bedrooms						
	Number of Bedrooms					
Type of du	**1**	**2**	**3**	**4**	**5**	**All**
Single Family	NA	2.3	3.12	3.90	4.67	3.18
Garden Apt.	1.47	2.09	3.23	NA	NA	2.09
Townhouse	1.75	2.12	2.69	NA	NA	2.49
High Rise Apt.	1.33	1.91	NA	NA	NA	1.58
Mobile Home	2.02	2.3	3.53	NA	NA	2.76
Duplex/Triplex Quadraplex	1.71	2.24	3.23	NA	NA	2.43

Note: The data in this table are for the Middle Atlantic states.

Source: *Fiscal Impact Assessment-Practioners Guide,* Burchell and Listokin, 1985.

Table 2-3 School-Age Children/du by Type of du and Number of Bedrooms						
	Number of Bedrooms					
Type of du	**1**	**2**	**3**	**4**	**5**	**All**
Single Family	NA	0.23	0.72	1.32	1.89	0.78
Garden Apt.	0.05	0.19	0.86	NA	NA	0.26
Townhouse	0.18	0.19	0.50	NA	NA	0.41
High Rise Apt.	0.02	0.07	NA	NA	NA	0.05
Mobile Home	0.19	0.21	0.99	NA	NA	0.51
Duplex/Triplex Quadraplex	0.10	0.25	0.81		NA	0.40

Note: The data in this table are for the South Atlantic states, which include Maryland and Virginia.

Source: *Fiscal Impact Assessment-Practioners Guide,* Burchell and Listokin, 1985.

residents were more likely to demand higher service levels or, in economic terms, the income elasticity of demand was positive. Weathier residents were, on average, more likely to inhabit single family detached units as opposed to garden apartments and trailers. Local planners should take into consideration the income levels and wealth, along with the type of dwelling unit, when considering potential demands for services.

Older persons with few or no children were more likely to be found in certain types of housing units, such as high rise apartments and townhouses, resulting in minimal demands for local education services. A report done by CH2M HILL found that residential golf course developments, consisting of townhouses and actively marketed toward empty nesters, had a fewer number of children per dwelling unit than did townhouses in general.

The key conclusion was that both the type of dwelling unit and the number of bedrooms interacted to determine population and school-age children/dwelling unit. Both were particularly important when considering the number of school-age children produced by a development with a mix of 2- and 3-bedroom attached and detached units. The type of dwelling unit became more important when considering population; and became even more important when considering school-age children and potential impacts on the educational expenditures. Impact studies and fiscal impact assessment models that assumed the same population or number of school-age children per dwelling unit across different bedroom sizes and dwelling unit types may have miscalculated the demand for labor-intensive services.

Locational Attributes

The spatial characteristics of residential development, in terms of its proximity to employment, existing urban service boundaries, and community facilities, were important in determining the cost of providing interneighborhood and regional services, and to a lesser extent, intraneighborhood services.

Proximity to Existing Service Areas

A number of the studies reviewed showed clearly that there were significant cost savings obtained from locating new residential development either at the edge of existing service areas or at infill projects on vacant land located within currently served areas. This point is made in Frank's study, *The Costs of Alternative Development Patterns* (specifically his Table 8), and also in the *Impact Assessment of the New Jersey Interim State Development and Redevelopment Plan*. The length and cost of interneighborhood capital facilities was minimized and, because existing systems with excess capacity can be used, this resulted in low marginal (and low precipitated) costs. The proximity of a new residential development to existing service areas was a major cost factor for interneighborhood and regional services.

The advantages of proximity to service areas or service centers also applied to labor intensive-service such as police, fire, education, and solid waste. The capital cost of vehicles to provide police, fire, and solid waste services, or school busing would depend upon the total length of the routes to be traveled, service standards to be maintained such as police and fire response times, and policies, such as walking distance. Annual operating costs would also be sensitive to the location of the population to be served. Vehicle operating costs, labor costs, and supplies and equipment were also dependent upon the total distance to be traveled, the annual minutes of operating time, and on the resulting efficiency (solid waste collections or student pick-ups per mile traveled).

A potentially adverse cost effect associated with the proximity to service centers was that the acquisition costs for rights-of-way were higher in more densely settled areas, particularly in urban areas. The higher construction costs of new roads in urban areas is partially due to this fact. Construction costs were also higher in urban areas with linear infrastructure, apart from the costs of acquiring the ROW. The *Impact Assessment of the New Jersey Interim State Development and Redevelopment Plan* took these differences into account when estimating the cost of constructing new state roads and local streets in urban areas.

Proximity to Employment

The proximity to employment and to mass transit affected the number and length of vehicle trips that persons would take to and from work. These trip characteristics combined determined the demand for streets and roads, particularly for arterials and expressways that will be used to convey traffic from residential areas to employment centers.

Proximity to Community Facilities

The number and length of vehicle trips was also determined by the proximity to community facilities such as schools, shopping, churches, and government centers. If people could walk to some of these facilities, the demand for local and collector streets, and arterials would be lower.

Proximity to employment and community facilities could be enhanced by providing residents with opportunities to use mass transit. This would reduce the demand and cost for roads, streets, and parking facilities, and provide other benefits as well. *The Impact Assessment for the New Jersey Interim State Development and Redevelopment Plan* projected significant capital cost savings for state and local roads due, in part, to a shifting of trips from automobiles to mass transit and due to shorter average trip distances.

Service Characteristics

Service levels influenced the cost of providing services in two ways: (1) capacity utilization affected the unit costs by determining the number of demand units (that is, persons or dwelling units) over which annual costs can be allocated, and (2) the desired service level determined the design or service standard that would be used in designing a facility or in deciding the number of facilities needed to serve a population.

Many studies indicated that the service level or design standard required or desired in providing services to residential development was a major determinant of cost. Several studies, in particular Windsor's review of *The Costs of Sprawl*, noted how changing design standards, such as street ROW and cartway widths, could achieve capital cost savings in providing infrastructure.

Capacity Utilization

Capacity utilization, or the amount of spare or excess capacity, is defined as the current operating level divided by the design capacity. Most service systems unit costs, defined as total annual costs (annual capital plus O&M) divided by the number of units served, decline as the capacity utilization approaches 100 percent. Fixed annual capital costs were allocated over more units and economies of scale produced operating cost efficiencies as total usage approached the design capacity.

There were two ways that capacity utilization affected capital costs. First, most capital facilities were designed to achieve a minimum initial level of capacity utilization when they began operation, which was then expected to increase over time to the design capacity as additional users moved into the service area. This was particularly true for interneighborhood and regional services. Based on forecasted demand and desired level of capacity utilization, the design capacity and ultimately the capital cost of a facility were determined. A greatly under-utilized facility could result in high, fixed capital costs being distributed to a few users.

Second, during operation, capacity utilization determined the number of users that would bear the capital costs through the payment of user fees or taxes needed to retire bonded indebtedness. In addition, during operation, optimum performance levels and operating cost efficiencies were often obtainable only by meeting a certain high level of utilization. Significant under-utilization could result in substandard performance and higher unit O&M costs.

The marginal capital cost incurred in providing service to new dwelling units would be low and could approach zero for service systems where the capacity utilization was low (that is, where there was substantial existing excess capacity). For example, the marginal capital costs of accommodating an additional student would be very low when there was space in a classroom (that is, vacant desks were available) for new students. Conversely, marginal capital costs would be high where a large increment of demand would require the construction of new capital facilities, such as the construction of a new school to accommodate the enrollment from a new large subdivision.

The size of the incremental increase in demand determined, to some extent, whether the marginal capital costs would be high or low. Small increments of demand could often be accommodated even when capacity utilization is high. However, this raises the issue that the cumulative effects of continuing small increments in demand (that is, lots of minor subdivisions) would ultimately create the need to construct new capacity. Large increments of demand were more likely to create a need to expand capacity, particularly when capacity utilization was already high.

Service and Design Standards

The service or design standard to be achieved or desired by residents was also a major determinant of service cost. For capital-intensive services, the design standard could be the major determinant of both capital and total costs. Examples include design standards for streets and roads (that is, cartway widths, pavement thickness, and paving materials), performance specifications for water and sewer pipe, and size of the storm event capacity for stormwater facilities.

Often the capacity and service levels were determined by physical and engineering factors, such as the size of the pipe diameter required to accommodate water, wastewater, and stormwater flows; or design criteria for highways to accommodate projected annual average daily traffic flows at acceptable levels of service. Capital costs could be determined by regulatory standards, such as the level of treatment to be provided for wastewater or the discharge levels required under the National Pollutant Discharge Elimination System (NPDES).

Design standards were also determined by the characteristics of the population served, particularly their income and education levels. Some studies (for example, Ladd, 1992) showed a positive income elasticity of demand, indicating that more affluent residents demanded more and a higher level of services. The Dupage County, Illinois study (*Impacts of Development on Dupage County Property Taxes*) hypothesized about the existence of an income effect in which existing residents demanded more and higher quality services as the result of development that increased the value of the local real property tax base. The rationale was that residents felt that either their community had an increased ability to afford higher quality services or that these costs could be shifted increasingly to the non-residential sector.

The cost of labor-intensive services was primarily determined by the maximum number of units of demand to be served. For example, the number of police and fire substations required was a function of the number of people or number of dwelling units that should be served by a new facility. The number of new classrooms required was determined by the standard of the maximum number of students permitted in each classroom.

Two of the issues identified by some of the studies reviewed were the change in service standards over time and the level of similarity or difference in acceptable service standards across different communities. Several studies (*Impacts of Development on Dupage County Property Taxes* and *The Costs of Alternative Development Patterns*) indicated that service standards have changed and continue to change over time. As a result, the per capita costs of providing services, when corrected for inflation, have over time increased due to rising standards. Examples included increasing performance and design standards for treating wastewater and controlling stormwater runoff. The Dupage County study suggested that, in some cases, an income effect was at work in communities—as the area's tax bases and tax revenues increased, tax payers felt wealthier and began to demand a higher quality of service, which was ultimately reflected in higher taxes and per capita service expenditures.

One of the difficulties encountered in reviewing the studies for this report was that service and design standards varied from municipality, particularly when comparing suburban and rural municipalities. Service standards were often higher in wealthy suburban metropolitan municipalities, such as the suburbs of Baltimore, Harrisburg, Richmond, and Washington, due to the preferences and affluence of the residents. In contrast, service standards were often lower in rural areas, due primarily to lower incomes and taxes bases.

Regulatory Standards

Regulatory standards determined capital costs in two ways: (1) by presenting performance standards that must be met, which in turn determined the design and the cost of a facility, and (2) by including or referencing design standards. The regulatory standards that influenced the cost of residential housing the most were the local zoning, subdivision, and site planning ordinances. The former contained the overall land use plan that described the location, composition, and intensity of major land use classes within the community, including the areas proposed for residential development. The other components of a master plan, such as the water and sewer plan, the transportation plan, the recreation element, and the capital improvement plan, determined the location and phasing of the capital facilities required to support new residential development.

The three ordinances (zoning, subdivision, and site plan) regulated the type, location, and characteristics of development. The most significant direct impact of the zoning ordinance was on the cost of the housing and on the capital cost of onsite services. Regulations, such as minimum lot size, gross density, yard setbacks, site planning and design standards, clustering provisions, and landscaping requirements, all determined the cost of the housing and the capital cost of the onsite sewer and water connectors, and storm water facilities. Local site planning regulations also often contained design standards for subcollector and collector streets (that is, cartway widths, pavement thicknesses) and stormwater management facilities.

The more general master plan had a larger effect on the capital cost of inter-neighborhood and regional services, while the zoning, subdivision, and site planning ordinances had larger effects on the capital cost of intraneighborhood facilities and on the cost of onsite services.

The former determined the overall land use pattern of a municipality or county, while the latter determined the gross and net development densities, and the lot size and shape.

One issue that was mentioned in some of the studies was the effect of local zoning ordinance regulations on the affordability of housing. Certainly, minimum lot size requirements created a minimum price for housing based simply on the cost of the land. Large minimum lot sizes have been found, in some cases, to constitute exclusionary zoning. A related concern was that the desire to minimize the environmental impacts produced by new residential development through the use of innovative site planning and site design methods increased the cost of housing, making such housing affordable only by the affluent. (This may be more attributable to the desire and ability of affluent persons to obtain a high quality of life in semi-rural areas by purchasing large homes on large lots than on the costs of environmentally beneficial site planning per se.) While this issue is outside the scope of this study, interested readers are referred to *Cost Effective Site Planning* (National Association of Home Builders), *Affordable Residential Land Development* (National Association of Home Builders), and more recently, *Not In My Backyard* (United States Department of Housing and Urban Development.)

Regulatory standards contained in state and federal legislation, particularly environmental legislation, also influenced the capital cost of interneighborhood and regional services, and to a lesser extent, influenced the capital cost of intraneighborhood services. These regulatory standards specified performance standards that must be achieved, which in turn determined the capacity, design, treatment processes, and ultimately the capital cost of new facilities. For example, state environmental regulations for landfills often contained detailed provisions covering the design and operation of a landfill. Similarly, performance standards contained in a state's NPDES program were major determinants of the treatment level that must be achieved by a wastewater treatment plant, the processes required to meet these levels, and ultimately of its capital cost.

Shape

The shape of the service area also affected the cost of delivering services, particularly the capital cost of providing infrastructure. In terms of linear infrastructure, the issue was whether there were obvious differences in the total length and capital cost of the pipe or road network between circular or square shaped service areas or subdivision and a highly rectangular or linear service area. As noted in Frank's *Costs of Alternative Development Patterns*, a study performed by Stone in 1983 in England found that it cost 14 to 17 percent more to provide highways to star-shaped or linear regions than it did to rectangular regions. For the purposes of residential development at the neighborhood or subdivision level, the question was whether a rectangular or circular shape provided capital cost economies for linear infrastructure, as opposed to the costs of serving a linearly-shaped development.

Another component of service annual operating costs was that the shape of the service area affected the cost and efficiency of those services that used vehicles operating out of a central facility to provide coverage to a service territory. Both capital costs (the number of vehicles required to provide service), service levels (response time by police and fire), and operating costs (number of collection points per mile for solid waste trucks and school buses) were affected by the shape of the area.

Conclusion

This chapter presented the trends and methods found in cost of development studies; presented a categorization system for local public services, based primarily on the capital cost component; and identified and described how various factors determined the capital costs of the different services. All three components are precursors to the objective of the next chapter, which is to show how sensitive the capital cost of the various type of services are to the factors that effect capital costs.

Chapter 3
Sensitivity of Capital Cost for Different Service Types

This chapter to indicates how the capital costs for the three different types of government services identified in Chapter 2 are affected by the factors that influence the cost of providing service to new residential development. This analysis is presented for the three types of services identified in Chapter 2: intraneighborhood, interneighborhood, and regional. Capital cost is the focus of this section because these costs have become the primary budgetary concern of local governments and utility authorities in extending services to new residential development. Capital costs are often large, short-term expenditures for such facilities as schools, roads, water, and sewer that must be financed over a long period.

While the objective of this report is to make findings, based on the literature and on how the capital costs of serving residential development vary according to different factors, it is also necessary to consider annual operating and maintenance costs of serving residential development. The annual O&M costs comprise approximately two-thirds of the total annual costs required to provide the full range of intraneighborhood, interneighborhood, and regional services to new residential dwelling units. Annual general fund expenditures by local government entities, such as municipalities, school districts, and counties, usually comprise 80 percent or more of the total annual budget. The issue of annual O&M expenditures vs capital expenditures is discussed briefly in the final section of this chapter. This topic is outside of the scope of this study but the magnitude of capital costs incurred in serving new residential development needs to be put into its proper perspective for local decision-makers.

The analysis in this chapter is presented in a tabular form. A summary table is presented for each of the three types of services, preceded by a table that presents the attributes of each type of service. Each summary table provides local planning officials with an indication of the sensitivity of the capital cost for an individual service to the different factors of residential development that determine the capital costs of serving it. (Appendix C: Tables contains tables that present, in more detail, the capital sensitivities of the three service types. Five tables are presented for each service type that presents capital cost sensitivities in regard to: development density, character of the development, population characteristics, locational attributes, and service characteristics.)

The summary tables present an ordinal ranking of capital cost sensitivity using the following scale:

- Highly Sensitive: a factor has a strong, direct effect on the capital cost of a service

- Sensitive: a factor has a direct but not overly strong effect on the capital cost of a service

- Moderately Sensitive: a factor has a weak effect on the capital cost of service

- Minimally Sensitive: a factor has little or no affect on the capital cost of a service

This scale expresses the strength of the relationship between variations in the factor and the resulting capital cost for a service type. The use of an ordinal scale necessarily implies judgement and interpretation in evaluating and classifying capital cost sensitivity. The determinations of sensitivity were made by CH2M HILL consultants based on the literature reviewed for this study, and on our experience in conducting planning studies, and in preparing designs for different types of infrastructure.

The capital sensitivities are presented for the following groups of factors:

- Development Density
  - Gross density
  - Net density

- Character of the Development
  - Lot size and shape
  - Type of dwelling unit (du)

- Population Characteristics
  - Total number of persons served
  - Density

- Locational Attributes
  - Proximity to existing service area
  - Proximity to employment centers
  - Proximity to community facilities

- Service Characteristics
  - Capacity utilization
  - Service and design standards
  - Shape of the study area

The number of bedrooms was eliminated because it is correlated with the type of dwelling unit. The number of school-age children is not presented because it directly affects only education services.

The following tables show the sensitivity of the capital costs of different types of services to the characteristics of new residential development taking place at or beyond current service boundaries. This best meets the objective of the Subcommittee on Population Growth and Development which is to obtain a better understanding of how new residential development taking place within the Chesapeake Bay watershed is affecting the capital cost of providing this development with local public services. It is recognized that some of these services are increasingly being incurred by the homeowner through impact fees and proffer charges.

The tables shown in this chapter are summaries of the more detailed data found in Appendix C: Tables.

Capital Cost Sensitivity of Intraneighborhood Services

The discussion below summarizes the material presented in Tables C-1 through C-5 contained in Appendix C: Tables.

Attributes of the Service

As presented in Table 3-1, all of the intraneighborhood services are defined as having high levels of capital intensity. These services are also primarily linear facilities located in public ROWs that are arrayed in a fine network or grid that provide service to the lot line of individual dwelling units or residential structures. Because of these characteristics, the capital cost of providing them are particularly sensitive to lot size and shape, and development density.

An exception to the linear configuration are drainage improvements. They consist of retention and detention basins that receive stormwater runoff from a group of dwelling units, a subdivision, or a large residential structure, such as an apartment building.

Development Density

Table 3-2 shows that the capital costs of the linear intraneighborhood facilities are sensitive to gross density and are highly sensitive to net density with the exception drainage improvements. Since these are facilities that provide services within a neighborhood or development, the area covered by actual residential development (net density) accurately represents the distance between or concentration of the dwelling units. This, in turn, determines the length of the intraneighborhood network for these facilities, or the length of pipe or road per dwelling unit served. In areas where gross density equals net density, such as in standard subdivisions with single family development dwelling units and no clustering, the effects on capital cost will be similar.

Pipeline Capital Cost as a Function of Diameter and Length

Relationship of Diameter and Capacity. Simple geometry can affect both the cost and capacity of a network of pipes, particularly at the intraneighborhood level. Geometry affects both the capacity of a pipe as measured by its cross sectional area and the total length of the spatial network required to serve an area. This point was noted by Frank in his review of a previous study performed by John Kain in 1967.

Additional service capacity can be provided using water and sewer pipes by either extending them to pick up new dwelling units (assuming that the receiving trunk lines have sufficient capacity), or by concentrating development through clustering or infill, and

Table 3-1
Attributes of Intraneighborhood Services

Service	Capital Intensity	Form	Spatial Arrangement
Sanitary Sewer Collector Lines	High. Capital cost determined by length and by percent increase in capacity	Linear consists of pipes conveying flows from individual dus or residential structures	Fine network. Pipes placed in public ROWs primarily located in sub-collector and collector street ROWs, network leads to lot line of individual dus or residential structures
Storm Sewer Collector Lines	High. Capital cost determined by length	Linear consists of pipes conveying flows from individual dus or residential structures	Fine network. Pipes placed in public ROWs primarily located in sub-collector and collector street ROWs, network leads to lot line of individual dus or residential structures
Water Distribution Lines	High. Capital cost determined by length	Linear consists of pipes conveying flows to individual dus or residential structures	Fine network. Pipes placed in public ROWs primarily located in sub-collector and collector street ROWs, network leads to lot line of individual dus or residential structures
Local Streets	High. Capital cost determined primarily by length but also by design standard (that is, pavement width and thickness)	Linear consists of subcollector streets, cul-de-sacs, loops, and lanes leading to individual dus and residential structures	Fine network. Consists of subcollector streets, cul-de-sacs, loops, and lanes leading to individual dus and residential structures
Streetlighting	High. Capital cost determined by length of system	Linear consists of cable, poles, and fixtures	Fine network. Cable and poles located in public ROWs primarily located in sub-collector and collector street ROWs, network leads to lot line of individual dus or residential
Sidewalks	High. Capital cost determined by length of system	Linear	Fine network. Sidwalk located in yards on private property adjacent to streets, network leads to lot
Drainage Improvements	High. Cost dependent upon volume of flow to be accomodated	Primarily point facilities, includes detention and retention basins	Centrally located facilities fed by stormwater collector pipes

Table 3-2

Capital Costs Sensitivity of Intraneighborhood Services

	Development Density		Character of Development		Population		Location Attributes			Service Characteristics		
	Gross Density	Net Density	Lot Size	Type of du	Total Population Served	Density	Prox. to Service Area	Prox. to Employment	Prox. to Comm. Facilities	Capacity Utilization	Service and Design Standards	Shape of Service Area
Sanitary Sewer Collector Lines	Sensitive	Highly Sensitive	Highly Sensitive	Moderately Sensitive	Sensitive	Moderately Sensitive	Minimally Sensitive	Minimally Sensitive	Minimally Sensitive	Moderately Sensitive	Sensitive	Moderately Sensitive
Storm Sewer Collector Lines	Sensitive	Highly Sensitive	Highly Sensitive	Moderately Sensitive	Minimally Sensitive	Moderately Sensitive	Minimally Sensitive	Minimally Sensitive	Minimally Sensitive	Moderately Sensitive	Sensitive	Moderately Sensitive
Water Distribution Lines	Sensitive	Highly Sensitive	Highly Sensitive	Sensitive	Sensitive	Moderately Sensitive	Minimally Sensitive	Minimally Sensitive	Minimally Sensitive	Moderately Sensitive	Sensitive	Moderately Sensitive
Local Streets	Sensitive	Highly Sensitive	Highly Sensitive	Sensitive	Moderately Sensitive	Moderately Sensitive	Minimally Sensitive	Moderately Sensitive	Moderately Sensitive	Moderately Sensitive	Highly Sensitive	Moderately Sensitive
Streetlighting	Sensitive	Highly Sensitive	Highly Sensitive	Minimally Sensitive	Minimally Sensitive	Moderately Sensitive	Minimally Sensitive	Minimally Sensitive	Minimally Sensitive	Minimally Sensitive	Moderately Sensitive	Moderately Sensitive
Sidewalks	Sensitive	Highly Sensitive	Highly Sensitive	Minimally Sensitive	Minimally Sensitive	Moderately Sensitive	Minimally Sensitive	Minimally Sensitive	Minimally Sensitive	Minimally Sensitive	Minimally Sensitive	Moderately Sensitive
Drainage Improvements	Moderately Sensitive	Sensitive	Sensitive	Moderately Sensitive	Minimally Sensitive	Moderately Sensitive	Minimally Sensitive	Minimally Sensitive	Minimally Sensitive	Minimally Sensitive	Highly Sensitive	Minimally Sensitive

● Highly Sensitive ◒ Sensitive ◍ Moderately Sensitive ○ Minimally Sensitive

increasing capacity by using larger diameter pipes to accommodate a larger volume of flow coming from a concentrated residential area.

Figure 3-1 shows that increasing a pipe's cross sectional area, and thus its capacity, requires a much smaller proportional increase in its radius. The figure shows that only an 11.8 percent increase in radius is needed to increase cross sectional area by 25 percent, and that only a 22.5 percent increase in radius is needed to produce a 50 percent increase in cross sectional area. The result is that a pipe with 50 percent more capacity will not be 50 percent more expensive because the increase in material cost (a function of its circumference) is proportionately much less. In addition, construction costs increase only minimally as diameter changes. Virtually the same amount of construction hours and the same-sized trench is required for a 12" diameter pipe as is required for an 18" pipe.

A substantial increase in water or sewer capacity can be obtained at a modest increase in capital cost. Local policy makers could consider increasing density within an area proposed for new residential development as opposed to permitting the same number of units spread over a larger area at a lower density. The other implication is that using regularly shaped service areas provides efficiencies for school, police, and fire services. Circular service areas can be expanded with the least increase in radius, which translates into the least increase in response time from a centrally located facility to new dwelling units located at the periphery.

Character of the Development

Table 3-2 also indicates, as expected, that the capital cost for most intraneighborhood services is highly sensitive to lot size and shape but is less sensitive to the type of dwelling unit. The first conclusion is expected because lot size and shape are closely related to and correlate with net development density. Both factors determine the length of pipe or road required per dwelling unit (that is, frontage along a lot).

The type of dwelling unit affects capital cost to a lesser extent than does lot size although the type of dwelling unit correlates to some extent with lot size. Single family dwelling units tend to be located on larger lots and require longer lengths of pipe/parcel frontage to service them. Thus, the length of linear infrastructure/dwelling unit is only indirectly a function of dwelling unit type.

The capital cost of local streets (that is, subcollectors, cul-de-sacs, and collectors) is sensitive to dwelling unit type. The capital cost for drainage improvements, streetlighting, and sidewalks are moderately to minimally sensitive to dwelling unit type.

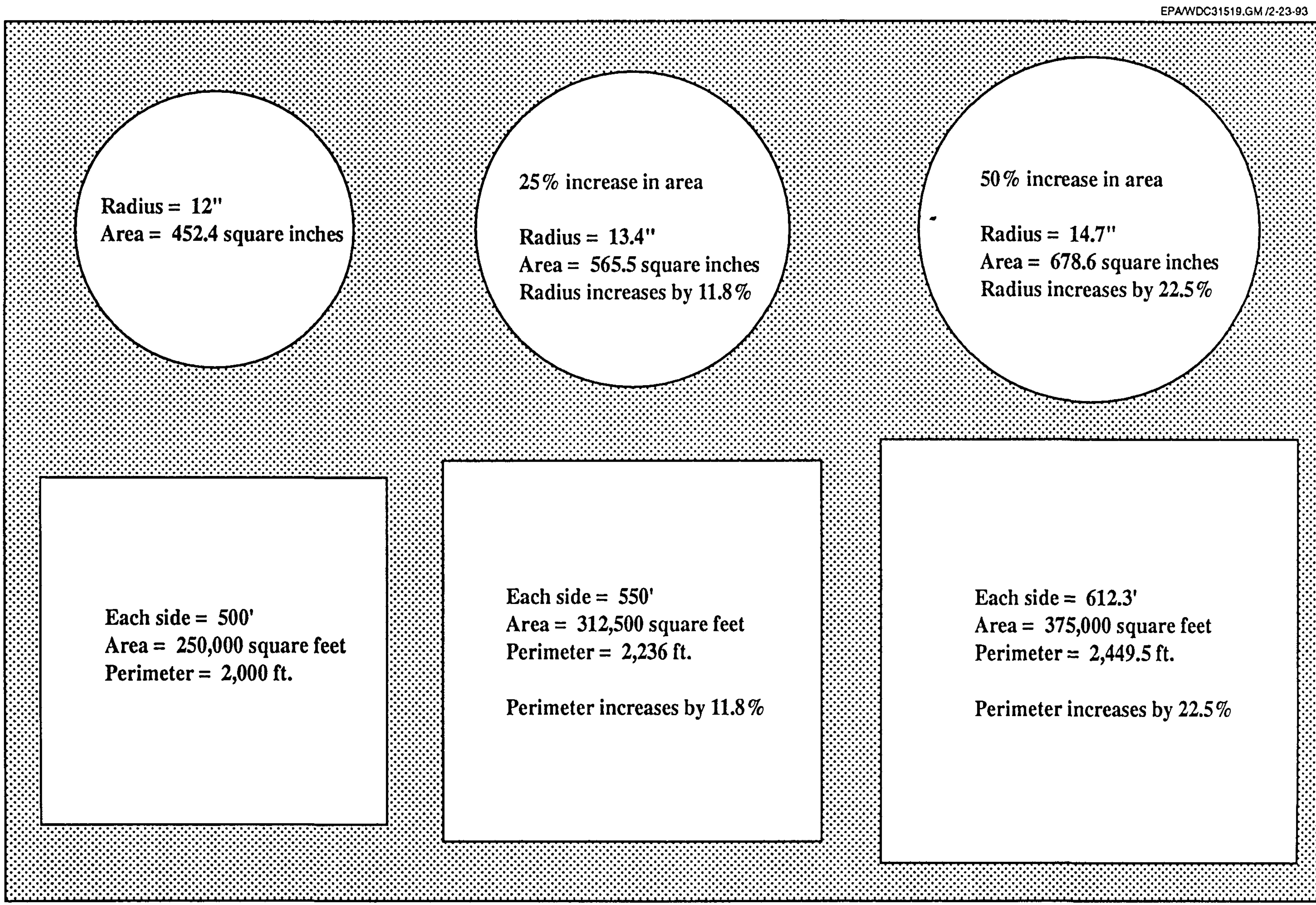

Figure 3-1
Change in Radius and Perimeter vs Change in Area

Population

Table 3-2 shows that the sensitivity of capital costs for intraneighborhood services varies widely based on population to be served, and that this sensitivity is less than lot size or development density. For water and sewer service, the total flow to be accommodated is determined, for the most part, by the number of persons to be served, although the type of dwelling unit and the socioeconomic characteristics of the residents are also factors in determining demand. The total flow, in turn, determines the diameter of the collector or distribution pipes that will be needed. The one exception is stormwater collectors and drainage improvements, whose size and capacity depends more on dwelling unit character (that is, amount of impervious surface and lot size), and less on population.

Population density correlates at the intraneighborhood level with development density as concentrations of population occur when development densities are high. Concentrating population provides efficiencies in delivering many types of service, either because the length of pipe or road/dwelling unit served is reduced, or because more persons can be served more efficiently, as with fire and police services. However, increasing population density also requires that more capacity is required for water, sewer (larger diameter pipes), and transportation facilities (more lane miles).

Locational Attributes

For the most part, the capital costs of intraneighborhood services are only minimally sensitive to the regional location of the development. An exception is the capital costs for local streets which are moderately sensitive to proximity to employment and to community facilities.

A higher proportion of residents may be able to walk to work, public transportation, schools, and community facilities when the development is located close to these facilities, although it is still difficult to convince people to give up their cars even in settings conducive to walking. Residents of leapfrog developments will have to drive to more places, resulting in more total vehicle trips and a greater capacity in lane miles.

The primary effect of regional location on transportation capital costs is more significant for arterials and highways than for local streets.

Service Characteristics

The effect of service characteristics on capital costs are often underestimated. This is particularly true for linear, capital-intensive facilities. Capital costs for intraneighborhood services are, in general, more sensitive to service and design standards, and less sensitive to the shape of the service area and to capacity utilization.

The design standards for the linear infrastructure are based on the total expected flow, be it traffic, wastewater, treated water, or stormwater, which is, in turn, a function of population. Since flow determines the cross section, which determines cost, the capital cost of most interneighborhood services is sensitive to the design standard. There is also usually a desired level of capacity utilization, either to avoid incurring very high marginal capital costs that occur when facilities are very underutilized or to obtain efficiencies in operating costs. Intraneighborhood water and sewer pipes are designed to operate at a higher level of capacity (that is, a larger percentage of cross sectional area is used) than interneighborhood water and sewer pipe. Regulations, such as a site planning ordinance, often contain or reference design standards.

Capital costs per dwelling unit served can be reduced by changing design standards, such as by mandating the use of narrower subcollector streets or cul-de-sacs, or other less-expensive levels of service. The intraneighborhood services whose capital cost most sensitive to design standards are local streets and drainage improvements because their capacity and ultimate cost are defined by engineering considerations (that is, the highest volumes for which it must be designed), and by regulatory standards. Site planning standards can decrease the cost of off-site stormwater facilities.

Interneighborhood Services

The discussion below summarizes the material presented in Tables C-6 through C-10 contained in Appendix C: Tables.

Characteristics of the Service

As shown in Table 3-3, interneighborhood services vary in terms of their capital intensity. The three types of trunk lines and arterial streets are highly capital-intensive, while other services, such as police, fire, and solid waste, are lower. Interneighborhood facilities consist of a mix of linear and point facilities, ranging from trunk pipelines to police precinct and fire stations, recreation centers, and transfer stations. They are either arrayed in a coarse network or consist of a network of facilities distributed throughout the service area based on the location of the population.

Interneighborhood services and, to a greater extent, regional services have large service areas and provide services universally to both residential and non-residential users located there (with the obvious exception of education). For example, collector streets and arterials carry local residential and non-residential traffic to and from commercial, institutional, government, and industrial destinations. Police, fire, and emergency medical services are provided to both the residential and non-residential users, while sewer trunk lines convey wastewater from both residential and non-residential sources. The total demand for these two types of services is more evenly spread across the residential and non-residential sectors, making it harder to accurately allocate the total demand and costs for the services between the two sectors. This is in contrast to intraneighborhood services, which are provided to small, homogeneous residential areas the demand for which is easily and almost entirely attributable to residential users.

Table 3–3
Attributes of Interneighborhood Services

Service	Service Attributes		
	Capital Intensity	**Form**	**Spatial Arrangement**
Sanitary Sewer Trunk Lines	High. Capital cost determined more by length; to a lesser extent by pipe capacity (that is, cross sectional area)	Linear. Consists of pipes receiving flows from collector pipes and conveying effluent to central treatment plant.	Coarse network consisting of a few high capacity pipes; placed in public ROWs primarily located in collector and arterial streets.
Storm Sewer Trunk Lines	High. Capital cost determined more by length; to a lesser extent by pipe capacity (that is, cross sectional area)	Linear. Consists of pipes receiving flows from collector pipes and conveying runoff to discharge location.	Coarse network consisting of a few high capacity pipes; placed in public ROWs primarily located in collector and arterial streets.
Water Trunk Lines	High. Capital cost determined more by length; to a lesser extent by pipe capacity (that is, cross sectional area).	Linear. Consists of pipes conveying water from a central treatment facility to residential areas, where the water then goes to water distribution lines.	Coarse network consisting of a few high capacity pipes; placed in public ROWs primarily located in collector and arterial streets.
Elementary and Middle Schools	Low. Capital costs determined by number of pupils served. Total annual costs determined largely by salaries.	Point facilities. Scattered school buildings.	Individual buildings located, to the extent possible, at the center of the service area.
Police	Low. Capital costs determined by number of stations, and to a much lesser extent, by equipment required. Total annual costs determined largely by salaries.	Point facilities. Individual buildings or stations.	Centrally located headquarters supporting satellite precinct stations that serve developed areas.
Fire	Low. Capital costs determined by number of stations, and to a lesser extent, by equipment required. Total annual costs determined largely by salaries.	Point facilities. Individual buildings or stations.	Centrally located headquarters supporting satellite fire stations that serve developed areas.
Solid Waste Collection	Low. Capital costs determined by number and capacity of processing or disposal facilities, and by vehicles required for collection. Total annual costs determined largely by salaries.	Point facilities. Individual transfer stations.	Often use satellite transfer stations that serve the central waste disposal facility; vehicles use road and street network to collect from individual dus.
Parks and Recreation	Average. Capital costs determined by the number of facilities and by the types of activities supported at each. Total annual costs determined largely by salaries.	Point facilities. Individual parks and recreation centers.	Scattered parks serving neighborhoods with larger, full–service, centrally located recreation centers; located, if possible, in the center of the service area, often at schools.
Emergency Medical	Low. Capital costs determined by number of stations, and to a lesser extent, by equipment required. Total annual costs determined largely by salariers.	Point facilities. Individual buildings or stations.	Centrally located headquarters supporting satellite precinct stations that serve developed areas.
Collector and Arterial Streets	High. Cost dependent upon total lane miles of capacity required and upon level of service to be maintained.	Linear. High capacity collectors and arterial streets receiving local traffic and conveying it to distant locations.	Coarse Network. Contains few, larger capacity collectors and arterials linking local residential areas with regional highways.

Development Density

In general, the capital costs for capital-intensive interneighborhood services are more sensitive to gross density, which is a function of the regional land use patterns. This is in contrast to intraneighborhood services, whose capital costs are more sensitive to net density. The capital cost of linear interneighborhood trunk lines and local streets are highly sensitive to gross development density as shown in Table 3-4. This is a point made by Kain and noted by Frank in his monograph. Interneighborhood facilities serve groups of neighborhoods so that the spacing between them (that is, gross density within the service area) is the crucial factor in determining the length of the trunk lines.

The capital cost of the less capital-intensive services, such as education, police, and fire are sensitive to gross development density because it determines service standards, such as response time and areal extent of the service area, particularly for schools. The capital costs for transportation equipment needed for solid waste collection is moderately sensitive to gross density. Fewer trucks will be needed in densely developed areas as more pick-ups can be made per mile or route or hour of operation.

Development Character

As shown in Table 3-4, the capital cost of interneighborhood services is minimally sensitive to lot size, with the exception of trunk lines which have a moderate sensitivity. This is consistent with the above finding for their sensitivity to gross and net development density.

The capital cost of elementary and middle schools is highly sensitive to the type of dwelling unit. As noted in Chapter 2, the type of dwelling unit determined the number of school-age children present. The capital costs of some of other interneighborhood services is sensitive to dwelling unit type, including water trunk lines, solid waste collection, parks and recreation, and arterial streets. Demand for these services is a function of dwelling unit, although not to the extent of that for education. The comments from one reviewer (Valenza, 1993) noted that demand for police and fire services is, to some extent, related to the type of dwelling unit.

Population

Table 3-4 shows that the capital costs of the labor-intensive interneighborhood services, such as police, fire, solid waste, recreation, and emergency medical, are highly sensitive to the size of the population to be served. The total number of persons determines the demand for labor-intensive services. For example, the more persons to be served, the more police cars, solid waste collection trucks, or fire trucks—all of which are capital equipment—will be required. The capital cost of providing these services is less sensitive to population density.

Table 3-4

Capital Costs Sensitivity of Interneighborhood Services

	Development Density		Character of Development		Population		Locational Attributes			Service Characteristics		
	Gross Density	Net Density	Lot Size	Type of du	Total Population Served	Density	Prox. to Service Area	Prox. to Employment	Prox. to Comm. Facilities	Capacity Utilization	Service and Design Standards	Shape of Service Area
Sanitary Sewer Trunk Lines	●	◍	◍	◍	◒	◍	●	○	○	◒	◒	◒
Storm Sewer Trunk Lines	●	◍	◍	◍	◍	◍	○	○	○	◒	◒	○
Water Trunk Lines	●	◍	◍	◒	◒	◍	●	○	○	◒	◒	◒
Elem. & Middle Schools	◒	○	○	●	◍	◒	○	○	○	◍	◒	◍
Police	◒	○	○	◍	●	◒	○	○	○	◍	◒	○
Fire	◒	○	○	◍	●	◒	○	○	○	◍	◒	○
Solid Waste Collection	◍	○	○	◒	●	◒	○	○	○	◍	◍	○
Parks and Recreation	◍	◍	○	◒	●	◒	○	○	○	◍	◒	◍
Emergency Medical	◒	○	○	◍	●	◒	○	○	○	◍	◒	○
Arterial Streets	●	◍	○	◒	◒	◒	○	◒	●	●	●	●

● Highly Sensitive ◒ Sensitive ◍ Moderately Sensitive ○ Minimally Sensitive

Because they are labor-intensive, the primary cost impact of most interneighborhood services (except for the trunk lines and arterial streets) is as an annual O&M expense. The total annual cost to service a dwelling unit is substantially greater than the annual capital cost as will be discussed in Chapter 4.

Higher population densities allow labor-intensive services to be provided more efficiently (that is, more households covered in the same amount of police patrol time or more dwelling units served per mile of a solid waste collection route), thus potentially offsetting the need to obtain additional vehicles.

Locational Attributes

The location of a residential development within a region has widely varying impacts on the capital cost of interneighborhood services as shown in Table 3-4. As expected, the cost of the capital-intensive services that connect residential areas to regional treatment or processing facilities (water and sewer trunk lines) are highly sensitive to proximity to existing service areas. This is consistent with a number of studies, for example, *Impact Assessment of the Interim State Development and Redevelopment Plan* and *Search For Efficient Urban Growth Patterns*) that have shown that infill development or locating new residential developments at the edge of existing service areas is the most economically efficient way of providing interneighborhood services. The length of the more expensive trunk lines and arterial streets is minimized, and existing excess capacity at the central treatment or disposal facilities may be available.

The capital costs of labor-intensive services are only minimally sensitive to proximity to an existing service area. Services will be extended to these areas, particularly when they are contiguous, by incurring additional O&M expenses for new personnel so as to extend the service area. Some capital costs may be incurred for new trucks, police cars, solid waste collection trucks, or school buses.

As one reviewer (Avin, 1993) has noted, it is likely that, in situations of leapfrog development, interneighborhood services can be most economically provided to constructing satellite or decentralized facilities. This would be particularly true for labor-intensive services where it would not be feasible to extend the service area because decreasing returns to scale would result. Examples include the construction of police precinct stations, libraries, community service centers, and recreation centers.

The proximity to employment centers and community facilities affects trip lengths which, in turn, determine the total lane miles of capacity that will be needed for arterial streets and highways. The effect of proximity to community facilities on the capital cost of materials is greater than that for proximity to work as trips to community facilities tend to be shorter and arterials more localized. In contrast, distance to employment is more significant for highways. Using infill locations or mixed use developments can lessen the total number of trips, particularly to community facilities, when they are located within walking distance.

Service Characteristics

The capital cost of the capital-intensive interneighborhood services, as shown in Table 3-4, is sensitive or highly sensitive to the level of capacity utilization in two ways: (1) the projected demand and flow determine the design and the size, which in turn determines the capital cost; and (2) the actual level of utilization determines the number of users who will be required to pay the capital costs for the trunk lines through user fees or taxes.

The difficult decision in designing water, stormwater, and sewer trunk lines; collector and arterial roads; and, to a lesser extent, schools, is forecasting increases in utilization over time and then designing the facility so that future increases in use can be accommodated. Excess capacity needs to be installed initially to accommodate future growth and because there may be cost efficiencies obtained in constructing one larger capacity facility initially as opposed to several smaller ones incrementally over time. However, having a large amount of excess capacity initially means higher marginal capital costs until future development brings future users among whom the fixed capital costs can be apportioned.

The capital costs of the labor-intensive services are moderately sensitive to capacity utilization. Additional capital equipment needed to meet small increases in demand can be added in small increments as needed (that is, additional police cars, fire trucks, and solid waste collection vehicles can be acquired). The capital cost of the labor-intensive services are, in general, more sensitive to design and service standards than they are to capacity utilization. Service standards determine the desired response times (for police and fire) and the capital equipment required to support these standards. Standards may also include the number of police officers or firemen per 1,000 population, maximum class size, and acres of park space per 1,000 population.

The sensitivity of the capital cost of interneighborhood services to regulatory standards mirrors that for design standards. Often regulations contain or reference design standards or engineering criteria to be applied, such as the amount of square footage per student in classrooms.

The capital costs of arterial roads are highly sensitive to both design and service standards. Geometric design standards (that is, pavement width and capacity, sight lines, turning angles, grade, and lane width) determine the design and the capital cost of roads, while performance standards specify the desired levels of service (that is, a measure of capacity utilization or even overutilization) to be achieved.

The capital cost of the linear interneighborhood services are the most sensitive to the shape of the service area. As noted in *The Costs of Alternative Development Patterns*, a study done by Stone (1973) in England found that the capital cost for providing main roads was 14 to 17 percent higher in star-shaped and linear regions than that in rectangular regions.

Regional Services

The discussion below summarizes the material presented in Tables C-11 through C-15 contained in Appendix C: Tables.

Characteristics of the Service

Table 3-5 indicates that the capital intensity of the regional services is variable. These regional services consist primarily of large, centrally located treatment, processing and disposal, or service centers. One factor common to most of them is that there are economies of scale, in terms of both unit capital and annual unit O&M costs, that can be achieved by building larger facilities. These cost savings can be used to offset the cost inefficiencies that are sometimes incurred in constructing the distribution systems, such as water and sewer trunk lines. Two of the services, high schools and general government, are labor-intensive as opposed to capital-intensive, even though they also consist of centrally located facilities.

The size of the area covered by regional services can vary widely but usually at a minimum, encompasses at least a portion of a municipality (that is, a high school in a densely populated residential town), a county (for example, solid waste disposal facilities), and on up to a multi-county region, such as a wastewater treatment plant serving several counties.

The ability to capture economies of scale in constructing regional facilities means that it is often most economical to provide additional capacity in large increments. It is usually not cost-effective to construct facilities in small increments that closely follow increases in demand over time, although this can be done to some extent with smaller package wastewater treatment plants by constructing precinct stations or by adding temporary classrooms. The "lumpy" nature of regional capital facilities means that equitably allocating their capital costs over time between current and future users is a major pricing and financing concern.

Development Density

As indicated in Table 3-6, the capital cost of regional facilities are only minimally sensitive to gross density, with the exception of highways, whose capital cost is sensitive to regional gross density, and high schools, whose capital costs are moderately sensitive to gross density. The distribution or collection component of these service systems, which are the most sensitive to geography and density, are linear capital facilities that are classified as either interneighborhood or intraneighborhood facilities. For high schools, regional gross density will determine the number, location, and size of the high schools. New residential development will face jurisdictions with county-wide systems and large regional high schools with the choices of either building new schools (which is more difficult to do for high schools than for elementary schools), providing additional busing or possibly, in the short-run, adding temporary classrooms.

Table 3-5
Attributes of Regional Services

Service	Capital Intensity	Form	Spatial Arrangement
Wastewater Treatment Plants	Average to High. Economies of scale for both capital and O&M costs are achieved in constructing larger capacity facilities.	Point Facility. Receives effluent from trunk lines that convey wastewater from developed areas.	Service provided to an entire region from a centrally located facility or facilities.
Water Treatment Plants	Average to High. Economies of scale for both capital and O&M costs are achieved in constructing larger capacity facilities.	Point Facility. Sends treated water via mains and trunk lines to developed areas.	Service provided to an entire region from a centrally located facility or facilities.
Water Supply	High. Supply facilities, such as reservoirs, have high capital costs; pumping stations are usually needed to convey water to treatment plant.	Point Facility. Sends raw water via main supply lines to treatment plant.	Located where water is available or obtainable.
High Schools	Low. Capital costs are determined by number of pupils served.	Point facilities. Centrally located building serving entire municipality or larger area.	Individual building located, to the extent possible, at the centroid of the attendance area.
Solid Waste Disposal	Low. Capital costs determined by total capacity, either daily (for resource recovery plants) or lifetime (for landfills).	Point facilities. Individual disposal or processing facilities.	Centrally located processing or disposal facility, desirably located at the centroid of the service area.
General Goverment	Low. Capital cost depends on the population being served, which determines the number and type of personnel required, and the facilities to house them. Primary costs are for labor.	Point facility. Individual building located at the administrative center. The building does not have to be located at the centroid of jurisdiction but it needs to be easily accessible.	Service provided uniformly to all residents and businesses located in the jurisdiction.
Highways	High. Capital cost is a function of total lane miles of capacity required, desired level of service, and design standards.	Linear. High capacity arterials are located in heavily traveled corridors linking developed areas to important regional destinations.	Coarse Network. Contains few high capacity roads located in developed, heavily traveled corridors.

Table 3-6

Capital Costs Sensitivity of Regional Services

	Development Density		Character of Development		Population		Locational Attributes			Service Characteristics		
	Gross Density	Net Density	Lot Size	Type of du	Total Population Served	Density	Prox. to Service Area	Prox. to Employment	Prox. to Comm. Facilities	Capacity Utilization	Service and Design Standards	Shape of Service Area
Wastewater Treatment Plant	Minimally Sensitive	Minimally Sensitive	Minimally Sensitive	Moderately Sensitive	Highly Sensitive	Moderately Sensitive	Minimally Sensitive	Minimally Sensitive	Minimally Sensitive	Sensitive	Sensitive	Minimally Sensitive
Water Treatment Plant	Minimally Sensitive	Minimally Sensitive	Minimally Sensitive	Sensitive	Highly Sensitive	Moderately Sensitive	Minimally Sensitive	Minimally Sensitive	Minimally Sensitive	Sensitive	Sensitive	Minimally Sensitive
Water Supply	Minimally Sensitive	Minimally Sensitive	Minimally Sensitive	Sensitive	Highly Sensitive	Moderately Sensitive	Minimally Sensitive	Minimally Sensitive	Minimally Sensitive	Sensitive	Sensitive	Minimally Sensitive
High Schools	Moderately Sensitive	Minimally Sensitive	Minimally Sensitive	Highly Sensitive	Sensitive	Sensitive	Minimally Sensitive	Minimally Sensitive	Minimally Sensitive	Moderately Sensitive	Sensitive	Moderately Sensitive
Solid Waste Disposal	Minimally Sensitive	Minimally Sensitive	Minimally Sensitive	Moderately Sensitive	Highly Sensitive	Sensitive	Minimally Sensitive	Minimally Sensitive	Minimally Sensitive	Moderately Sensitive	Moderately Sensitive	Minimally Sensitive
General Government	Minimally Sensitive	Minimally Sensitive	Minimally Sensitive	Minimally Sensitive	Moderately Sensitive	Sensitive	Minimally Sensitive	Minimally Sensitive	Minimally Sensitive	Minimally Sensitive	Minimally Sensitive	Minimally Sensitive
Highways	Sensitive	Moderately Sensitive	Minimally Sensitive	Sensitive	Sensitive	Sensitive	Minimally Sensitive	Highly Sensitive	Sensitive	Highly Sensitive	Highly Sensitive	Sensitive

● Highly Sensitive ◒ Sensitive ◍ Moderately Sensitive ○ Minimally Sensitive

Highways are capital-intensive structures and, because of their regional function, their capacity and capital costs are determined by a number of factors in addition to the location and character of residential areas within a region. Other factors, such as the amount and composition of non-residential land use and the road's regional function (such as connecting two metropolitan centers), are important determinants of a highway's capital cost.

Character of the Development

The type of dwelling unit has a widely varying affect on the capital cost of regional facilities as shown in Table 3-6. The capital cost of high schools is highly sensitive to the type of dwelling unit, while the cost of water treatment and supply facilities is sensitive to du type. The demand for water, the number of school-age children, and the number of trips generated/dwelling unit differ by the type of dwelling unit. Lot size has no effect on capital costs.

Population

Table 3-6 indicates that the capital cost of most regional services is sensitive or highly sensitive to the total number of persons residing in the service area. The demand from the residential sector for these services is directly related to the number of persons served. This is true for water and sewer treatment services, water supply, and solid waste disposal.

Recent research has shown that there is a correlation between regional population density and both the per capita annual O&M costs and the per capita annual capital costs incurred by county governments (Ladd, 1992). The relationship is stronger for the increase in annual per capita O&M costs as a function of population density. Allowing for a lag effect, in which population density ultimately requires local governments to increase service capacity through capital spending, population density does ultimately affect the capital cost of providing public services.

Table 3-6 shows that the capital costs of regional facilities are moderately sensitive to sensitive to population density. The total population to be served is in most cases the most important factor in determining demand, capacity, and, ultimately, capital cost.

In some sparsely settled areas, the combination of a small to medium capacity required for a treatment or disposal facility where economies of scale due to size are not obtainable, and the relatively high costs of providing distribution infrastructure (that is, water and sewer trunk lines and collection pipes) to fewer users, may justify the construction of several, smaller-capacity facilities throughout the service territory. This would to provide more localized service, as opposed to extending the service area from existing facilities.

Locational Attributes

The capital cost of regional services is minimally sensitive to the regional locational characteristics of the development as shown in Table 3-6. These regional services are point facilities. The capital costs incurred in constructing and operating the distribution and collection components of these service systems have been considered previously. Only the capital cost of highways are highly sensitive to proximity to work and are sensitive to proximity to community facilities.

Service Characteristics

The ability to capture economies of scale in constructing some regional services, in combination with their capital intensity, means that the capital costs of some of these services are sensitive to capacity utilization. This is particularly true for water and wastewater treatment plants, water supply facilities, and highways.

As shown in Table 3-6, the capital cost of most regional services are sensitive to highly sensitive to design and service standards. Design standards, such as classroom area per high school student, desired levels of service, and pavement designs for highways, determine capital costs. Regulatory standards have a very significant impact on the capital cost of wastewater treatment and water treatment plants. These standards specify the treatment levels, performance standards, or effluent limits that must be achieved by these plants, which in turn determine the processes to be used, which eventually determine, along with total capacity, the design and capital cost of the treatment plant.

The capital cost of highways are sensitive to the shape of the service area. They are less sensitive to this factor than arterials are because some of the determinants of the size, route, and cost of a highway are due to other factor from outside the region. The capital cost for buses required to transport pupils is moderately sensitive to the shape of the attendance area or jurisdiction. This would be particularly true in Maryland and Virginia with their county-wide school districts and large, regional high schools.

Capital Costs in Relation to Total Annual Local Government Service Costs

Capital costs, because of their large values, their "lumpiness" in adding capacity increments, and the need to obtain long-term financing, are often the major focus of local decision-makers. Focusing exclusively on capital costs misses the point that capital costs, when properly annualized, comprise a small proportion of most municipalities total annual expenditures (annual capital costs plus O&M costs). Land use policies that focus only on controlling the capital cost per dwelling unit are directed at only a minority of the total annual costs per dwelling unit, even when the capital costs are properly calculated using a life cycle cost approach. Well-intentioned land use policies, that are directed toward obtaining some proportion of the marginal capital costs required by a new dwelling unit, through proffer charges and impact fees, may not be as effective as they could be if the effects on operating costs are not taken into account.

It is helpful to have some idea of the distribution of total annual costs per dwelling unit by capital and operating components, and by service category (that is, police, fire, education, recreation, etc.). This will first show the true proportion of annual capital costs to total annual costs and will further identify those service categories where the annual costs are the highest. Understanding what factors determine the costs of those service will enable local decision-makers to consider the full range of costs when developing land use policies. The annual local government service cost/dwelling varies widely from municipality to municipality, depending upon a number of factors:

- The range of services provided (that is, public water and sewer vs on-lot septic system and on-site wells, police, fire, solid waste, etc.)
- The service standard
- The income of the residents and their ability to afford and demand high quality services
- Unit of government providing the service, which can achieve economies of scale (that is, county-wide school districts in Virginia and Maryland vs a municipal-level district in Pennsylvania)
- Capacity of the system (that is, are economies of scale achievable?)

There is no standard distribution of annual service (because of the criteria listed above) but it is helpful to get some idea of a representative distribution of costs based on the bundle of local government services provided to suburban residential development.

Baltimore County

The most relevant example is from a county located within the Chesapeake Bay watershed. Baltimore County is a good example, given its location, the full range services it provides (county-wide education system and other normal local services), and the high level of services it provides. An analysis of Baltimore County's proposed 1993 budget indicates the following:

- Proposed capital expenditures during fiscal 1993 comprise 11.8 percent of the total budget (General Fund plus special funds, and including both local and non-local revenue sources)
- Proposed capital expenditures, assuming all of them are paid for from locally generated revenues (which will not be the case) comprise 13.7 percent of total local revenues

- Removing the local expenditures for the community college (which many municipalities and counties do not fund) and, still assuming that all capital expenditures are locally funded, raises the proportion of annual capital expenditures to 14.2 percent of total local revenues

This analysis confirms, at a preliminary level, that annual capital expenditures (to all land use types, including residential) comprise a small proportion of total local government annual expenditures.

Annual Costs of Serving Residential Development

Another issue of more direct relevance to this study is what relationship exists between the annual capital costs and the total annual costs (annual capital and annual O&M) incurred in providing services to individual dwelling units. What proportion of total annual costs incurred in serving a dwelling unit are annual capital costs? Is this percentage comparable to the proportions presented above? This issue is also important for local planning and zoning officials because they need to be aware, particularly over the long run, of the relationship between annual O&M costs and annual capital costs that will be incurred by a local government in providing service to new residential development. If the proportion of annual capital costs is relatively low, then local decision-makers may be mis-directing their efforts in managing residential growth by focusing too narrowly on controlling capital expenditures.

The literature review found little information that accurately estimated the relationship between annual capital costs/du and total annual costs/du. Most cost of development studies, and many of the studies that estimate impact fees and proffer charges are designed to estimate the total marginal capital costs of providing services and infrastructure to a new du. These studies do not normally calculate the total annual O&M costs/du, and many studies do not annualized the capital costs.

There is some information that gives a preliminary indication of the proportion between annual capital and total annual costs/du.

The Search for Efficient Urban Growth Patterns

This study estimated the total annual costs to provide services to single family dwelling units. These estimates were for a mix of different types of residential developments (that is, compact, contiguous, scattered, linear, and satellite) which tended, for the most part, to be contiguous or infill developments. The study calculated that, on average, annual capital costs were about 23.5 percent of the total annual cost incurred to provide the full range of services to single family dwelling units.

Because the study considered developments located in Florida, the proportion of annual O&M expenditures to total annual expenditures, for some service categories, would be different from those in the Chesapeake Bay watershed. For example, annual street and road costs would be higher in the watershed, because of snow plowing, road salting, and repairing pavement due to the use of salt. Annual expenditures, for parks and recreation would be lower because of the shorter outdoor season. Even allowing for these differences, the Florida study indicates that the annual capital costs per single family du are a low proportion of total annual costs/du.

The Costs of Sprawl

The Costs of Sprawl estimated total capital and total O&M costs for the 1,000 du neighborhood prototype and the 10,000 community prototypes. Because this study considered a "greenfield" or new residential prototype, its results are more applicable to the situation of local governments considering approval of a new residential development located beyond current services boundaries. Using the community analysis so as to obtain the full range of services, and omitting costs for electric and gas, and residential capital costs; the data from *The Costs of Sprawl* indicates that annual capital costs range between 41 percent and almost 50 percent of total annual costs per du, depending upon the prototype considered and the length of time over which capital costs are annualized.

This percentage occurs for several reasons. First, *The Costs of Sprawl* underestimated the number of school-age children in the community cost analysis so that annual education O&M costs were likely underestimated. Because education costs comprise the largest share of most local expenditures (approximately two-thirds of annual local expenditures), higher education costs would decrease the proportion attributable to annual capital costs. There are also other shortcoming in *The Costs of Sprawl* that limit its applicability (see Windsor, 1979). The proportions from *The Costs of Sprawl* should be viewed cautiously. It is likely that they constitute an upper boundary on the proportion of total annual local expenditures/du that would be attributable to annual capital costs. The data from *The Costs of Sprawl* indicates that annual capital costs are likely to be less than half of total annual expenditures for local government services to new dwelling units. It is more likely that this proportion is less than 40 percent.

Virginia Beach Growth Management Study

In 1989, CH2M HILL prepared an analysis of two alternative growth scenarios for a section of the City of Virginia Beach. (This study is reviewed in Appendix B). The study analyzed the capital and operating costs/du associated with alternative forms of a large mixed use development just south of an urban services boundary in Virginia Beach. The development would have contained, using either scenario, a total of 32,500 dwelling units, along with a mix of retail and commercial uses. Data from the study, plus other material supplied to CH2M HILL by the City of Virginia Beach indicated that the annual capital costs/du would be about 25 percent of total annual costs/du.

Conclusion

Annual capital costs comprise a minority of the total annual local government costs incurred in providing services to residential development. The literature indicates that annual capital costs comprise approximately 20 to 30 percent of total annual costs, although this proportion would vary widely depending upon a number of factors, such as the location of the development, service standards, lot size and density, etc.

Chapter 4
The Cost of Development

How the capital cost of providing services and infrastructure varies according to characteristics of residential development is difficult to assess. As noted in Appendix A, particularly in the review of *The Costs of Alternative Development Patterns* by James Frank, there are relatively few studies that have attempted to estimate these capital costs, the most well-known study being *The Costs of Sprawl.* This study is not without its own deficiencies as has been noted by Altshuler in 1977 and by Windsor in 1979.

This chapter presents an estimate regarding the cost of providing public services to new residential development. These estimates have been modified to fit the definitions applied in this study. This is a difficult and complex question to answer from the existing studies for a number of reasons:

- Many of the studies analyzed different sets of services so that the results from them are not directly comparable. For example, some of the studies considered only onsite or intraneighborhood services, and did not consider either interneighborhood or regional services. The cost of regional services were considered in only a few studies.

- Some of the studies, specifically the fiscal impact models and New Jersey's review of the *IPLAN*, determined the cost impacts for municipal-wide or even state-wide broad residential land use classifications. Their results, therefore, answer the question of how capital costs vary by residential development form only in a broad sense.

- Services are provided at different levels (that is, municipality, township, county, or regional authority) in states, which results in cost differences. As an example, many services in Pennsylvania and New Jersey are provided at the township level, while in Virginia and Maryland, these services are provided at the county level. Examples include education, police, fire, and solid waste. There are economies of scale in providing services in Maryland and Virginia. These same economies of scale may not be achievable in New Jersey or in Pennsylvania.

- Service and design standards have changed over time. Costs developed for studies some years ago may have used service standards that are no longer applicable. Because of recent technological advances, some capital facilities can be constructed more efficiently (that is, fewer hours of labor/$ of capital cost) today.

The purpose of this chapter is not to provide a definitive estimate of the capital costs per du as a function of location or density. However, it is important to know what trends that are present in the studies have estimated as the capital costs of serving residential development. Before doing so, it is necessary to note a caveat against the literal interpretation of these numbers. This caution was best stated by Frank in his comprehensive review of cost of development studies, *The Costs of Alternative Development Patterns*:

> "Distinctions among alternative development factors form the experimental variables that are manipulated to observe the extent to which development costs change concurrently. The crucial terms are density and lot size or lot width, municipal improvement standards, characteristics of the occupants, contiguity of development, distance to central facilities, and size of the urban area. Each one, when allowed to vary, has a discernible effect on development costs, but when they are all allowed to vary at the same time, the independent effect of each is difficult to measure because of simultaneous effects." (Frank, p. 37.)

The author makes two important points. First, there are a number of different factors that affect the costs of the development in addition to density and lot size. The list identified by Frank corresponds to the list of factors identified in Chapter 2. Second, it is difficult to precisely isolate the effect of the different factors on the cost of providing public services to residential development. It is reasonable to assume that density and lot size are the dominant factors in determining capital costs particularly for intraneighborhood costs. In reality, the relative effect of the different factors from the existing cost of development studies cannot be ascertained.

Keeping the above caveat in mind, and recognizing that one purpose of this report is to present data contained in the relevant literature, the following capital cost information/du from *The Costs of Alternative Development Patterns* is presented.

Capital Costs of Intraneighborhood Services

Most of the cost of development studies have assessed the capital costs of intraneighborhood services, while some studies have also assessed some of the interneighborhood capital costs. Intraneighborhood costs have usually been assessed using a hypothetical neighborhood design, such as in *The Costs of Sprawl*, *Cost-Effective Site Planning*, and *Environmental and Economic Impact of Lot Size and Other Development Standards*. The most recent definitive assessment of capital costs/dwelling unit for intraneighborhood and interneighborhood services was presented in Frank's *The Costs of Alternative Development Patterns*. Table 4-1 presents a summary of the costs presented in his report, updated to 1992 dollars, using *Engineering News-Record*'s Building Construction Index (BCI).

Table 4-1 Cost of Capital Facilities for Intraneighborhood Services		
du Type and Density	**Neighborhood Costs**[a]	**Intraneighborhood Capital Cost**[a]
SFD, 1 du/acre	$50,200	$33,700
SFD, 3 dus/acre	$34,800	$17,500
SF Clustered, 5 dus/acre	$29,400	$10,500
Townhouses, 10 dus/acre	$22,800	$7,200
Garden Apts., 15 dus/acre	$19,300	$4,600
High-rise Apts., 30 dus/acre	$8,600	$2,200
Mix, 12 dus/acre	$22,900	$6,300

Source: Frank; 1989. *The Costs of Alternative Development Patterns*;
[a] 1992 dollars in cost/dwelling unit. Column 3 from his Table 8.
Note: The mix consists of 20 percent each of sfd, sf clustered, townhouses, garden apartments, and high-rise apartments.

The table above presents only the capital cost estimates for densities of 1 du/acre (which qualifies as sprawl, based on the definition presented in Chapter 1) or greater. Figures for single family developments (sfd) at 1 du/4 acres were presented in *The Costs of Alternative Development Patterns*. These figures are not presented here for the following reasons:

- Frank notes in footnote 1 of his Table 8 that neighborhood costs for 1 du/acre and 1 du/4 acres are multiples of the 3 dus/acre figures from *The Costs of Sprawl*. It is unclear what the magnitude of the increase in neighborhood capital cost/du would be in going from 3 dus/acre to 1 du/acre, much less to 1 du/4 acres. If such a development at 1 du/4 acres required public water and sewer, it would incur higher costs because the lengths of water and sewer pipe, streetlighting, etc. per du would be higher than those for 3 dus/acre.

- Development occurring within the Chesapeake Bay watershed at a density of 1 du/4 acres would most likely use septic systems and on-site wells, eliminating the two most expensive components of local government service. These costs would be incurred by the owners.

While it is clear that the capital costs/du of neighborhood services (as defined by Frank) for residential development at a density of 1 du/acre or less would increase over the capital costs at 3 dus/acre based on an increase in lot size and the length of infrastructure/du, it is unclear that the cost increases would be as significant as those presented in *The Costs of Alternative Development Patterns*. The capital costs/du would be higher but, based on larger lot frontages and lower development density, at some point, much of the costs would be incurred by the homeowner.

The following types of services are included within the category of Neighborhood Costs listed in Table 4-1, Column 2:

- Streets, including local or minor streets, collectors, and arterials, along with sidewalks and street lighting
- Utilities, consisting of sewer, water, and storm water collector pipes; storm drainage facilities; and gas, electric, and telephone connections
- Schools, including primary and secondary

Neighborhood Costs, in Table 4-1, Column 2, contains more services than the classification of intraneighborhood services used in this study. Subtracting the cost of the schools and the phone, gas, and electric utilities produces the estimates presented in column three of Table 4-1, Column 3. This presents the figures from *The Costs of Sprawl* and *The Costs of Alternative Development Patterns* in a format consist with this study.

The figures in Table 4-1 show a decline in capital costs/du as density increases. This should not be interpreted to mean that density is the only factor causing such a decline in capital costs. Frank's caution presented above should be kept in mind. A glance at Table 3-2 also indicates that factors other than density and lot size, such as service standards and the type of dwelling unit, also affect intraneighborhood capital costs.

Based on the literature and the figures presented in Table 4-1, the capital cost/du of intraneighborhood services for residential development at a density of 1 du/acre or greater declines on a per du basis as density increases. While such a decline may be due primarily to development density and lot size, other factors also have an effect.

Capital Cost of Interneighborhood and Regional Services

The capital costs of interneighborhood services have been estimated in relatively few studies. For example, *The Costs of Sprawl* estimated the cost of public facilities in both the neighborhood and community analyses. These included the capital costs required for providing police, fire, solid waste collection and disposal, library, health, general government, and churches. *The Costs of Sprawl* paid only limited attention to the capital costs for other interneighborhood services that were external to a residential development. As Frank has noted, even where interneighborhood capital costs, such as water and sewer trunk lines connecting treatment plants to leapfrog residential developments have been estimated, the estimates have often been flawed.

The Costs of Sprawl did estimate linkage costs in its community cost analysis. These costs were defined as those required to connect the individual residential areas located within a larger 6,000-acre community: water, sewer, storm sewer, road, electric, gas, and phone infrastructure required to traverse undeveloped or passed-over areas between separate residential subdivisions. These services are, to some extent, consistent with the definition of interneighborhood services applied in this study but not completely because *The Costs of Sprawl* did not account for the full costs incurred when connecting an individual subdivision with a central treatment or disposal facility. As Frank noted on page 30 of *The Costs of Alternative Development Patterns, The Costs of Sprawl* did not estimate the cost for facilities external to the 10,000 person community such as roads to employment centers, sewer interceptors, and water mains.

The Costs of Alternative Development Patterns presented updated estimates of what were called "community costs" that had been estimated in an earlier study performed by the Rand Corporation. Community costs represented the capital costs of providing fire, street, sanitary sewer, and storm sewer facilities to new residential developments located at the edge of existing service areas, and of providing them for developments located 5 miles beyond existing service areas. Frank also presented results from a study prepared by Downing and Gustely that estimated the capital costs/mile for providing police, fire, sanitation, school, water supply, storm drainage, and sewer capital facilities to connect new leapfrog developments with central facilities.

Table 4-2 presents a partial estimate of the capital cost for providing both interneighborhood services and some regional services. It includes the costs for sewer, water, and storm sewer trunk lines; all schools; solid waste collection and disposal; police, fire, parks and recreation; general government; and arterial streets. It excludes the cost of constructing new wastewater treatment and water treatment plants, and a new water supply facility. Capital costs are presented for 5-mile and 10-mile distances between the residential development and employment centers, water and wastewater treatment plants, and a receiving body of water. The costs have been rounded off to the nearest $100.

Table 4-2 shows, as expected, that the capital costs/du of inter-regional and some regional costs vary relatively little according to the density of housing, particularly when compared to the decline in intraneighborhood costs. A glance at Tables 3-2 and 3-4 indicates that other factors such as proximity to the service area (for sewer and water trunk lines), population (for water and sewer treatment plants), and locational attributes (for arterial streets and highways) have a significant effect on capital cost.

Table 4-2
Cost of Capital Facilities for Interneighborhood and Selected Regional Services

du Type and Density	Five Miles[a]	Ten Miles[a]
SFD, 1 du/acre	$25,300	$33,500
SFD, 3 dus/acre	$25,200	$33,500
SF Clustered, 5 dus/acre	$25,200	$33,500
Townhouses, 10 dus/acre	$22,500	$30,200
Garden Apts., 15 dus/acre	$22,500	$30,300
High-rise Apts., 30 dus/acre	$13,900	$20,500
Mix, 12 dus/acre	$22,500	$30,300

Note: This table includes the capital costs for public facilities as presented in *The Costs of Sprawl*'s community cost analysis. This includes the costs for police, fire, solid waste collection and disposal, library, health, and general government. These were revised by correcting for changes in population by type of dwelling unit and by excluding the cost of churches.

[a]1992 dollars in cost/du. Distances to employment, sewage plant, water plant, receiving body of water from residential development.

Sources: Frank, 1989. *The Costs of Alternative Development Patterns*. National Association of Home Builders, 1986; *Cost Effective Site Planning*. Real Estate Research Corporation, 1974; *The Costs of Sprawl*.

Table 4-2 does not include the community costs presented in Table 8 of *The Costs of Alternative Development Patterns* because it was not clear to what extent including these costs would mean "double counting" with the 5 and 10 mile linkage capital costs also presented in Table 8.

There are other cost variations between single family dwelling unit and detached dwelling units, particularly the decline in the number of school-age children per dwelling unit, which significantly decreases the school capital costs per du for attached housing. The capital costs for public services (that is, police, fire, solid waste, library, health, and general government) are not sensitive to development densities and lot size, but more according to the population of the service area. The capital costs/du of the labor-intensive interneighborhood services are little affected by the form and density of residential development.

The figures presented in Table 4-2 do not include the costs that would be required to provide additional water treatment or sewer treatment capacity, or additional capacity for highways. While capital costs for water and sewer treatment capacity were included in *The Costs of Sprawl's* community cost analysis, it is difficult to use the cost figures from that report. This is for two reasons: (1) the number of pupils/dwelling unit varied by type of dwelling unit in the neighborhood analysis but was held constant across all types of dwelling units in the community analysis, and (2) the community analysis consisted of a mix of housing types and densities, while the neighborhood analysis consisted of homogeneous developments with one type of dwelling unit. As a result, the development densities are different.

There are economies of scale in terms of linkage costs and other capital facilities that can be achieved in a community of 10,000 dwelling units (used in the community cost analysis) that cannot be obtained in a development of 1,000 dwelling units (used in the neighborhood cost analysis).

Table 4-3 combines the figures from Tables 4-1 and 4-2 and presents the capital costs/du for intraneighborhood, interneighborhood, and some regional services. Table 4-3 shows that the total capital cost/du of facilities needed to service new residential development declines as development density increases. As noted above, such a decline is due to many factors other than density and lot size, particularly when considering interneighborhood and regional services. These cost factors were discussed in Chapter 3 and are presented in Tables 3-2, 3-4, and 3-6. The precise interrelationship between these factors in determining the capital cost/du of new residential development has not been addressed yet by any cost of development study. As noted by Frank, simply trying to isolate the effects of density alone has been difficult.

Table 4-3
Cost of Capital Facilities for Intraneighborhood, Interneighborhood, and Selected Regional Services

du Type and Density	Contiguous[a]	Five Miles[a]	Ten Miles[a]
SFD, 1 du/acre	$50,700	$59,000	$67,200
SFD, 3 dus/acre	$34,500	$42,700	$51,000
SF Clustered, 5 dus/acre	$27,500	$35,700	$44,000
Townhouses, 10 dus/acre	$21,900	$29,700	$37,500
Garden Apts., 15 dus/acre	$19,400	$27,100	$34,900
High-rise Apts., 30 dus/acre	$9,500	$16,100	$22,700
Mix, 12 dus/acre	$21,000	$28,800	$36,600

Note: This table does not include the capital costs for new sewage treatment plant capacity, water treatment plant capacity, water supply capacity, or demand for new regional highways.
[a] 1992 dollar in cost/du. Distances to employment, sewage plant, water plant, receiving body of water from residential development.
Sources: Frank, 1989; *The Costs of Alternative Development Patterns*. National Association of Home Builders, 1986; *Cost Effective Site Planning*. Real Estate Research Corporation, 1974; *The Costs of Sprawl*.

The caveats contained in the literature, and the complexity of the relationship that determines the capital cost of providing services and infrastructure to residential development, make it virtually impossible to precisely specify the effect contributed by any one factor. It would not be accurate to interpret that the above tables show that density is the most important factor. Density is clearly not the only factor that reduces capital costs/du in providing public services and infrastructure. When looking individually at the three classes of service, and assuming that the capital costs of the full bundle of services is incurred by local jurisdictions, some conclusions can be drawn.

The capital cost/du of providing intraneighborhood services does decline as density increases, primarily because of the spatial effects note in this study (that is, declining length of collector and distribution pipe). High density, more compact residential developments are cheaper to provide services to (up to a point) on a du basis. The literature indicates that above a point (for example, for high rise apartments), the capital costs/du begin to increase over the costs for attached housing, such as townhouses. The decrease in intraneighborhood capital costs/du observed as density increases is clearly due not only to density. Other factors have an effect, such as the service standard and the change in the type of du that occurs as density increases, which shifts some on-site costs incurred by single family detached owners to the public sector. The capital costs/du can be lowered by changing standards, such as narrowing street design standards, having fewer trash pick ups, etc. Public costs/du can also be lowered by shifting marginal capital costs to property owners through impact fees.

The largest proportion of capital costs incurred in providing public services for new dus are due to the intraneighborhood services identified in this study, whose capital costs are most sensitive to variations in development density and lot size; and to education, which is usually the largest capital cost/du.

For interneighborhood and regional services, the effect of density, lot size, and type of du has much less of an affect of capital costs, while population, locational attributes, and in some cases, the type of du become more important. Design standards and service levels continue to effect capital costs. The capital costs of interneighborhood and regional services are, for the most part, relatively unaffected by changes in density and lot size. It is difficult to properly allocate the correct proportion of capital costs for some interneighborhood and regional services attributable to new residential development, although the costs can be allocated accurately for some services, such as education, solid waste, and recreation.

Chapter 5

Conclusions

This chapter presents general conclusions that can be drawn from the literature, specifically the material presented in Chapters 2 and 3, and in Appendices A and B. Data limitations in the literature prevent detailed conclusions being made for all of the cost factors identified in Chapter 3. However, some general conclusions can be made using the classification of the services presented in Chapter 3. The conclusions will be general as the literature does not always present unambiguous, quantitative results.

It is tempting when reviewing the literature to generalize about the cause and effect relationship between the capital cost of serving residential development and the factors that determine that cost. Nevertheless some basic conclusions can be drawn. It should be remembered that the focus of these conclusions is on the capital cost of providing the full range of local public services to a new residential development. The bundle of services considered do not include the social services that would be provided in urban areas, nor do they consist of extremely limited or low qualities of service that are often provided in rural areas.

Some general overall conclusions will be presented below, followed by conclusions for each of the three classes of service.

Conclusion 1: The capital cost/du of intraneighborhood services declines as density increases and lot size diminishes, although the decline is due primarily to development density and lot size, other factors also have an effect.

The cost of these services, and their characteristics (for example, high capital intensity, linear form, detailed network serving individual dus) make them most sensitive to variations in lot size and development density. Smaller lot sizes and higher density combine to minimize the length of pipes, local streets, streetlights, etc. along parcel frontages. This conclusion assumes that the full bundle of services is being provided (including water and sewer), that they are being publicly funded, and that median levels of service are being provided. The use of more compact, higher density residential forms will minimize capital costs/du up to a point. For very dense forms, such as high rise apartments, capital costs/du begin to increase.

The cost of development studies reviewed in *The Costs of Alternative Development Patterns* indicate that the capital cost/du of providing services declines as density increases and lot sizes increase. There is a logical geometric and spatial basis for this argument in that setting houses closer together clearly lessens the amount of pipe, sidewalk, roads, streetlighting etc. per du, and thus lessens cost. Table 8 of *The Costs of Alternative Development Patterns* shows that the total neighborhood capital costs/du (Frank's definition – includes the cost of schools) declines from $36,300/du (1992 dollars) for a single family du on a 1 acre lot to $15,500/du for cluster housing at 5 dus/acre.

Frank made an important point about intraneighborhood services and education:

> "By now it is apparent that the large items requiring outlays of capital associated with residential building are the costs of sewers, water systems, streets, storm drainage, and schools." ". . . An additional $2,000 or so above the amounts shown in that table (Table 8 of *The Costs of Alternative Development Patterns*) can be identified for other services (for example, police, fire, solid waste, general government, sewer and water treatment facilities), but the magnitude of these costs is not at all sensitive to the parameters of residential building."

The facilities noted by Frank are those whose capital cost is most sensitive to density and lot size as shown by Table 3-2. However, the service and design level also effects capital cost.

Windsor in his recalculation of *The Costs of Sprawl* showed infrastructure costs/du decreasing from $17,600/du (1992 dollars) for a single family du to $12,800 for clustered townhouses. After correcting for the methodological flaws he noted, Windsor still found a decrease in capital costs/du, although his decrease was less dramatic than that calculated in *The Costs of Sprawl.* The literature indicated that public infrastructure costs/du do decline up to about 15 dus/acre; above that level, as for example with high rise apartments, capital costs/du begin to increase. This conclusion should be tempered by the fact that other factors are influencing capital costs. As a result, the magnitude of the effect based solely on density is probably less than the literature indicated.

Conclusion 2: An increasing proportion of the marginal capital costs/du, particularly for capital intensive intraneighbhorhood services, are being incurred by the homeowners through the imposition of impact fees and proffer charges.

A crucial issue in assessing the cost of development is who incurs the cost for which services? An increasing proportion of marginal intraneighborhood capital costs are being borne by the homeowner through the imposition of impact fees and proffer charges. Frank made this point in his study:

> "Therefore, while large lots increase the cost of development, those increases are largely paid for by the occupants of that development in the form of the sale price of final dwellings rather than by existing taxpayers." (*The Costs of Alternative Development Patterns*; 1989.)

This cost-shifting reduces, in the short-run, the marginal capital costs incurred by the local government. This can have a positive effect on local finances when the infrastructure contributions are reflected in higher assessed values and higher property tax revenues. In the long-run, local municipal finances could be adversely affected as local governments incur maintenance responsibilities for interior collector streets, and package water and wastewater plants whose capital costs were incurred by homeowners.

Frank also noted:

> "Another implication is that in most communities, costs beyond the neighborhood level are not fully passed on to the consumer as part of buying a house, whether those costs are the extra amount induced by leapfrogging or the normal ones associated with contiguous development." (*The Costs of Alternative Development Patterns*; 1989.)

If home owners are not paying the full marginal capital cost, particularly for interneighborhood and regional services, they are, in effect, being subsidized by the existing residents of the jurisdictions. Such a subsidy could lead to an over demand for leapfrog developments.

The use of impact fees to shift marginal capital costs onto property owners raises several questions well beyond the scope of this study. The first question is whether people should be allowed to obtain low density sprawl housing if they are willing and able to pay the full marginal capital costs. Are there other types of external costs, specifically environmental, that will occur even if the property owners incur the appropriate marginal capital costs?

Conclusion 3: Density and lot size are not the only factors that determine the capital cost of providing intraneighborhood services. Service and design standards also affect capital costs.

There are factors other than density and lot size that determine the capital cost of residential development at the intraneighborhood level. Service and design standards determine the width and pavement thickness of streets, type and capacity of drainage improvements, and the diameter of pipes; all of these determine capital costs. Service and design standards affect the capital cost of all three classes of services, while population and capacity utilization have an increasing affect on the capital cost of interneighborhood and regional services.

Conclusion 4: The precise contribution of cost factors in determining the total capital cost/du remains unclear, particularly for interneighborhood and regional services, but some idea of relative effects can be ascertained.

Tables 3-2, 3-4, and 3-6 make an attempt at beginning to understand the relative effects of different factors. In some cases, the relative effects can be easily inferred. For example, the length and capital cost of sewer collector pipe is clearly more a function of lot size and development density than it is of the type of the dwelling unit. It becomes more difficult to say with precision that the capital costs of labor-intensive interneighborhood services, such as police, fire, elementary schools, and emergency medical, are more sensitive to gross density than to service levels (Table 3-4 indicates that the capital cost of these four services are sensitive to both factors). Service levels, such as the desired response time, may be second only to the number of people to be served, in determining the number of trucks and stations required. It is possible that gross density determines the size and shape of the service area, the number and length of routes that are required, which in turn will affect annual O&M costs more than capital costs.

Conclusion 5: The greatest reduction in total capital costs/du through the use of higher density residential development is achieved in intraneighborhood services. The reduction in capital cost/du from the use of denser development forms is greater at the subdivision or neighborhood level and is smaller at the municipal, county, or regional level.

Higher densities decrease the length of linear infrastructure required per dwelling unit, thus reducing capital costs. As noted in Table 3-2, the capital cost of intraneighborhood services are highly sensitive to lot and net density, and are sensitive to gross density. As noted by Frank above, infrastructure costs, other than streets, water systems, storm drainage, and sewers, are not sensitive to the parameters of residential building. Reductions in the capital costs for interneighborhood and regional services are produced more by character of development and population factors. Gross density over a multi-neighborhood service area determines the length and cost of trunk lines and arterials.

Conclusion 6: The use of compact, higher density residential development forms produces a small percentage savings in capital costs at the regional and state-wide levels.

The analysis of the *Interim State Development and Redevelopment Plan*, and *The Greater Toronto Area Urban Structure Concepts Study* both showed infrastructure capital costs savings between trend and compact alternatives to be between approximately 4 percent and 8 percent. Cost of development studies indicate the potential for greater differences in capital costs/du, particularly for intraneighborhood costs, at the subdivision or neighborhood level.

Conclusion 7: Infill development or contiguous development will minimize marginal capital costs for interneighborhood services and, to a lesser extent, for regional services.

The Search For Efficient Urban Growth Patterns (Frank, 1989) contained the following statement:

> "The conclusion that can be drawn from this study is that the intuitive insights and theoretical studies on the public costs of development have a basis in reality: compact, infill and higher density land development is more efficient to serve than scattered, linear, and lower density sprawl development."

The conclusions from the study (if not the actual cost figures because the study was done in Florida) are relevant because it compared infill and leapfrog developments, and because it estimated annual O&M and annual capital costs per du. There are clear short-run capital cost advantages in locating new development either at infill locations, where existing service systems have excess capacity (that is, marginal capital costs would be low), or contiguous to existing service areas, where interneighborhood and, to a lesser extent, regional marginal capital costs would be lower. For example, the cost of extending water and sewer trunk lines, or new arterials, would be less because they would be shorter. Intraneighborhood infrastructure capacity is less likely to be available as subdivision or neighborhood level collection and distribution systems are designed to be used close to capacity from start-up.

Infill development has another advantage. It is often cheaper, on a marginal cost basis, to add small increments of capacity to existing systems than to construct a new larger facility at another location. The "lumpy" nature of many systems and the ability to capture economies in design and building often means that large increments of demand may have to be added. In the short-run, this has the potential for requiring current residents to subsidize the capital costs of new and future residents. It may be cheaper to add new classrooms to an existing school building, construct a sewer collector or trunk line, or add new police and fire squads to nearby fire and police stations. It may not be possible to cheaply expand all infrastructure systems in infill locations, particularly in more urban areas where it would be costly to expand roads, sewer, and water infrastructure.

The only way to properly analyze the potential benefits of infill development would be through a life cycle cost analysis in which long-term operating costs, and potential future rehabilitation and expansion capital costs would be considered. Infill locations may not offer the same initial level of service as other locations.

Conclusion 8: Increases in the population growth rate and population density produce increases in local per capita annual O&M expenditures and, to a lesser extent, in annual per capita capital spending..

Recent research by Ladd and others has shown that counties experiencing an increase in population density also experience an increase in per capital annual O&M costs and, to a lesser extent, annual per capita capital costs. This affect occurs for counties with population densities between 250 and 1,250 people per square mile. The size of the population density correlates directly with the increase in per capita spending—the higher the density, the higher is per capita spending.

Ladd's study identified two main effects of population growth: a surge-effect in which the short-term per capita costs decrease because local governments are slow to respond to increases in population and try to serve more people with the same facilities; and a long-term effect in which the increase in population density increases per capita spending. At a county or Chesapeake Bay region-level, a continued increase in population density, particularly in rural counties located at the edge of metropolitan areas whose population density is more than 250 people per square mile (Carroll and Washington in Maryland, and Chesterfield in Virginia), will increase local per capita spending.

Conclusion 9: The capital cost/du of providing services is only a minor proportion of the total annual costs/du (annual O&M cost plus annualized capital cost).

As noted at the end of Chapter 3, annual capital costs comprise may comprise 20 to 30 percent of the total annual local government cost of serving a du. By focusing too narrowly on land use and capital improvement policies designed to limit capital costs, local officials may be missing opportunities to control the majority of the annual costs/du. The proportion of annual capital costs to total annual costs may vary according to service levels, economies of scale achievable in providing new services, and current capacity utilization. Reductions in annual O&M costs, particularly for labor-intensive interneighborhood services, can be achieved by changing service standards. Annual O&M costs are also sensitive to land use policies that affect the gross development density and the total population of a service area.

Conclusion 10: Not all local jurisdictions provide comparable bundles of services, either in terms of the types provided or service levels. This complicates comparing the cost of providing services to dus located in rural as opposed to those in suburban areas.

In rural areas, some government services are either not provided, are provided by the state government, or the costs are incurred by the property owners (for example, septic systems and private wells). Fair comparisons can be made across different residential development forms only when the same range of services at comparable levels of service are compared. A policy that allows low-density residential development on large lots where septic systems and wells are used (and perform satisfactorily) will lessen, in the short-term, public capital outlays for infrastructure, with the costs incurred by the homeowner. Several reviewers noted that, over the long-term, scattered low density residential development may produce environmental impacts, lead to congestion of local roads, and possibly require the local community to incur substantial future capital costs in extending sewer and water service.

Conclusion 11: Demographic characteristics of the occupants of dus to be served are a major factor in determining the demand for and resulting cost of providing labor-intensive services to new residential development.

In many of the studies reviewed for this report, particularly county-level fiscal impact assessment models, both the capital cost and annual O&M costs of providing labor-intensive services, such as education, police, fire, solid waste, and emergency medical, are dependent upon demographic characteristics, particularly the number of persons and school-age children per du. The capital cost of such regional services as water, waste water treatment, and high schools are also highly sensitive to the size of the population to be served.

Education costs are determined by the number of school-age children to be served, which in turn is closely related to the type of dwelling unit. Several reviewers noted that the demand for police and fire services, as measured by the number of service calls, is most closely related to the total population of a service area, regardless of the form or type of dus, although the type of du may affect the demand for police services. Local policy makers, particularly when forecasting future fiscal impacts, need know the demographic characteristics of the population to be served, particularly as they may vary by type of du. It may be misleading to state that a change in the size of the population to be served is due to a change in the composition of dwelling units (that is, increasing the proportion of multi-family housing will decrease the number of school-age children), particularly at the regional level.

Several reviewers have noted that the education and income levels of the inhabitants could be a factor in the demand for public services. The literature contains little on this question. As Ladd noted, the income elasticity of demand for public services is positive. Meaning that, on average, higher-income residents will demand more public services—either a larger bundle or services or an increase in service levels. This could be a factor in rural counties experiencing an in-migration of more affluent residents.

Conclusion 12: The cost of providing education services, both capital and operating, is the largest cost/du in most local budgets. Education costs are only minimally sensitive to development density, lot size, and to a lesser extent, the location of new development.

Education costs (K to 12) comprise approximately 60 to 65 percent of total local government annual expenditures in most areas and is therefore the largest component of total annual service costs/du. Education also comprises the largest capital cost/du to serve new residential development. Capital costs of education are only minimally sensitive to lot size, density, and location; but are sensitive to the type of du, number of school age children, and service standards. It is likely that the income level and educational attainment of residents plays a significant role in determining the demand for education services.

Presented below are some conclusions for each of the three types of services considered by this study.

Intraneighborhood Services

Because of their linear, capital-intensive nature, the capital costs of intraneighborhood services are the most sensitive to the form and development density of residential development. Intraneighborhood services also have the greatest potential for shifting their capital costs from local governments to property owners through the use of impact fees.

- The capital cost of all but one intraneighborhood service is highly sensitive to lot size and net development density, the exception being stormwater structures. Both factors interact to determine the spacing between dwelling units; frontage length of pipe, streets, street lighting, and sidewalks required per residential lot; and, ultimately, capital cost.

- Intraneighborhood capital costs are slightly less sensitive to gross density than to net density. Where gross and net densities are nearly equal, as in standard subdivisions where there is no clustering, capital costs will be highly sensitive to gross density.

- Intraneighborhood services can be provided most efficiently (cost/dwelling unit) for high-density, compact, residential developments, although density and lot size are not the only important factors. As shown in Table 3-2, intraneighborhood capital costs also are sensitive to service and design standards.

- The marginal capital cost of providing intraneighborhood facilities to new residential development is much lower when density is increased or infill development occurs than it is when the new development is built in unserved areas in a leapfrog or scattered form. Changes in density and, thus flow coming from within a given residential area, produce relatively small changes in the capital cost of intraneighborhood and interneighborhood facilities, particularly water and sewer pipes.

Interneighborhood Services

The capital cost of interneighborhood services are, in general, less sensitive to lot size and net density, and are more sensitive to gross density and the size of the population to be served. The major conclusions about interneighborhood services are presented below.

- The capital cost of interneighborhood services is less sensitive than that of intraneighborhood services to the development density and lot size of the residential areas being served, and is more sensitive to population density within the service area and locational factors.

- The cost of linear, interneighborhood services, such as water, sewer, and stormwater trunk lines, and roads, are highly sensitive to the gross development density of the service area. This determines the total length of the network that connects demand centers, such as neighborhood and subdivisions, with interceptors or central treatment facilities.

- The most expensive residential land use pattern, in terms of capital costs/du, consists of scattered, noncontiguous neighborhoods or subdivisions which produce lower service area gross density.

- The capital cost of interneighborhood services, with the exception of education, are a much smaller proportion of total capital costs/du than are those of intraneighborhood services.

- Capital costs for education, reflected in the number of schools and classrooms required, are highly sensitive to the type of du, which determines the number of school-age children. Education capital costs are also sensitive to population density, which determines the number, size and location of schools; and are sensitive to service standards, such as the number of students/classroom.

- Locating new residential development at the edge of existing service areas decreases the capital and annual costs of providing interneighborhood services. The capital cost of providing the linear capital facilities that connect a new development to the existing infrastructure systems is minimized. A contiguous location also allows for the more cost-effective provision of the capital facilities that support such labor-intensive interneighborhood services as solid waste, police, fire, and emergency medical.

Regional Services

In general, the capital costs for providing regional services are most sensitive to the population factors and service standards, and are not sensitive to the development density, type, and location of the new residential development. Regional services, with the exception of general government, generally are provided in large increments of capacity, have long service lives, and often enable economies of scale in unit capital and O&M costs to be obtained.

- The capital costs of water and wastewater treatment, water supply facilities, and solid waste disposal facilities are highly sensitive to the number of persons to be served, which includes both the current and projected populations. Often these facilities must be designed with substantial initial excess capacity to accommodate future development.

- The capital cost of most regional services are sensitive to service characteristics, specifically to service standards and capacity utilization. Design standards determine the capital cost of regional facilities through engineering standards and through regulations that may specific treatment methods. Under-utilized regional facilities, particularly water and wastewater treatment plants, highways, and water supply facilities, can impose high initial marginal costs on existing residents.

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Adams County, PA, Planning Commission	John Callenbach
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Center for Development and Population Activities	
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Fairfax County Federation of Citizens Association, Transportation Committee	George Smith
Fairfax County Chamber of Commerce	Clark Massey
Florida Joint Center for Environment and Urban Problems	John DeGrove and Marie York
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National Association of Home Builders	Dave Crowe and Joe Molinaro
National Association of Home Builders Research Center	Carol Shaake
National Lands Trust	Randall Arendt

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New Jersey Office State Planning	John Epling
Northern Virginia Planning District Commission	Mike Cocoska and Kimberly Davis
Northern Virginia Building and Associates	Scott McGary and Ben Graham
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Northern Virginia Building Industry Association	Scott McGary
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Population-Environment Balance	Mark Nowak
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Virginia Comm. on Population, Growth & Development	Katherine Imhoff
Virginia Commonwealth University	John Moeser and Gary Johnson
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Virginia Center for Public Service	John Knapp
York County, PA, Planning Commission	Reed Drum, Director

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Appendix A
Review and Analysis of Relevant Studies

This appendix reviews the most recent relevant cost of development studies and focuses on those that have attempted to measure or estimate the costs of providing public services to alternative residential forms and to different land uses. This report does not provide a review of *The Costs of Sprawl*, clearly the most well-known cost of development study. *The Costs of Sprawl* has been reviewed a number of times. Three reviews in particular (Frank, 1989; Windsor, 1979; and Altshuler, 1977) were read for this study.

The results of *The Costs of Sprawl* were presented in a manner most compatible with the objectives of our study in Frank's *The Costs of Alternative Development Patterns*, which is reviewed below.

The objective of this appendix is to identify the trends in the literature, including:

- Describing the types of methodologies used in the studies, focusing on their relevance to the Chesapeake Bay region
- Identifying the factors that influence the cost of providing public services to residential development
- Describing how these factors vary in terms of their influence on capital costs
- Determining, if possible, the cost of providing public services (in $/du) to different residential forms

While seeking to identify these trends, the review of each study continually focuses on the question of how applicable the results are to the Chesapeake Bay watershed. The costs presented in this section are presented in 1992 dollars, unless otherwise noted.

Impact Assessment of the New Jersey Interim State Development and Redevelopment Plan

The New Jersey Office of State Planning (OSP) was formed in 1986 to create a State Development and Redevelopment Plan for New Jersey. The State Planning Act contained six principles to be followed in preparing the plan. *The Preliminary State Development and Redevelopment Plan* was released in 1989 and went through a process of cross acceptance in which local municipalities made changes to their zoning ordinances and master plans and the OSP made changes to the preliminary plan so that there was consistency between them.

The result of this process was the *Interim State Development and Redevelopment Plan*, called the *IPLAN Communities of Place*, issued in July 1991. The major strategy of the *IPLAN* was

> "to achieve all the state planning goals by coordinating public and private actions to guide future growth into compact forms of development and redevelopment, located to make the most efficient use of infrastructure systems and to support the maintenance of capacities in infrastructure, environmental, natural resource, fiscal, economic and other systems."

The *IPLAN* encouraged the development of five types of population centers: urban centers, towns, regional centers, villages, and hamlets. The *IPLAN* stated that "centers are compact forms of development that, compared to sprawl development, consume less land, deplete fewer natural resources and are more efficient in the delivery of public services."

The *IPLAN* categorized land areas located outside these population centers into five designated planning areas. The planning areas are intended to guide the application of the policy objectives of the State Plan and guide local planning and zoning decisions. These areas were delineated based on their desired minimum or maximum population density, proximity to public water and sewer, size, and distance to metropolitan centers. The policy objectives for each area present the desired mix of land uses, housing types, economic activities, transportation policies, and other uses.

The *IPLAN's* emphasis on encouraging more compact development forms, particularly in and adjacent to the centers, made it very controversial. Many people questioned whether the *IPLAN's* major strategy would produce the desired economic, social, and environmental benefits. As a result, the OSP conducted a comprehensive impact assessment of the *IPLAN* that compared its impacts with those that would occur if the current development trend continued. The impact assessment considered the following general types of impacts: economic, fiscal, environmental, infrastructure, community life, and intergovernmental coordination.

The following analysis focuses on the fiscal impact and infrastructure components of the impact assessment.

Methodology

Fiscal impacts were evaluated in two ways: (1) the net fiscal impacts on local municipalities and school districts were calculated, defined as annual revenues less annual capital and O&M costs; and (2) the amount and cost of infrastructure (transportation, water and sewer, and schools) were estimated.

The same population and employment totals were used in comparing the *IPLAN* and TREND scenarios. TREND was defined as the continuation of historic growth patterns in the state. This pattern has consisted of relatively unmanaged growth driven by market forces, which in recent years has resulted in lower density development being extended past the suburban fringe into rural areas. In contrast, the *IPLAN* scenario would manage and concentrate this growth into the various centers, particularly those with surplus capacity in their service system and capital facilities.

Fiscal Impacts of Growth

The precursor to all the impact assessments was to forecast population and employment totals for the entire state, and by region within the state. These totals were then converted into forecasts of population, households, and employment by county and municipality to determine the demand for services, infrastructure, and land that will occur within local municipalities, centers, and planning areas. A land capacity model was then used to compare the local population and employment projections with the physical capacity of the area, based on land capability and land use regulations. Land consumption was then estimated for the planned growth under the *IPLAN* and for the unplanned growth under the TREND.

The fiscal component of the study was directed by Robert Burchell and David Listokin of Rutgers University's Center for Urban Policy Research. The overall approach followed these four steps:

- Determine the size and composition of the population to be served in governmental jurisdictions, including that of school-age children and employees

- Determine the demand for and the cost of public services, based on the population to be served

- Calculate the revenues that the governmental jurisdictions would receive

- Compare cost to revenues to determine net fiscal impacts

The analysis then used the per capita approach in estimating the service costs for New Jersey municipalities and school districts. The per capita approach was used because of the large size of the study (567 municipalities and 400 school districts). A per capita approach divides total cost for a service by the population served to determine the cost per person. The data used to calculate the per capita service costs were obtained from municipal and school district budgets, which are compiled by the New Jersey Department of Community Affairs.

The fiscal impact assessment model required 23 input variables, including population, total municipal expenditures by service type, population employment, composition of the local real property tax base, school district per capita costs, and infrastructure amounts and costs. The model did take into account the availability of excess capacity in local infrastructure systems. The last input was a key part of the model because it was essential in estimating differences in capital cost requirements between the

TREND and the *IPLAN.* Along with cost inputs, the fiscal impact assessment model also required revenue inputs. These included value and composition of the real property tax base, tax rates, and per capita estimates of non-property tax revenues. The model produced a total of 26 outputs. These included estimates of future service costs (outputs 1 through 13), revenue generation (outputs 14 through 22), and net fiscal impacts (outputs 23 through 26).

Before running the model, the impact assessment report anticipated that there could be differences between the TREND and *IPLAN* scenarios for the following reasons:

- The two scenarios may differ in the level of population and jobs at the municipal level; at the regional and state levels the scenarios are the same. These two primary drivers of demand for local government services would be reflected in different fiscal outcomes (*IPLAN* and TREND used the same state-wide population and employment figures).

- The *IPLAN's* more concentrated growth patterns would produce higher land costs, which in turn provide higher real property tax revenues for those municipalities receiving the new population and employment.

- *IPLAN* could distribute growth into municipalities where service costs are lower. *IPLAN* directs growth into municipalities with excess infrastructure capacity and into municipalities that have historically lost population, which also have excess service capacities.

- The land use characteristics of *IPLAN* (that is, higher density and clustered development relative to TREND) will provide service efficiencies resulting in lower costs. Initial per capita infrastructure needs are lower under *IPLAN* which, in the short run, lowers new infrastructure capital costs and which, in the long run, lowers annual O&M costs (fewer lane miles of roads to maintain, fewer school buildings, and fewer miles of water and sanitary sewer pipe).

One could argue if and how much the concentration of growth into areas with excess infrastructure will increase property values and ultimately property tax revenues to local governments. While it is possible at a macro-level that channeling the same amount of development into a smaller area will increase pressure and property values, it is not clear how significant this will be in older urban areas as compared to already developed suburban areas that have higher locational and amenity values. These suburban areas, as opposed to central cities, are more likely to be desired by new development, unless there is no chance for developers to avoid locating in central city areas.

Infrastructure—Local and State Roads

The road infrastructure assessment evaluated three approaches for estimating the demand for road infrastructure produced by alternative land use patterns:

- A model developed by the New Jersey OSP
- The Florida model developed by James Duncan and Associates
- A model developed by Rutgers' Center for Urban Policy Research (CUPR) for Maryland

OSP Model. The primary rationale underlying the OSP's model was that the demand for transportation infrastructure, as measured by total lane miles of roads, is a function of population density. The density of population determines the number of trips that will be generated within an area, which then determines the demand for road infrastructure.

Regression analysis was used to estimate an equation that forecasts local road density (measured as center-line miles of roadway per square mile) as a function of municipal population density. The regression analysis produced sufficiently high correlations to warrant its use. Local road density was then converted to an estimate of total lane miles. Total capital cost was estimated using capital costs per lane mile of new roadway. The study considered municipal, county, and state roads. Although the study attempted to exclude intra-neighborhood streets within subdivisions that had been paid for by the homeowners (where maintenance responsibility for these roads has been transferred to the local municipality), these streets may have been included in the study.

Florida Model. The Florida model more explicitly considers land use variables by using as inputs land use type, density, trip lengths for residential and non-residential trips, and roadway capacity. This model was designed for urban and suburban areas, and is not designed for rural areas. Estimates for the inputs were obtained from eight case studies conducted in Florida that analyzed residential development patterns ranging from low-density, leap-frog development to high-density, urban development.

Roadway costs were estimated as a function of the number of peak hour trips by land use type, average trip length, percent of new trips, peak hour lane-mile capacity at different levels of service, and average capital and right-of-way (ROW) costs.

CUPR Model. CUPR's model (developed for Maryland) estimates total road costs as a function of land use type, where the demand for each land use type is determined by the total number of households and employment that will be created there. CUPR's model contains empirical estimates of road capital costs per dwelling unit and per 1,000 square feet of non-residential floor area. These cost factors were obtained from impact fee studies performed around the country. Capital cost estimates obtained by multiplying the number of dwelling units or employment by the cost factors were then adjusted up or down to account for efficiencies due to type of development environment (developed, growth, and rural), the use of clustering for trend growth, and the use of clustering in planned growth.

The OSP planning model was selected to be used in the study because of the scope of the study and the model's relatively simple data and computational requirements.

The model used one figure of $400,000/lane mile for the cost of local roads. This number was based on discussions with state and local transportation engineers and was felt to reflect an overall state-wide average, regardless of the location. Three different figures were used for state highways: $3 million/lane mile in rural areas, $6 million/lane mile in suburban areas, and $9 million/lane mile in urban areas. These differences reflect both the difference in construction and the cost of ROWs in these areas.

Infrastructure—Water and Sewer

The fiscal impact study also estimated the amount of water and sewer infrastructure required under the *IPLAN* and TREND scenarios. The capital cost of the water infrastructure for residential demand was based on the number of hookups required. The number of hookups was obtained from the population projections. Capital cost factors expressed as $/hookup were developed or obtained from literature that considered developments in rural vs suburban and urban areas, the type of infrastructure required, and cost efficiencies gained by clustering.

The OSP developed a sewer cost model that used survey data on existing wastewater treatment systems in New Jersey. The demand for sewer infrastructure was based on the population and employment forecasts by municipality. Total wastewater flows were estimated using per capita demand figures. Capital cost factors from the USEPA for seven components of a wastewater treatment system (secondary treatment, advanced treatment, infiltration/inflow, replacement/rehabilitation, new collector lines, new interceptor lines, and combined sewer overflows) were then used to estimate total capital costs.

The CUPR adjusted the OSP model to take into account the variation in collection system capital costs due to the density of development (the number of dwelling units per acre). Collection system capital costs per dwelling unit were assumed to be higher in low-density areas and to be lower in high-density areas. Finally, adjustments in capital costs were made to reflect differences in construction costs in different parts of the state.

Infrastructure—School

The first step in estimating school infrastructure costs was to convert the municipal population and housing unit projections into total enrollment. This was done using empirically derived population ratio factors that estimated school enrollment as a percentage of total population. This approach was taken instead of the multiplier approach because of the magnitude and data needs of a statewide study. (The multiplier approach determines school enrollment based on estimates of the number of school-age children per dwelling unit for different dwelling unit types).

The study then estimated the future demand for classrooms based on the projected enrollment. The capital cost figures took the grade distribution of students into account. The OSP model estimated net enrollment from the gross enrollment, based on the ratio of actual enrollment to enrollment capacity for individual school districts. Capital cost figures (square foot/pupil) were then multiplied by the net enrollment projections to estimate capital cost. The capital cost figures took into account differences by grade (costs per square foot are higher for high school students than those for elementary students), location (construction costs are higher in northern New Jersey than those in southern New Jersey), and area (costs are higher in urban and suburban areas than those in rural areas because of higher land costs).

The result was that while the same total increase in enrollment was forecast for both plans, *IPLAN* would take more advantage of schools with existing excess capacity. The net increase in pupil spaces required is less under *IPLAN* than that under TREND. The capital cost required for schools is $18.1 million less under *IPLAN*, or 3.4% less, than the capital cost under TREND.

Results

The research findings were summarized by comparing the impacts of the TREND and *IPLAN* scenarios. The net fiscal impacts were the difference between annual revenues and annual costs (capital and O&M). The capital costs were the total value of expenditures that would have to be made between 1990 and 2010 to accommodate the demands of growth.

Fiscal Impacts

The study showed that the net annual fiscal impacts would be more positive under the *IPLAN* scenario than under the TREND scenario: either the fiscal surpluses would be greater or the fiscal deficits would be smaller. By 2010, the *IPLAN* scenario would produce an annual net fiscal benefit of $112 million for New Jersey municipalities compared to the annual benefit under TREND. While total service costs would be slightly higher under *IPLAN* than under TREND, annual revenues would also be higher under *IPLAN*. Growth would be directed into already developed areas where land and buildings would have a higher value and produce more property tax revenues.

Similar results were forecast for schools. By 2010, annual school expenditures under *IPLAN* would be slightly lower than those under TREND, while revenues under *IPLAN* would be slightly higher than those under TREND. The net fiscal deficit for schools in 2010 would be $266 million less under *IPLAN* than that under TREND.
The combined municipal and school fiscal impacts projected that, in 2010, the annual fiscal deficit under *IPLAN* would be $398 million less than the annual deficit under TREND. These deficits under *IPLAN* and TREND represent only a small proportion

of total revenues. The combined (municipal plus school) fiscal deficit under *IPLAN* is equal to only 1.6 percent of anticipated revenues, while the combined deficit under TREND is equal to only 3.8 percent of anticipated revenues. The difference in the overall net fiscal impacts between the two scenarios is small and both scenario's net fiscal impacts are relatively small (approximately 2 percent of total revenues).

The primary reasons for these savings in annual service costs include the following:

- *IPLAN* would concentrate growth in areas with existing infrastructure capacity where the marginal costs of providing services to new residents are low

- The use of more compact development forms under *IPLAN* results in less infrastructure than that required under TREND, which reduces annual debt service and O&M costs

In summary, the study noted that:

> "In short, the differing land use scenarios affect, but do not dramatically alter the local municipal and school district financial consequences. For both TREND and *IPLAN* an overall moderate fiscal impact deficit ensues measured against the full revenue base (*IPLAN*, p. 81)."

Infrastructure—Local and State Roads

IPLAN would require 1,600 fewer lane miles of local roads and 27 fewer lane miles of state roads by the year 2010 than TREND would require. *IPLAN* would produce capital cost savings (roads that do not have to be built) of $650 million for local roads and $90 million for state roads, for a combined capital cost savings of $740 million by the year 2010.

Infrastructure—Water and Sewer

The increase in demand for water and sewer service between 1990 and 2010, under *IPLAN*, would be 57.5 million gallons per day and 46.7 million gallons per day, respectively. The comparable figures for TREND would be 60 million gallons per day and 46.1 million gallons per day. The capital cost savings under *IPLAN* for providing water infrastructure were estimated at $61 million because of the greater use of existing infrastructure, greater clustering of dwelling units, and a greater proportion of attached and multifamily housing units under *IPLAN*. All of these reasons reduce the per capita demand for water, specifically for outdoor uses such as lawn watering and swimming pools.

The higher increase in demand for sewer service under *IPLAN* is because of the concentration of new dwelling units in already developed areas. In contrast, under TREND, a slightly smaller number of dwelling units would be dispersed throughout suburban and rural areas on more total acreage, where they would use on-lot septic systems instead of municipal systems. While water demands vary across housing type due to outside water use, sewer demand does not vary as much by dwelling unit type. Therefore, demand for sewer services does not vary much between TREND and *IPLAN*.

By the year 2010, even with its slightly higher demand, *IPLAN* would result in a capital cost savings of $379 million for water and sewer infrastructure. This cost savings is due to a number of factors, including greater use of existing systems with surplus capacity and greater use of higher density residential development forms, both of which produce lower collection system capital costs per dwelling unit.

Infrastructure—Schools

Although both scenarios would have to accommodate the same gross increase in enrollment of 330,700 students, the net demands for new classroom space would differ. *IPLAN* would require a total of 278,000 new pupil spaces by the year 2010, as compared to the 288,000 spaces required under the TREND plan. Under *IPLAN*, more new growth will be directed into already developed areas that have excess school capacity. The capital cost to accommodate the new students would be $5.115 billion under *IPLAN* and $5.296 billion under TREND, resulting in a capital cost savings of $181 million under *IPLAN*.

There appears to be some slight inconsistency between the two plans in projecting enrollment. Since *IPLAN* would have a greater proportion of attached housing units, which have fewer students per dwelling, it should have resulted in *IPLAN* having a lower gross enrollment increase. However, this was not the case. If this was the case, the net fiscal impacts under *IPLAN* would increase somewhat.

Summary and Applicability

The impact assessment of *IPLAN* indicates that there would be substantial annual cost and total capital cost savings produced by a combination of concentrating new development in centers at higher densities and by directing development into areas with existing capacity in their service systems. At a state-wide level, the savings produced by IPLAN are substantial in absolute dollars. However, when the savings are viewed as a percentage of total capital costs or annual revenues, they are small. This study's findings are significant to the Chesapeake Bay region because the findings are state-wide in terms of land use and development patterns. This study goes well beyond other studies that have looked at specific residential development patterns at either the subdivision or community levels (for example, *The Costs of Sprawl*, and *Cost Effective Site Planning*), and presents for the first time an estimate of the magnitude of the economic savings. The study also describes the other types of savings, such as environmental and quality of life, that could be achieved by state-wide or region-wide growth management.

Because of the state-wide scope of the impact assessment, it does not present specific estimates of the capital and O&M costs per dwelling unit for different types and densities of dwelling units in providing services to new residential development. However, the research assumptions and underlying cost factors used in the study indicate that the savings are produced by a combination of needing less infrastructure per new dwelling unit under *IPLAN* and by taking advantage of existing infrastructure capacity. This combination would result in low marginal capital costs for servicing new dwelling units.

Table A-1 presents some of the major impacts forecast in the study. The table shows clear differences between *IPLAN* and TREND. The number of housing units are very similar under the two scenarios. The sewer costs are less under *IPLAN* because more growth would be directed into areas with excess capacity, in spite of the higher proportion of dwelling units under TREND that would use septic tanks. Over a 20-year period, the *IPLAN* concept of concentrated growth (including both residential and non-residential growth) would produce savings in capital infrastructure costs of $1.36 billion for the same amount of population, school children, and employment, and almost the same exact number of houses, but built on 127,000 fewer acres of land.

Table A-1
Impact Differences Between *IPLAN* vs TREND From 1990–2010
(1992 Dollars Where Applicable)

Category/Units	TREND	IPLAN	Diff.	%
Population Growth (persons)	520,000	520,000	0	0
Employment Growth (employees)	654,000	654,000	0	0
Land Consumption (acres)	292,000	165,000	+127,000	43.5
Number of Housing Units	430,447	431,105	-658	0.15
Water ($ millions)	$634	$573	+$61	9.6
Sewer ($ millions)	$6,790	$6,411	+$379	5.6
Roads ($ millions)	$2,924	$2,185	+$739	25.2
Education ($ millions)	$5,296	$5,115	+$181	3.4
Total Capital Cost of Water, Sewer Roads, and Schools ($ millions)	$15,644	$14,284	+$1,360	8.7

The cost savings would be produced for the following reasons:

- Higher development densities that enable services and infrastructure to be provided more efficiently

- Development closer to existing development and in-fill development that minimizes the amount of new, regional connective infrastructure required

- Using existing infrastructure systems with excess capacity that result in a minimal marginal capital cost for serving new development

- The use of residential development forms and types, such as attached housing, clustering, and multi-family housing, that reduce service demands per dwelling unit

- Higher density development forms that reduce the length of linear, capital-intensive infrastructure such as water, sewer, stormwater, and roads required per new dwelling unit. Because the cost of these systems is the most sensitive to the form of residential development, substantial capital cost savings would be achieved.

An interesting question raised by one of the reviewers (Avin, 1993) is to what extent demographic multipliers and service demands will change significantly based on the change in the type of housing. Changes in the housing mix at the local level may change demands and demographic multipliers in the short run (that is, families decide to live elsewhere due to a lack of single family detached homes in one community). In a larger area, such as a region or a state, this would not occur in the short-run. Families would be required to move into attached housing because of the decline in single family detached housing units. At a state-wide level, using dramatically different estimates of residents and students per dwelling unit would tend to overestimate the reduction in service demands produced by increasing the proportion of attached housing.

This study is the largest and most comprehensive of its type. Because of its stated objective of assessing state-wide impacts and the immensity of its scope, this assessment used the per capita approach in estimating many of the costs and revenues of providing public services and infrastructure. The assessment did not look at the cost of providing services and infrastructure to individual residential developments, and was not able to differentiate service costs by residential dwelling unit type. Given the scope of the study, its results were not given in a form that enabled the total service and infrastructure for different forms of residential development to be determined.

In spite of these limitations, individual sections within the assessment contained data and present assumptions that were directly relevant to the issue of the cost of providing public services and infrastructure to different development forms. Some of the significant data and assumptions are presented below:

- Longer lengths of sewer and water pipe are needed to service low-density residential development forms, resulting in higher sewer and water collection system costs in low-density areas

- The capital cost/hookup for a new water collection system is $2,500 to $3,500 in rural areas and only $2,000 in suburban areas

- The number of school children is 0.74 pupil per single-family detached dwelling unit and 0.24 pupil per multi-family dwelling unit

- The number of road miles for both local and state roads increases at a decreasing rate with increases in population density (that is, the amount of new roads is a convex, non-linear function of population density where the exponent has a value of less than 1)

- Annual operating costs for providing services and infrastructure capital costs are lower when new residential development is either located at the edge of existing service areas or when an infill strategy is followed. This enables existing, excess capacity to be used. However, once the excess capacity is used, the slight fiscal advantage provided by *IPLAN* vs TREND would disappear.

- Population growth and employment are directed under *IPLAN* into already developed areas having excess capacity and occupying fewer acres

These assumptions and others drove the results to produce a small fiscal advantage for *IPLAN* vs. TREND. The assessment of *IPLAN* reinforced the general conclusion that the use of more compact and higher density residential development forms, even at a state-wide level, enabled public services and infrastructure to be provided more efficiently (that is, on either a cost per dwelling unit or a per capita basis).

Development in Wright County, Minnesota: The Revenue/Cost Relationship
Resource Management Consultants, Inc., 1989

Wright County is a rapidly growing rural community located within commuting distance of the Twin Cities and the City of St. Cloud, both Minnesota metropolitan areas. Most of the county's land area is devoted to farming but 75 percent of the work force commutes to one of the nearby metropolitan areas. Land consumption for development and costs to local jurisdictions to provide services are increasing. The purpose of the study was to assess the revenues and costs associated with various development densities. The study highlighted the cost/revenue relationship of growth near existing infrastructure and of development in rural areas lacking infrastructure.

Methodology

Three hypothetical scenarios were chosen for study:

- A relatively high-density development of 50 units of mixed rental apartments, condominiums, and single-family homes on 1/4-acre lots in the City of Buffalo; the City provides all utilities including water, sewer and electricity

- A subdivision of 50 units of single-family two, three, and four-bedroom homes, each on one acre, in the Township of Otsego; no utilities are provided by the Township

- A subdivision of 50 units of two, three, and four-bedroom homes, each on 7-1/2 acres, in the Township of Silver Creek; no utilities are provided by the Township

Some of the methodology and factors were derived from *The New Practitioners Guide to Fiscal Impact Analysis*. Costs and revenues are determined from local sources only (county, city, township, or school district levels rather than the state or federal level). Nine separate budgets were reviewed: three from the county, one from each of the jurisdictions in the three scenarios, and three from school districts. Sources of revenues were determined and allocated to individual residential uses. Local residential costs per household were balanced with household property tax plus the per capita share of fines, fees, and other local revenues. Specific issues giving rise to separate costs for roads, schools, added school transportation, and sewage treatment plants were discussed in individual scenarios. Commercial and industrial costs, and a multiplier effect were not factored into the formulas used to compute overall costs.

Results

In each of the scenarios, the housing types with only two bedrooms and with apartments had either positive impacts or had lower negative fiscal impacts than single-family or condominium units with three bedrooms. The net annual local fiscal surplus per dwelling unit ranges from between $144 and $188 for 2-bedroom dwelling units up to $670 for apartments. The annual net fiscal deficit ranges from $347 to $915 for 3- and 4-bedroom single-family dwelling units.

The annual net fiscal deficit increases as both the lot size increases and as the dwelling units are located further away from existing water and sewer service areas. The following figures were produced for 3-bedroom homes:

- City of Buffalo, 3-bedroom home on a 1/4 acre lot: annual net fiscal deficit (city, county, and school district) of -$585.90.

- Otsego Township, 3-bedroom home on a 1 acre lot: annual net fiscal deficit (city, county, and school district) of -$495.49.

- Silver Creek Township, 3-bedroom home on a 7.5 to 10 acre lot: annual net fiscal deficit (city, county, and school district) of -$500.28.

The report noted that while the annual deficits are currently similar in Otsego and Silver Creek, both townships will require significant, near-term investments in new water, sewer, school, and transportation infrastructure, thus raising dramatically the net fiscal deficits. There are a wider range of services provided to residents of Buffalo than to residents of Otsego or Silver Creek. The report makes a valid point—initially, new residential development in a rural township may look favorable from a fiscal perspective but when viewed over the longer term, this development will ultimately generate demands for new services and infrastructure that will have to be paid for either through impact fees or taxes. This trend is reinforced because new residential development on large lots often has both a large floor area and a lot of bedrooms, both of which increase the number of residents and the number of school-age children that have to be served.

However, it may not be necessary for Silver Creek to extend sanitary sewer and water infrastructure to homes on 7.5 acre to 10 acre lots if on-lot septic systems perform well and water is available. If this investment does not occur, the costs of providing public services to these lots would remain low.

Average cost/revenue ratios indicate that a more beneficial relationship exists among costs and revenues for development that is closer to and served by utilities. Cost figures for Otsego and Silver Creek will be exacerbated in the future when they have to make capital expenditures for water, sewer, additional school capacity, and road improvements. In addition to being more costly, development in the lower density areas is more land consumptive and accelerates the loss of valuable farmland.

Summary and Applicability

The results of the study show that higher density development close to existing urban infrastructure is less expensive to serve with general local government services than low-density development with no established infrastructure that is located further from service centers. The study's conclusion is that it is fiscally sound to concentrate growth around areas with existing infrastructure and to discourage growth on large lots in farming areas.

The study's conclusions and results are applicable to rural townships in all three states that are receiving new residential development. The results are most applicable to Pennsylvania municipalities since municipal- and township-level school districts were analyzed.

This study was a relatively straightforward cost/revenue analysis. The researchers were careful to isolate residential costs and revenues and to eliminate state and federal contributions to local revenues that might have skewed their findings. The methodology, although simple, appears to be sound and the results appear to be accurate. The limitation of this study is that it calculated the net fiscal impacts based on the share of costs supported by locally generated revenues, not the total cost of providing the services.

The researchers of the Wright County study had a similar focus to that of the Subcommittee. They were primarily interested in the comparison between the costs of serving development on large lots in rural areas and those on smaller lots in more urban population centers. The analysis would have benefitted from greater specificity in the contents of the budgets used for the three scenarios and from a more in-depth assessment of marginal costs.

Loudon County, Virginia Fiscal Impact Assessment Model

Loudon County, Virginia experienced major growth during the 1980s that required the introduction or expansion of county services and substantial investment in capital facilities. The Loudon County Department of Economic Development performed an analysis in 1985 for one of its planning areas. The analysis showed that the average new house dollars required $3,200 ($3,850 in 1992 dollars) in public services and $9,200 ($11,100 in 1992 dollars) in new capital facilities. County officials became increasingly concerned about the fiscal impacts of continued development trends, particularly the costs that would be imposed on the county's taxpayers to finance increases in service and provide new infrastructure. The officials realized that they needed a fiscal impact model for their master planning process and for assessing the fiscal impacts of new developments.

In April 1989, Loudon County retained a consultant to prepare a fiscal impact assessment model. The finished model was delivered in March 1990. The model is designed to do the following:

- Assess the financial consequences to the County of project development at the aggregate county level for the next two decades (1990 through 2010). This assessment includes project revenues, operating expenses, and capital needs.

- Analyze the fiscal impact of projected development at the sub-county level, including the fiscal effects of modifying current land use policies

- Estimate the direct and secondary financial impacts of individual residential, commercial, and industrial development

Loudon County officials decided in the spring of 1990 to use this model in their comprehensive planning process to assess the financial impacts of alternative land use policies and alternative development phasing scenarios. This was to be done for four subareas within the County.

In August 1990, the Northern Virginia Builders Industry Association submitted comments and questions about the model. The model designer responded to these questions in several public workshops. Because of these concerns, the Loudon County Board of Commissioners decided to appoint a permanent technical review committee (TRC). This committee was to provide technical input to the consultant and the Economic Development Department's staff on the model's structure, data inputs to be used, the assumptions to be used in modeling future years. Five Loudon County residents were appointed to the TRC. The committee held six public work sessions and worked with the consultant and the County staff in developing the model.

The model is described in detail because it is a good example of a fairly sophisticated, average cost-based, fiscal impact model.

Methodology

Inputs

Historical time series were used to develop current estimates for demographic, economic, fiscal, and infrastructure cost values that were put into the model. The time series was used to develop a trend projection that can be adjusted based on input from the TRC, the consultant, and the County staff.

Development Baseline. The model required the following development-related inputs:

- Number of dwelling units for six types of dwelling units
- Total floor area for six types of non-residential development
- Per capita personal income and average household personal income

The model also required the following county-wide baseline totals:

- Population
- Number of households
- Number of children in public schools
- Employment
- Personal income
- Number of residential building permits and estimated new residential dwelling units constructed
- Population density and area in square miles
- Value of unimproved and agricultural land

Residential Assumptions. Using these inputs, the model then applied a number of assumptions to produce the forecasts of future development totals and fiscal impacts. The assumptions for the six types of dwelling units included the following:

- Average household size and number of school children/dwelling unit
- Income and real property value per dwelling unit
- Appreciation rate in the value of real residential property
- Utilization factor (number of total current dwelling units currently occupied)
- Inflation

Non-Residential Assumptions. The demographic and economic module also contained the following assumptions for the six classes of non-residential uses:

- Employees per 1,000 square feet for the six non-residential land use classes
- Real property value ($/square foot) for non-residential property classes
- Utilization factor
- Real property value appreciation factor

Economic Assumptions. The model required assumptions about inflation, income escalation, and real property appreciation.

Fiscal Assumptions. Finally, the model contained a variety of fiscal assumptions that enabled it to estimate the costs and revenues of providing services and infrastructure. These assumptions included the following items:

- Total value of residential, non-residential, unimproved, and agricultural land
- Real, personal property, and sales tax rates
- Intergovernmental revenues from federal and state sources
- Per capita costs for 12 governmental service areas
- Local government employment (employees per $1,000 of expenditure) for the same 12 governmental service areas
- Capital costs for eight infrastructure areas
- Capital fund sources, including general fund revenues, intergovernmental aid, bond proceeds, and other proceeds
- Debt service

Many of the fiscal assumptions were obtained by analyzing recent county budgets to obtain empirical estimates of per capita service costs, number of employees, and per capita capital costs.

Results

Demographic and Economic Forecast

The first phase in running the model was to produce a baseline economic and demographic forecast for the years 1991 to 2010 in a pro forma arrangement. These forecasts were primary inputs into producing the remaining forecasts (see below), particularly the fiscal impacts. The total demand for services and infrastructure was determined by the number of persons and school children, the total number and distribution by type of dwelling units, the total amount and distribution by type of non-residential floor area, and the total number of employees that must be served. Revenues were determined by forecast incomes and total property values, which were determined by the number of dwelling units by type and by the non-residential floor area by class.

Real Property Forecast

The next output of the model was a forecast of real property values by the six residential and six non-residential land use types. It also produced a forecast of unimproved and agricultural land values. These two sets of outputs were summed to produce a forecast of total taxable value of real property.

Revenue Forecast

Based on the forecast of total population, projected residential and non-residential development, and the model assumptions, a revenue forecast was produced. This forecast estimates both total local revenues for eight revenue classes and total intergovernmental revenues.

Expenditure and Labor Forecast

Using the fiscal assumptions, and the demographic and economic forecast, the model produced a forecast of local governmental expenditures and employment for 12 service areas.

Capital Cost Component

Using the fiscal and capital cost assumptions, the model estimated the capital costs for nine infrastructure categories. The total capital costs were then allocated annually over the planning period. Finally, the probable sources of the capital funds from four sources (general fund revenues, intergovernmental aid, bond proceeds, and other sources, such as proffer charges) was forecast, including any necessary debt service.

Operating Revenues and Expenditures Forecast

The final output from the model summarized all of the previous data into a form that presents the total annual operating revenues and expenditures that would be produced by the project. The estimate of annual expenditures included annual operating and maintenance costs, the total forecast capital expenditures, and the total annual debt service. The model then determined the annual cash flow to Loudon County produced by the project, which consisted of net annual current expenditures (annual revenues less annual operating and maintenance expenditures) less the amount of general fund revenues that would be needed to cover capital outlays.

Summary and Applicability

The Loudon County fiscal impact analysis model used the standard approach of per capita cost and revenue multipliers. The model included per capita estimates of annual general fund revenues, annual operating and maintenance costs, and capital infrastructure costs. The per capita cost and revenue estimates did not vary directly according to the type of dwelling unit but instead changed indirectly as the demographic assumptions change the number of persons inhabiting the types of dwelling units considered by the model. The model used one set of demographic assumptions for the four types of single-family detached dwelling units and another set for the two types of multi-family dwelling units. The cost estimates contained in the model did not take into account the density, lot size, or location of the different types of dwelling units independent of the number of persons living in them, and was instead driven by demographic assumptions, such as persons per dwelling unit, school children per dwelling unit, and workers per 1,000 square feet for non-residential land uses.

The structure of the model would easily allow for inputing different demographic assumptions for the four types of single-family detached dwelling units, assuming that the accompanying per capita service and capital cost estimates would still be valid. This was not likely to be the case because there are clearly efficiencies in providing services and infrastructure to higher density single-family detached and multi-family housing areas.

The model contains a wealth of per capita cost, revenue, and infrastructure data that was derived from Loudon County data sources. The use of county-specific data means that the model could do a good job in performing its primary task, which was to estimate the fiscal impacts on Loudon County of different development scenarios. The structure of the model would also allow different annual service costs, annual revenues, and capital costs to be used in evaluating different scenarios.

The Loudon County model is an example of a fairly sophisticated, locally specified, per capita cost-based, fiscal impact assessment model. It did not take into account either the marginal capital costs of providing service or infrastructure to new developments, or the difference in per capita infrastructure costs based on the density of single-family housing. For both residential and non-residential land uses, demographic assumptions drove the model's outcome. The model did not directly address the primary concerns of the Subcommittee. The model's accuracy was highly dependent upon its many assumptions, including per capita service cost and revenue figures, demographic multipliers, and assumptions on future growth rates.

The Search for Efficient Growth Patterns
A Study of Fiscal Impacts of Development in Florida
James Duncan and Associates, et al., 1989

This study was the result of research efforts by the Governor's Task Force to prepare a report for Florida's governor about the comparative costs of development, public services, and facilities. The Governor's Task Force was charged with a number of responsibilities, including the following items:

- Identify where and how programs and processes of state, regional, and local governments encourage sprawling and inefficient development
- Determine where such programs could be used to encourage efficient development
- Recommend new programs and policies to provide incentives for more compact urban development and to reduce or eliminate urban sprawl

The study was intended to identify the public service costs of land development patterns, and the savings that could result from the adoption of policies, regulations, and other public actions designed to reduce the amount of sprawling, inefficient development.

The study focused on the offsite external community costs of mixed use development. The study avoided the onsite internal costs of developments that are exclusively residential because studies of those aspects of development that have concluded that density affects internal costs have been generally accepted. Evaluations of the findings of previous studies were incorporated into the findings of this study.

Methodology

Eight case studies examined the capital costs for infrastructure, O&M costs, and revenues for selected public services. The study did not consider the costs of streets, sewer pipe, and water pipe needed within a residential subdivision. The study did not consider the on-lot capital costs for sewer, water, gas, and electric infrastructure that run between the dwelling unit and the adjacent public ROW. These internal neighborhood costs have been widely studied and shown to be strongly related to density, and typically have been borne by developers and passed on to consumers. Internal drainage costs and library costs were also not included. Specific system costs for water and wastewater were not calculated for each detailed study area because of the enormous complexity of large grid systems and the lack of sufficient local data. Generalized calculations were utilized to develop these costs and revenues.

The study defined efficient development, from the perspective of providing public services and infrastructure, to consist of:

> "Development that pays the marginal costs (capital and operating) of providing services and facilities to it, except where equity considerations outweigh efficiency ones (James Duncan and Associates, et al, p. 9)."

Eight detailed study areas (DSAs) were identified, representing one or more of the following urban form classifications:

- Scattered
- Contiguous
- Linear
- Satellite
- Compact

Each DSA had mixtures of land uses, either residential, or residential and some commercial uses.

The study analyzed the total capital cost, and annual costs and revenues for the following facilities and services:

- Roadways
- Education
- Wastewater
- Potable water
- Solid waste
- Law enforcement
- Fire and emergency protection
- Parks

Costs and revenues were examined for each facility and service. Costs included capital facilities, and O&M. Service and staffing levels, and factors such as travel distance and response times were included as appropriate. The revenues analyzed were those collected in taxes or those collected in fees, or both. Revenue-cost ratios were analyzed and the results were graphed for each detailed study area.

Results

The comparative fiscal analysis indicated that for the eight study areas, both external capital facility costs to support residential development and overall areawide annual revenue-cost ratios were significantly lower or more efficient in compact, close-in urban areas than they were in scattered, outlying suburban areas. Results of the study were summarized in the following categories:

- Total residential unit capital costs
- Annual residential unit service costs
- Annualized capital-intensive service costs
- Annual DSA revenue-cost ratios

The eight DSAs required the following external capital public facility costs, (in 1992 dollars) per single family dwelling unit:

- DSA 1 Compact Form $ 10,049
- DSA 2 Contiguous Form $ 10,656
- DSA 3 Contiguous Form $ 14,142
- DSA 4 Scattered Form $ 16,708
- DSA 5 Satellite Form $ 16,853
- DSA 6 Linear Form $ 17,740
- DSA 7 Linear Form $ 18,017
- DSA 8 Scattered Form $ 26,140

The average external capital cost was about $16,288 per dwelling unit, and ranged from $10,049 and $12,400 per dwelling unit in compact and contiguous DSAs, up to $16,853 to $17,879 per unit in satellite and linear DSAs, and up to $26,140 per dwelling unit in scattered DSAs located some distance from employment centers. More than 80 percent of the total capital costs per dwelling unit came from two areas: education and roads. The high capital costs for DSA were produced by the linear infrastructure required to serve it: roads, water, and sewer; and by the costs for solid waste disposal.

Total annualized residential unit service costs were the highest for education followed by police, roads, wastewater, fire/rescue, water, parks, and solid waste. When all of the DSA costs were averaged, education accounted for 39 percent of the total annual costs and roads accounted for 29 percent of the costs. Wastewater and law enforcement accounted for 11 and 8 percent of those costs, respectively. Each of the other services accounted for less than five percent of the total annual costs.

The three most capital–intensive services (annual capital costs as a percentage of total annual costs) were: roads (92 percent), water (43 percent), and waste water (34 percent). The costs of these three systems were also the most spatially oriented because of their network character. The capital and annual costs of these three systems varied the most as a function of housing density and location. The capital and annual costs of other services, such as education, police, and fire were less affected by alternative development patterns. Level of service was found to be an important consideration to the cost of services, particularly those services with costs that were less sensitive to spatial factors, such as police, fire, and recreation. The areas with the lowest service ratings had the lowest costs.

Areas with revenue-cost ratios that were less than 1.0 can be assumed to be subsidized by other parts of the community or from intergovernmental transfers. Predominantly residential areas tended to be farther from services than mixed-use or compact urban areas and tended to have higher cost-revenue ratios. Only one of the DSAs, a contiguous mixed office and single-family development, had a ratio greater than one. A compact development and a contiguous development had ratios of 0.90 and 0.78, respectively. A linear mixed residential development, including recreational uses, had a ratio of 0.62. The remaining four study areas were satellite, linear, or scattered in form and each had ratios of 0.45 or lower.

Summary and Applicability

The conclusion drawn from this study was that the intuitive insights and theoretical studies on the public infrastructure costs of development had a basis in reality: compact, infill, and higher density land development was more efficient to serve than scattered, linear, and low-density sprawl development. Developments in low-density, sprawling configurations did not always pay their full share of the costs of providing the off-site public facilities and services they required. If both the external capital costs evaluated in this study were considered along with internal capital costs (that also varied directly with housing density and lot size), then the difference in total capital costs per dwelling unit between high- and low-density housing patterns would have been even greater.

This study came only somewhat close to the type of study envisioned by the Subcommittee. This study examined the appropriate costs of development and compared them to the revenues generated by development. However, the DSAs tended to be infill locations and tended to consist of both residential and non-residential uses. The study did not directly evaluate the question of the costs of providing services to residential development, particularly the cost of leapfrog development. The study accounted for direct and indirect public subsidies that can affect the allocation of costs (for example, development regulation, public service pricing, and taxation).

The study utilized existing development for examples and drew from a variety of development forms. The analytical methodology appeared to be sound. There was adequate supporting documentation of the analysis. The study methodology may be useful for conducting similar studies in the Chesapeake Bay region. However, the study was essentially a per capita cost-based study and may not have adequately measured marginal costs, particularly for regional infrastructure. Cost factors usually varied among regions, so the factors developed for Florida must be carefully analyzed for their applicability to the Chesapeake Bay region.

The study is also applicable because it considered a variety of different residential forms both in terms of their density and their location within a region. Because the study considered primarily county forms of government with county-wide school district, the results are most applicable to Virginia and Maryland. Because the study considered very recent growth, its findings would be most applicable to counties located at the edge of expanding metropolitan areas within the Chesapeake Bay watershed, such as Baltimore, Washington, DC, and Richmond.

The Costs of Alternative Development Patterns: A Review of the Literature
James E. Frank, 1989; Prepared for the Urban Land Institute (ULI)

This study reviewed all of the major cost of development studies that had been performed to date (1989), critically evaluated their methods, and provided estimates of the differences in the capital costs incurred in providing services to new residential developments that vary by density, type, and proximity to service areas. This study provided the most comprehensive assessment to date of the methods and results found in cost of development studies. This study provided an excellent discussion of the methodologies and assumptions employed by the studies that were reviewed.

Starting in the mid 1950s, a small group of studies have analyzed the cost of providing government services and infrastructure to alternative development forms, in particular (self-evident) to alternative types, densities, and locations of residential housing. The a priori hypothesis going into these studies was that it would cost more per dwelling unit, in terms of both total capital and operating costs, to provide infrastructure and services to low-density, sprawl housing than it would cost to provide these same items to higher density housing. This hypothesis was based on the observation that sprawl developments required longer lengths of road, sewers, and water pipe to service them than did more compact developments, or developments located within or adjacent to currently serviced areas. This conclusion was reached in the highly publicized and controversial study, *The Costs of Sprawl.*

The conclusion that sprawl costs more is not universally accepted and rests on several crucial assumptions. These assumptions are that the levels of service are the same in sprawl and non-sprawl areas, that the same bundle of services are provided in both types of areas, and that all service costs are borne by the public sector. The use of on-lot septic systems, individual wells, and small, gravel roads in rural areas means that both the range and level of public services provided to the dwelling units in rural areas is less than the range and type of public services provided to residences in well-developed suburban areas.

Methodology

Frank initially re-examined the literature discussing the costs of development for his work associated with Florida's Task Force on Urban Growth Patterns. He defined the least-cost forms of development that would help implement the state's growth management goals. ULI published this report, an important comparative evaluation of existing studies, including the projected costs and methodological approaches to these studies.

The studies reviewed spanned more than three decades. Each study had its weakness in methodology and conclusions. Viewed as a whole, the studies reached the same conclusion: low-density, discontinuous development increases the capital costs of public facilities. According to Frank, the costs could vary from 40 to 400 percent higher if development was instead located close to major facilities, was clustered in contiguous areas, and incorporated a variety of housing types. There was a difference between services and facilities provided onsite, within a neighborhood or subdivision, between neighborhoods, and at the regional level.

Results

Frank pointed out the need to account for and distinguish among the various types of facility costs. Capital costs and O&M costs were easy to distinguish and were important to analyzing full life-cycle costs that could be spread differentially over time. Distinctions among precipitated, inherited, and fully allocated costs were important in understanding differences between long-run and short-run costs. There was a clear difference between services and facilities provided onsite, within a neighborhood subdivision, between neighborhoods, and at the regional level.

The development factors crucial to cost change analyses included density and lot size, municipal improvement standards, characteristics of occupancy, contiguity of development, distance to central facilities, and size of urban area. (It is important to the effectiveness of any study that each variable be allowed to vary independently. If these variables are allowed to vary all at the same time, their independent effect is difficult to measure. Several factors can be allowed to vary in combinations, under controlled conditions, within the analysis.)

Frank focused on the costs of streets, sewers, water systems, storm drainage, and schools at the community or neighborhood level, and on the costs of providing regional highway, sewer, and water linkages. He concluded that the total capital cost to serve low-density sprawl (three dwelling units per acre) with the facilities listed above would be more than $39,600 (1992 dollars) per unit. If the unit were located 10 miles from facilities or major employment centers, then the costs would increase an additional $16,500. At a density of one dwelling unit per 4 acres, Frank estimated the per unit capital costs would increase to $87,700, if contiguous, and would increase to more than $104,000, if located 10 miles from control facilities.

The capital costs of infrastructure could be reduced to $27,300 per unit by increasing density to 12 units per acre, locating development close to central facilities and employment centers, and by including a mixture of housing types in equal proportions. The per unit cost could be reduced to $20,350 by choosing a central location, using a mix of housing types in which single-family units and townhouses constitute 30 percent of the total and apartments 70 percent of the total, and by planning contiguous development.

Reductions in local service and design standards could reduce per unit capital costs but overall costs would still be higher for sprawling development because of the effect of length. Capital costs could be reduced by locating development in areas where there are surpluses in facility capacity.

Frank raised the issue of using regulatory vs pricing policy measures to guide development. Do residential developments pay their fair share of facility capital costs? According to Frank, costs for facilities in mixed communities were spread evenly among three types of facilities: (1) onsite streets and utilities, (2) neighborhood schools and parks, and (3) community-level facilities. For communities that were comprised exclusively of large lot single-family units, the cost of onsite streets and utilities may have comprised 45 percent of the total facility costs. These costs tended to be borne by the buyers. (Impact fees are becoming more widely utilized in communities to more equitably distribute costs to those receiving the benefits but such fees rarely account for distance as a cost factor. The result is the stimulation of overconsumption of housing developed in costly-to-serve patterns.)

He recommended several areas for additional research. Those conducting further study may want to consider excess capacity of public facilities, include more detail of O&M costs (lower initial costs do not necessarily translate to low, long-term costs), and concentrate their analysis on infill rather than "greenfield" development. (The studies to date view the development of cities as proceeding on raw land and these studies tend to ignore temporal considerations.)

Frank believed that the element of time was underanalyzed and may be the most important variable in the analysis of long-term cost, especially in conjunction with the management of the dynamics of the building process. The techniques of totally incremental development and oversizing facilities to accommodate future development could each exert undue financial burden on existing residents. Standards for facilities may be upgraded at some time in the future, adding to the costs of either new or upgraded facilities. According to Frank, assignment of such costs was not obvious, and hinged on whether the new standard was the result of either social enlightenment or was the result of new development exceeding existing thresholds.

He suggested that a general area of research referred to as the "optimal facility expansion path problem" (which to date has been used mostly in theoretical research), be used to analyze the dynamics of development. (This technique accounts for uncertainties in the temporal pattern of demand facing decision makers.) Frank pointed out that existing research has not examined the extent to which building costs could be reduced, if the pattern of development could be synchronized through means such as adequate public facility ordinances. Generally, decisions at the local level regarding development and investment in facilities are made independently.

Summary and Applicability

The Costs of Alternative Development Patterns is an important resource because it brings together so much valuable information. Frank summarized and critiqued nine of the best-known cost of development studies. He adjusted the numbers from the earlier studies to provide a more current (1989) estimate of the capital cost of different types of development. The specific cost findings from his study are broadly applicable to present-day case studies in the Chesapeake Bay region. The concepts in his study are useful to the Subcommittee in establishing parameters and defining factors for analysis.

Development in Richmond County, Virginia: The Revenue/Cost Relationship Resource Management Consultants, Inc., 1988

Richmond County is located on Virginia's Northern Neck along the tidal Rappahannock River. The county has extensive areas of waterfront and important timber, agriculture, and shellfish harvesting industries. Richmond County is close enough to the Washington, DC and Richmond metropolitan areas to be affected by growth pressures in these too areas.

Prior to this study, county officials assumed that development would progress in an even and orderly fashion, and that new residents would primarily be retirees. Based on these assumptions, county officials reasoned that school costs and infrastructure costs would not accelerate enough to drain the county's economic resources. County officials assumed that due to the pace and nature of waterfront development, effects on water quality in the Rappahannock River were not a concern and they assumed that the lack of county-wide zoning would not affect the nature of development expected.

The goal of the study was to assess the revenue-cost impact of varying residential densities on Richmond County's budget. The report included discussion of environmental concerns related to effects of septic systems on water quality in the Rappahannock River. The intent was to assist the county in making long- and short-term land use and fiscal planning decisions.

Methodology

The study consisted of a comparative analysis of the revenues and costs to the county associated with residential development. Revenues included real estate, personal property, and local sales taxes and other county fees collected on or as a result of new development. Costs included the monies budgeted by the county for schools, administrative services, garbage collection, landfill, ambulance services, and possible costs for water monitoring, sewage treatment facilities, and roads.

Figures were obtained from the 1988 county budget and were assigned on a per-dwelling-unit basis and on a per-capita basis. Households with school-age children were assumed to contain 3.13 persons. Households of retirees were assumed to contain 2.0 persons. Assumptions then were made regarding the percentage of homes with school-age children and retirees. Four scenarios were run for each alternative, consisting of 10, 25, 33, and 50 percent of the households containing school-age children.

The analysis used predetermined real estate assessments for land based on lot size and dwelling-unit type. Average assessments were used for dwelling units. Waterfront units were equalized in value with non-waterfront units by decreasing waterfront unit value by 25 percent.

Personal property taxes and costs were determined based on line items in the county budget and were assigned on a per-capita basis. Costs or revenue per dwelling unit then varied accordingly, based on demographic multipliers on the number of persons and number of school children per du. An average cost per pupil was determined from the county budget and was used to determine the additional school costs contributed by new dwellings (no differentiation was made in student multiplier by dwelling type).

Five residential development patterns were selected:

- Wilma Creek subdivision (proposed)
  - 64 single-family units on acre lots
- 20-acre single-family dwelling subdivision (hypothetical)
  - Mixture of 0.5-, 1-, 2-, and 5-acre lots
- 50-unit townhouse rental development (hypothetical)
- 50-acre mobile home park (hypothetical)
- 500 1-acre lots subdivision (hypothetical)

For each of these five development patterns, revenues were aggregated for property based on the number and type of dwelling and selected lot sizes. Personal property taxes were determined based on the number of households containing either 2.0 or 3.13 persons. Costs were determined by multiplying the computed per capita costs of general county services by adult occupants of all dwelling types and by adding that figure to the product of the average per pupil school costs and the 1.13 students in each dwelling. Revenues and costs were averaged for the number of dwellings in each scenario and were then compared.

The analysis then addressed added costs for schools, garbage collection, septic systems, and roads that would be incurred by the county as a result of increased population.

Results

The two single-family residential developments generated revenue surpluses under the scenarios where households contained 10 and 25 percent school children. At 33 and 50 percent school children, these developments tended to have higher per-unit costs than revenues. The 50-unit townhouse rental development produced a slight revenue surplus when household contained 10 percent school children and produced revenue shortfalls at levels above 10 percent. The 50-acre mobile home park produced higher costs than revenues under all scenarios. Costs and revenues for the 500 single-family, 1-acre lot subdivision were determined to be proportionally the same as the smaller subdivisions with total costs and revenues being much higher. Sewage treatment costs were addressed for this option, with treatment types ranging from mass drainfields to package treatment plants.

Summary and Applicability

The basic conclusions of the study were that single- or multi-family residential developments, where 33 percent or more of the households have school-age children, generated more costs than revenues to local government. Higher density, lower-value housing tended to generate more costs than revenues no matter how many households contained school-age children. Large rural subdivisions on individual septic systems, mass drainfields, or package sewage treatment plants, potentially could have negative effects on water quality in nearby surface waters. Low-density, clustered residential development of waterfront property was more beneficial fiscally and environmentally than small-lot zoning.

Several factors make this study's findings relevant to the Subcommittee:

- It is in the Chesapeake Bay watershed
- It looks exclusively at residential development
- It consists of a revenue/cost analysis
- It includes some consideration of environmental and social impacts

There were several aspects of the study that did not match precisely with the criteria selected by the Subcommittee for its case study scenarios. This study did not look at costs of connecting parcels to utility systems and other infrastructure. Most of the other literature reviewed (see Frank) concurred that compact and contiguous development patterns are more efficient than less dense, scattered patterns.

Some readers may wish to see greater detail in how costs were allocated from the county budget and may wish to see a differentiation between the number of school age-children generated by varying dwelling types.

Impacts of Development on DuPage County Property Taxes
Dupage County, Illinois Development Department, Planning Division; 1989

This study was initiated by Dupage County, Illinois after discovering that, after decades of rapid urbanization and growth, local property taxes had steadily increased instead of decreasing as expected, and after discovering that the employment base had been growing more rapidly than the residential base. From 1982 to 1988, taxes had increased by 82 percent while, during the same period, the national rate of inflation rose only 23 percent. Development had been encouraged in DuPage County because of the belief that this development would bring about a higher quality of life through increased surplus of revenues over costs.

The study measured the empirical relationship between both residential and nonresidential growth rates, the cost of providing local services, and the accompanying increases in local property taxes. According to the authors, a change in the local development pattern from residential to nonresidential caused property tax levies to increase at a commensurable rate. The study also attempted to account for the the increased service demands of higher income areas and to account for the effect of annexation on increased costs for fragmented service areas.

While the methodology and the conclusions of this study have been controversial, it did address a question often overlooked by planners. Why, in some cases, has increasing commercial and industrial development been associated with increasing tax rates and service expenditures? Conventional wisdom says that such development produces a fiscal surplus and should act to limit the growth of tax rates or even possibly to lower them.

The most controversial finding was that new commercial and industrial development did lead to increasing property taxes and to increasing costs for services. The study implied that commercial and industrial development may not "pay for itself" in the long run due to the indirect impacts that accompanied new commercial and industrial development, and which ultimately led to increased demands for locally provided services.

Methodology

This study was not a typical fiscal impact assessment study in which costs and revenues per unit of development were estimated for different types of residential and non-residential uses to determine their net fiscal impacts. Instead, the study used a multiple regression analysis using an equation in the form of a production function. A logarithmic form was used and constant returns to scale were assumed. The equation sought to explain the increase in total property tax levies (the dependent variable), between 1986 and 1989, using the following independent variables:

- Change in residential equalized assessed valuation (REAV)
- Change in the total number of nonresidential firms (NRES)
- Change in the ratio of nonresidential equalized assessed valuation to residential equalized assessed valuation (NRSHR)
- Median residential property tax levy in 1989 (MEDLEV)
- Ratio of tax code equalized assessed valuation (EAV) to total municipal EAV in 1989 (Tax codes represent all different taxing bodies that levy their own taxes within a service area in addition to the municipality's tax levy. Other providers and districts include a library district, fire district, community college district, and the airport authority.)

In applying these variables, the authors made several crucial assumptions including the following:

- The tax levy, or the dollar value of taxes collected, represents the cost to a taxing body of providing its services
- Public services is provided locally based on each taxpayer's demand for those services, which in turn varies according to income, cost, and desired service level
- REAV represents the demand for public services
- Residents react to an increase in the non-residential share of the local tax base by demanding more public services, thinking that the cost burden for these new services is borne by the non-residential land use (that is supposed to generate the fiscal surplus to pay for these services).

Looking at these variables, their explanatory value may be somewhat limited and may due to different reasons than advanced in the study.

It is apparent from looking at the dependent and independent variables that a high degree of correlation, with positive signs or beta coefficients, should be expected. There was a direct relationship between increases in both residential EAV and non-residential EAV, and an increase in tax revenues. Even if the tax rate stayed the same, *an increase in the size of the tax base would have yielded more revenues.* One could expect some multicolinearity between the first two independent variables, REAV and NRES, and the third variable NRSHR (that is, as the REAV increases the NRSHR will change depending upon the relative growth rates of REAV and NREAV). There could also be multicolinearity between REAV and MEDLEV (that is, an increase in REAV would obviously affect the median residential tax levy).

As some reviewers have noted (Burchell and Listokin, 1992), the form of the equation is close to that of an identity. That is, the increase in the total property tax levy is by definition equal to increases in residential assessed valuation, the number of new non-residential firms, median tax levy, etc. If the equation is close to being an identity, the independent variables would all be statistically significant. The strong statistical correlation may not be similarly supported by a cause-and-effect relationship.

A sample of properties covering almost 60 percent of the county's tax base was selected and 133 of nearly 1,400 tax districts were examined. The study covered the three steepest years of tax rate increase, 1986 through 1989. Parcels were segregated into residential and nonresidential uses.

Results

The regression analysis showed a statistically significant positive relationship between the increase in property tax levies (the dependent variable) and the independent variables, as was expected. The study concluded that an increase in property tax levies was correlated with increased non-residential development. The study then reasoned that non-residential development caused tax levies to increase due to the direct and indirect demands for local services that such development produces. The result was that non-residential development did not necessarily lead to no growth in or slow the increase in property tax rates. The study presented the possibility that local expenditures can increase more quickly due to new development. The major reason was demand for services coming from the new non-residential development and, later on, from the demand of new residents attracted to the municipality by the jobs.

The study found that non-residential development had an effect on increasing the total tax levy that is three times greater than the effect for residential development. For example, a one percent increase in the residential assessed valuation resulted in a 0.4 percent increase in the total tax levy. In contrast, a one percent increase in the number of nonresidential firms resulted in a 1.3 percent increase in the total tax levy. A one percent increase in the ratio of nonresidential to residential development resulted in a 0.15 percent increase in the total property tax levy.

The study hypothesized about the relationship between the cycle of job growth and the influx of new residents in precipitating the imbalance between the tax base, tax rates, and the cost of services. New jobs brought new residents who frequently required higher-quality services. Non-residential development also may have caused existing residents to demand more services to cope with the new growth. These services include additional police for traffic duty and additional new roads to relieve rush hour congestion. The study speculated about an income effect through which, as development occurs, existing residents felt wealthier as a community as tax revenues increased and, as a result, demanded a higher level of services. Taxes then increased to meet the demands for higher quality services. An expanding job base also created demand for additional housing. The increased housing demand caused a rise in housing costs. The increase in the cost of living eventually required an increase in salaries of local government employees.

Indirect effects of nonresidential development also were noted. The perception of a higher quality of life, such as better schools, attracted more people to the community. Better educated people, in turn, demanded better schools. A significant relationship was found between the rising income of taxpayers and increasing levies.

Summary and Applicability

This study advanced the argument that new development, particularly commercial and industrial, generated increases in the cost of providing local services, and produced an increase in the local property tax rate. Was a plausible cause-and-effect relationship between non-residential development and subsequent increases in local tax rates and costs of providing government services? Did new non-residential development produce increases in local tax rates and levies, and the cost of services, or was the relationship merely statistical in nature with other factors at work that were not captured in the independent variables?

The limitations of the variables contained in the equation estimated in this study did not definitively answer the question of cause and effect between non-residential development and service costs. The study confirmed that non-residential development, as expected, increased local tax revenues. To what extent these new revenues were spent for either new services, higher levels of existing services, or extending more of the existing services to new businesses becomes a local political decision.

There were a number of other reasons why there may an association between, but not necessarily a cause and effect relationship between, commercial and industrial growth, and increasing local tax levies. These reasons included the following:

- The cost of providing services may increase due to rising service standards. Residents, believing that commercial and industrial growth generates a fiscal surplus, may demand more or better services, hoping to shift the costs to the commercial and industrial properties.

- An increase in service standards may be due to an income effect where local residents feel their community can afford better services due to the increase in the tax base, or where new residents bring with them higher incomes, higher ability to pay taxes, and higher service level expectations.

- Local officials may have been content to let the increased revenues from commercial and industrial development flow in, and found ways to spend these revenues, without attempting to restrain costs. This may have been particularly true in jurisdictions where elected officials could set the tax rates without voter approval.

The DuPage County study raised interesting questions about the relationship between the rate and type of development in a community and the increases in that community's property tax rate and cost of services. The study raised the possibility that non-residential development may produce higher demands for local services than previously thought.

This study did not address the study criteria adopted by the Subcommittee regarding the effects of residential density on the capital cost of infrastructure and the costs of public services. The authors of the DuPage County study emphasized that its direct applicability is limited to DuPage County because of its specificity.

Environmental and Economic Impacts of Lot Size and Other Development Standards
Maryland Office of State Planning, 1989

Much of the residential development in Maryland is scattered in decentralized, low-density development patterns (2 to 5 or more acres per lot). This development is consuming large amounts of forested and agricultural land. The goal of this study was to evaluate the potential environmental, transportation, and economic impacts of four hypothetical 100-lot subdivisions developed with different lot sizes. Each of the subdivision scenarios was accompanied by a set of assumptions describing the location of the subdivision, distance to employment and service centers, subdivision design, development standards, and other land use characteristics. Following the initial analysis, sensitivity tests were performed to evaluate the effects of changing the subdivision design and site development assumptions.

Methodology

The analysis was performed by defining the characteristics of four types of 100-lot subdivisions and by using available literature and data to determine model standards for water, transportation, air quality, energy, economic, and site development costs. The authors entered this data into a Lotus 1-2-3 spreadsheet to predict impacts.

For the analysis, each of the subdivisions was defined to have 100 houses and the same subdivision design, so that only the lot size varied between subdivision scenarios. Characteristics of the four types of subdivisions are summarized in Table A-2.

Table A-2 Subdivision Characteristics				
	Small	Medium	Large	Very Large
Lot Size (acres)	0.12	0.25	1.4	5.0
Average Distance to Work (miles)	15	15	20	30
Average Distance to School, Shopping, and Fire Station (miles)	3	3	6	9
Sidewalks	Yes	Yes	No	No
% of Site as Open Space	5	5	0	0
Public Water and Sewer	No	No	Yes	Yes

Based on the assumptions outlined in Table A-1 and the assumption that the prior land uses were 25 percent cropland, 25 percent pastureland, and 50 percent forested, the land use and land cover characteristics of each of the development scenarios are shown in Table A-3.

Table A-3 Land Use and Cover Characteristics				
	Small	Medium	Large	Very Large
Land Required (acres)	17.6	32.7	152.1	521.4
Land in Right-of-ways (acres)	4.7	6.1	12.1	21.4
Land in Open Space (acres)	0.9	1.6	None	None
Impervious Surface (acres)	7.4	9.2	11.9	18.3
Impervious Surface (% of total site)	42.1	28.0	7.8	3.5

Using these development characteristics, water quality impacts were evaluated by calculating nonpoint source pollution loads of biochemical oxygen demand (BOD_5), phosphorus, nitrogen, suspended solids, volatile solids, sediment associated with construction activity, and fecal coliform bacteria. These calculations were based, in part, on data specific to the region and on regression equations developed for BOD_5, nitrogen, and phosphorus. These calculations were also applied to much older data (suspended and volatile solids, and fecal coliform) collected in the 1960s and 1970s. The solids and fecal coliform data originated from a wide variety of locations and were not correlated well with development intensities. Although they provided order-of-magnitude estimates of water quality impacts associated with different lot sizes, the age and variability of the data and the extension of regression equations for BOD_5, nitrogen, and phosphorus to suspended and volatile solids and fecal coliform may limit the conclusions.

Air quality impacts resulting from automobile trips were calculated by modifying trip generation and length assumptions presented in *The Costs of Sprawl* by the Council on

Environmental Quality (1977) and were calculated by air pollution generation rates presented in the *Transportation Control Plan* for the Baltimore Region by the Regional Planning Council (1978).

Energy impacts were estimated on the basis of work-day auto fuel consumption and on the amount of energy imbedded in the roadway pavement. These estimates provided an indication of the differing energy requirements for developments of differing lot sizes but did not take into account energy consumption associated with non-workdays and imbedded energy in other required infrastructure improvements, such as wastewater and stormwater facilities.

Economic impacts were defined using the average market value of improved residential parcels in Maryland. Regression analysis showed a high degree of correlation (r^2= 99.7) between average parcel cost per acre and lot size as a non-linear or logarithmic function. Values for newly developed areas were adjusted upward to account for higher prices of new homes.

Site development costs were estimated using data on lots in Montgomery and Prince George's Counties for 30 different cost categories for various residential zoning densities. The costs were inclusive and detailed permitting fees, engineering, surveying, utility contributions and hook-ups, water, sewer or septic systems, clearing and grading, sidewalks, street paving, erosion controls and stormwater management, and landscaping. These costs and building costs were then compared to average market values, and the residual for raw land, carrying charges, and profit were calculated.

Following the cost calculations, sensitivity analyses were performed for each impact category by assuming wider lot frontages, reduced pavement widths, increased cul-de-sac radii, and the combined effects of the most land-consumptive development standards (for example, all of the above plus square lots, and four lots facing on a cul-de-sac circle).

Finally, the effect of clustering the very large lot subdivision (that is, 100 units on 5-acre lots spread over 521.4 acres), so that lot sizes were small, medium, and large was evaluated. The resulting open space, impervious surface, nitrogen loads in nonpoint source runoff, imbedded energy in roadways, and site development costs were estimated.

Results

As expected, development with small lot sizes resulted in less land consumption and less impervious area. Small lot size developments generated smaller nonpoint source pollutant loads, required fewer workday vehicle-miles of travel, generated fewer hydrocarbon emissions, and resulted in less energy embedded in roadway pavement. Development with small lot sizes also had lower site development costs and generated greater property tax revenues per acre, even though taxes per unit are less.

The sensitivity analysis indicated that wider lot frontages and increased cul-de-sac radii generally increased environmental, energy, and site development costs. Reducing pavement widths and increasing the number of lots on cul-de-sacs generally decreased those costs. The greatest savings in environmental, energy, and site development costs resulted from a combination of the least consumptive standards.

The effect of clustering was an increase in open space, site development cost savings, and reduced nonpoint sources of pollution. However, the benefits associated with clustering may be somewhat less than indicated. The effect of clustering was evaluated by assuming that a 521.4-acre parcel clustered to small lots (0.12 acre each) will result in the same nonpoint source pollution loads, road requirements, energy consumption, and site development costs per dwelling unit as a non-clustered subdivision with 0.12 acre lots. If the clustered subdivision was in a fringe area away from an urban core, infrastructure costs, energy requirements, and air pollution may be somewhat greater due to the longer distance of connecting the development to service areas, shopping, or work. If a centralized, on-site wastewater disposal plant or community septic system, and water supply are provided, then some additional connective infrastructure costs would be avoided, except for transportation improvements.

Summary and Applicability

In summary, the analysis indicated that small lot developments and clustering resulted in fewer environmental, energy, and site development costs than those of large lot developments. This study provided a detailed assessment of selected costs associated with different density residential developments. The analysis also calculated cost savings associated with clustering at higher densities. With the exception of selected nonpoint source pollution loadings, the analysis was based on data collected in the Chesapeake Bay watershed and has regional applicability.

The limitations of the analysis were that it dealt exclusively with development densities; the study treated small lot developments and clustering as the same development form, and did not address the location of the development and its relation to an urban core or fringe area. This study also focused its review of costs on onsite development costs rather than all costs. For example, costs associated with schools, recreation, libraries, police and fire, and infrastructure operation and maintenance costs were not addressed. In addition, the assessment of water quality impacts was limited to nonpoint sources and did not consider the variable effect of septic systems vs wastewater treatment plant effluents on total pollution loads to water bodies.

Crossroads: Two Growth Alternatives for Virginia Beach
Virginia Beach Growth Management Study
Prepared By: Siemon, Larsen & Purdy, Chicago, Illinois, et at.

The City of Virginia Beach experienced rapid growth during the early and mid 1980s, primarily as a result of development that occurred throughout the entire tidewater region near Norfolk, Virginia. Much of this growth was fueled by the increase in defense spending during the 1980s, and by the high quality of life and affordable cost of living offered by the region. As an example of the magnitude of growth in Virginia Beach, between 1980 and 1989, a total of 55,883 residential building permits were issued by the City. The development peaked during 1984, 1985 and 1986 when more than 7,000 residential building permits were issued. Approximately 47 percent of the permits were for single family detached dwelling units, and 51 percent were for multi-family and rental units.

The high rate of growth forced Virginia Beach to examine the impacts of unmanaged growth in a number of areas, including the fiscal impacts of providing services and infrastructure to the new dwelling units, environmental impacts on sensitive lands, and changes in quality of life. There was particular concern with the impacts associated with the expansion of new development into the sensitive environmental and agricultural lands located in the southern part of the city. The city realized that it had to manage its growth better and, as a result, updated its existing Comprehensive Plan in 1986.

In anticipation of the new comprehensive plan calling for controlled growth south of the "green line", the City had proposed a major "down zoning" in the residential districts located in southern part of the city. The downzoning produced a lot of controversy because persons owning land near the Courthouse/Sandbridge area (this rapidly growing area of the city represented a major southward extension toward previously agricultural lands) faced a significant drop in the development value of their properties. Maximum residential densities were lowered to control growth, decrease the future infrastructure costs to the City, and make residential development compatible with existing agricultural uses. The Virginia Supreme Court overturned the downzoning of several parcels located in the Courthouse/Sandbridge area. Because the new comprehensive plan would have to allow residential development in southern part of the city, the challenge became how to manage this development.

The major emphasis of the 1986 plan was that the city needed to find a more orderly and cost-effective way to provide the necessary roads, water, sewer, and storm sewer, and other local services required by the new development. Specific recommendations included the following:

- Establish a "green line" across the southern part of the city to designate the southern-most limit of medium and high density growth. New road, water, and sewer infrastructure would not be extended south of the green line. Infill development north of this line would be encouraged and the agricultural lands located south of this line would be protected.

- Modify the Capital Improvement Plan so that the major expenditures for infrastructure would occur north of the green line

- Revise the zoning ordinance to allow low density residential development in the agricultural zoning districts that comprise most of the land located south of the green line. Road-front residential development in agricultural areas on 1 to 3 acre lots was permitted.

Officials were concenred that allowing low density residential development south of the green line would result in linear sprawl development that would be expensive to serve, adversely affect the agricultural economy, and create negative environmental impacts. City officials hired a team of consultants to identify other means of accomplishing the objectives of the comprehensive plan, particularly controlling growth just south of the green line.

Methodology

The City was interested in the implementation of a transfer of development (TDR) program, and the use of alternative, higher density residential and mixed use development forms. The consultant team considered growth in three parts of the city: 1) north of the green line, which consisted primarily of infill development and redevelopment at higher densities; 2) a growth area located immediately south of the green line, near the Courthouse/Sandbridge area; and 3) the remaining rural areas, located south of the green line and the growth area.

The team prepared a market study and an analysis of the capacity of the land located within the city to determine how much development the city was likely to receive, and capable of accommodating, from 1990 to 2010. The following forecasts were produced for the three parts of the City:

- North of the green line: A total of 36,700 new residential dwelling units, 14,100 of which would be single family detached; 2.35 million square feet of office space; and 2.4 million square feet of retail space

- The growth area: A total of 32,500 new residential dwelling units, 21,700 of which would be single family detached; 2.285 million square feet of office space; and 1.982 million square feet of retail space

- Southern rural area: A total of only 800 new residential dwelling units, all of which would be single family detached; 62,400 square feet of office space; and 54,000 square feet of retail space

City-wide, a total of 70,000 new dwelling units were forecast, producing a population increase of 180,900 persons and a related increase in employment of 26,500 jobs.

The team designed two alternatives for accommodating development within the growth area located just south of the green line. A total of 13 different options were initially defined that accommodated the forecasted 32,500 dwelling units while varying in terms of the mix of dwelling unit types, net and gross densities, population, commercial and retail floor area, and number of employment opportunities. Out of these 13 scenarios, two of them were selected to be analyzed:

- The trend scenario consisted of 24,375 single family detached dus, 2,708 townhouses, and 5,417 multi-family units; had a average gross density of 2.85 dus/acre; and occupied 13,691 acres. A total population of 87,241 persons was projected.

- The community of place scenario consisted of 9,750 single family detached dus, 7,583 townhouses, and 15,167 multi-family units; had an average gross density of 5.16 dus/acre; and occupied 7,559 acres. A total population of 76,163 persons was projected.

The trend scenario consisted of the pattern of the development that occurred in Virginia Beach during the 1980s—a low density residential development form consisting primarily of single family detached dus. The major commercial, retail, and community facilities would be located along arterials and highways. The land use districts would be spatially distinct from each other and required reliance on the automobile for virtually all activities. Little opportunity would be provided for nearby employment.

The community of place scenario consisted of urban form representative of neo-traditional town planning. This scenario would contain a well-defined civic, commercial, and retail center, surrounded by moderate density residential neighborhoods. The design of the community of place would include a pedestrian environment that encouraged walking, minimized the land area needed for roads and parking, and provided proximity to community facilities, shopping, and employment.

The final purpose of the study was to compare the fiscal, demographic, and economic impacts that would be produced by developing the two scenarios in the growth area. Our summary focuses on the difference in the fiscal impacts of these scenarios.

Results

A major source of the data on the cost of providing local government services, including education and transportation infrastructure per dwelling unit, was *Infrastructure Costs, Fiscal Impacts, and Proffer Charges*, prepared for the City by Burchell and Listokin. Another source for information on cost of water and sewer infrastructure costs, which was not addressed in the Burchell and Listoking study, was *Growth Impact Analysis for the Courthouse/Sandbridge Study Area* by Harland Bartholomew and Associates. The consultant team made the necessary design assumptions to estimate costs for water, sewer, stormwater, and transportation infrastructure. These assumptions included estimating the amount of local and regional sewer and water pipe per du, and the number and length of vehicle trips/du.

This study estimated the gross costs for infrastructure, regardless of who paid for them (that is, the federal and state governments through grants-in-aid and revenue sharing, the City of Virginia Beach through taxes, or residents through user fees and purchase costs).

Table A-4 presents the results of the fiscal impacts on the general fund. The results showed clearly that, under the trend scenario, the net fiscal impacts would be negative for both single family and townhouse development, but would be positive for apartments and non-residential land uses. The net fiscal impacts were different under the communities of place scenario. The single family and townhouse uses would produce smaller negative impacts, while the apartment and non-residential uses would produce large, positive fiscal impacts.

Table A-5 presents the total capital costs of infrastructure. The total capital costs required under the trend scenario to serve the residential land uses were substantially larger for all three types of infrastructure than they were under the community of place scenario. This was primarily due to the increased density and the smaller total area of the development under the communities of place scenario, and, to a lesser extent, was due to a diminished demand for transportation infrastructure.

Summary and Applicability

The Virginia Beach study reached conclusions for a large, mixed use development, as opposed to the state-wide results presented in the analysis of New Jersey's *IPLAN*. Because the Virginia Beach study considered a mixed use development, as opposed to a residential project, results of the study are indirectly applicable to the purposes of our study. The Virginia Beach study did consider three different types of dwelling units, and the costs and revenues associated with these three types are shown in the accompanying tables. The reason that the percentage savings in capital costs for infrastructure are so great, as compared to the capital cost difference in the New Jersey study, is because the community of place scenario required about one-half the total acreage of the trend scenario. The community of place scenario had a relatively high

Table A-4: Annual Fiscal Impacts on the Virginia Beach General Fund (First quarter, 1990$)

Trend Scenario	Municipal Revenues	$/du	Municipal Costs	$/du	Net Fiscal Impacts	$/du
Single Family	$91,925,837	$4,236	$111,112,169	$5,120	($19,186,332)	($884)
Townhouse	$22,485,208	$2,811	$26,180,376	$3,273	($3,695,168)	($462)
Apartment	$4,481,978	$1,601	$3,947,603	$1,410	$534,375	$191
Subotal-Residential	$118,893,023	$8,648	$141,240,148	$9,803	($22,347,125)	($1,155)
		$/1,000 sq. ft.		**$/1,000 sq. ft.**		**$/1,000 sq. ft.**
Commercial	$3,639,932	$1,593	$1,778,155	$778	$1,861,777	$815
Retail	$2,320,644	$1,168	$903,006	$454	$1,417,638	$713
Subtotal-Commerical/Retail	$5,960,576	$2,761	$2,681,161	$1,232	$3,279,415	$1,528
Trend Scenario Total	$124,853,599		$143,921,309		($19,067,710)	
Communities of Place (C of P) Scenario	**Municipal Revenues**	**$/du**	**Municipal Costs**	**$/du**	**Net Fiscal Impacts**	**$/du**
Single Family	$39,183,695	$4,236	$47,361,278	$5,120	($8,177,583)	($884)
Townhouse	$21,783,188	$2,811	$25,363,104	$3,273	($3,579,916)	($462)
Apartment	$24,811,553	$1,601	$21,853,362	$1,410	$2,958,191	$191
Subotal-Residential	$85,778,436	$8,648	$94,577,744	$9,803	($8,799,308)	($1,155)
		$/1,000 sq. ft.		**$/1,000 sq. ft.**		**$/1,000 sq. ft.**
Commercial	$24,038,538	$1,593	$11,743,147	$778	$12,295,391	$815
Retail	$2,660,923	$1,168	$1,035,415	$454	$1,625,508	$714
Subtotal-Commercial/Retail	$26,699,461	$2,761	$12,778,562	$1,232	$13,920,899	$1,529
C of P Scenario Total	$112,477,897		$107,356,306		$5,121,591	

These figures represent the annual cost to the City of Virginia Beach, including debt service for capital facilities for the following services: general government, police, fire, emergency medical, road and streets, recreation, culture, and education.

Table A–5: Total Capital Costs for Infrastructure

Trend Scenario	General Government	$/du	Water, Sanitary Sewer, and Storm Water	$/du	Transportation	$/du	Total Costs	$/du
Single Family	$180,704,462	$8,327	$183,998,489	$8,479	$66,351,123	$3,058	$431,054,074	$19,864
Townhouse	$36,233,288	$4,529	$15,896,944	$1,987	$16,104,599	$2,013	$68,234,831	$8,529
Apartment	$2,962,977	$1,058	$3,352,182	$1,197	$4,977,191	$1,778	$11,292,350	$4,033
Subotal–Residential	$219,900,727	$13,914	$203,247,615	$11,663	$87,432,913	$6,849	$510,581,255	$32,426
		$/1,000 sq. ft.		**$/1,000 sq. ft.**		**$/1,000 sq. ft.**		**$/1,000 sq. ft.**
Commercial	$412,023	$180	$3,261,947	$1,427	$13,044,223	$5,708	$16,718,193	$7,315
Retail	$204,960	$103	$3,403,078	$1,713	$6,719,751	$3,382	$10,327,789	$5,198
Other Retail/Commercial	$0		$0		$76,054,128		$76,054,128	
Subtotal–Commercial/Retail	$616,983	$283	$6,665,025	$3,140	$95,818,102	$9,090	$103,100,110	$12,513
Trend Scenario Total	$220,517,710		$209,912,640		$183,251,015		$613,681,365	
Communities of Place (C of P) Scenario	**General Government**	**$/du**	**Water, Sanitary Sewer, and Storm Water**	**$/du**	**Transportation**	**$/du**	**Total Costs**	**$/du**
Single Family	$77,027,512	$8,327	$81,174,129	$8,776	$14,836,475	$1,604	$173,038,116	$18,707
Townhouse	$35,101,810	$4,529	$15,938,474	$2,057	$6,366,946	$822	$57,407,230	$7,408
Apartment	$16,402,576	$1,058	$19,205,366	$1,239	$9,487,097	$612	$45,095,039	$2,909
Subotal–Residential	$128,531,898	$13,914	$116,317,969	$12,072	$30,690,518	$3,038	$275,540,385	$29,024
		$/1,000 sq. ft.		**$/1,000 sq. ft.**		**$/1,000 sq. ft.**		**$/1,000 sq. ft.**
Commercial	$2,721,050	$180	$1,702,549	$113	$49,936,539	$3,309	$54,360,138	$3,602
Retail	$234,704	$103	$673,079	$295	$7,461,782	$3,275	$8,369,565	$3,673
Other Retail/Commercial	$0		$0		$0		$0	$0
Subtotal–Commercial/Retail	$2,955,754	$283	$2,375,628	$408	$57,398,321	$6,584	$62,729,703	$7,275
C of P Scenario Total	$131,487,652		$118,693,597		$88,088,839		$338,270,088	$0

1. General government includes buidlings and equipment for emergency medical, libraries, parks and recreation centers, and schools.

2. Other retail commercial costs for transportation infrastructure represent the cost for roads serving retail and commercial facilities located within the growth area that serve markets originating from outside of the growth area (that is, commuters or consumers)

residential density, producing dramatic reductions in the amount and cost of the infrastructure required.

The results of the Viginia Beach study are valuable to the Subcommittee because the study area was within the Chesapeake Bay watershed. The results are also more applicable to Virginia and Maryland because most of the service and infrastructure systems considered in the study were county-wide.

Appendix B
Other Reviewed Studies

This appendix contains other studies reviewed by CH2M HILL consultants that were not directly relevant to the issue of how the cost of local government services varies with the type and location of residential dwelling units. These studies were reviewed in less detail but they do contain findings and conclusions that are indirectly applicable to the purpose of this study.

The Cost of Community Services (COCS) in Three Pioneer Connecticut Valley Towns: Agawam, Deerfield, and Gill (Review Draft) The American Farmland Trust; 1992

The American Farmland Trust (AFT), a private, national conservation organization, was concerned that local officials lacked sufficient information to determine both the impact of residential development on local tax bases and the role of farmland and open space preservation in improving the ratio of tax revenues to public service costs.

AFT conducted cost of community services (COCS) studies to determine the contributions of various land uses to the revenues collected by local government and to the costs incurred by government to provide public services. This study did not compare different forms and locations of residential development but instead compared, at a municipality-wide level, three categories of land use: residential, commercial and industrial, and farm and open lands. Three towns in the Pioneer Valley section of the Connecticut River Valley were selected to determine if the conversion of farmland and open space to "higher and better uses" precipitated increases in the need for local governments to provide new infrastructure and additional services. New infrastructure and additional services cost more than the revenues generated by the new development.

Methodology

The COCS study compared annual revenues to the costs of serving different land use sectors. The studies began by defining basic land use categories, including undeveloped lands. Income and expenses were allocated by land use for a recent, typical year and were analyzed with the aid of a computer spreadsheet program. A ratio was determined for each land use for services and infrastructure expenditures and revenues. The study was composed of five basic steps:

- Define land use categories
- Collect data
- Group revenues and allocate by land use
- Group expenditures and allocate by land use
- Analyze data and calculate ratios

Revenues and expenditures were allocated among four land use categories: residential, commercial, industrial, and farm and open land. The revenues analyzed included property taxes, state aid, local receipts, and free cash. Expenditures come from one of five classes: general government, public safety, education, social services, and public works. Budget appropriations were used to allocate expenditures, when adequate records and documentation were not available to adequately allocate expenditures by actual expenses.

The COCS study had some elements of a fiscal impact study. The COSC study attempted to allocate costs and revenues to land uses based on the demands for services and generation of revenues. The allocation of property tax revenues was done on the basis of assessed value, while the costs were allocated based on the demands for each service type that arose from each type of land use. For example, education and social services were allocated totally to the residential sector, along with the vast majority of public safety and public works costs. Because farm houses were allocated to the residential category, it was implicitly assumed that there were no persons present on farm land. Parcels of land classified as vacant residential, commercial, and industrial were put into the farm and open land category. Assuming these types of parcels were often assessed based on their highest and best use under the local zoning ordinance, this may have led to over allocations of local revenues to the farm and open land category.

The COCS study was not a typical fiscal impact study because it did not apply marginal costs (that is, by determining the amount of excess capacity available in service areas), did not estimate revenues and costs in terms of units of development (for example, dwelling units or 1,000 square feet of non-residential development), and did not consider service levels.

Results

The results of the study showed that the demand for residential services consistently exceeded the revenues generated by residential development. Commercial and industrial land uses showed a positive balance of revenues to expenditures. Farm and open land also created a surplus of revenues over expenditures, although the study probably overstated the magnitude of the fiscal surplus produced by farm land (which also included vacant commercial, residential, and industrial land). In Agawam, residential uses provided 74.5 percent of the property tax revenues and 81.2 percent of the total revenues, but required 91.2 percent of expenditures. Similar figures were found for the other two towns in the study. Undeveloped land in Agawam generated only 1.7 percent of the revenues but this land required less than one-half of one percent of the expenditures. In Gill, 21.1 percent of the town's total revenues came from farm and open land and these areas accounted for only 3.8 percent of the expenditures. This difference is consistent with the fact that Agawam has relatively little land, while Gill is almost entirely undeveloped.

The median ratios of revenues to expenditures by land use are as follows:

	Revenues/Expenditures
• Residential	$1/1.15
• Commercial/Industrial	$1/0.38
• Farm and Open Lands	$1/0.29

The residential ratio says that for every $1 in revenues collected, $1.15 is expended in providing local services to all residential land uses within the municipality. The low ratio for the Farm and Open Land category may have been due to an over allocàtion of revenues and an under allocation of costs to this category, and an over allocation of costs to the other sectors based on using assessed values.

Summary and Applicability

The ratios found in the Pioneer Valley study are consistent with findings in other COCS studies, namely that residential land use does not pay its own way. The study also stated that farmland and open space generates a small but positive net fiscal impact on local governments, even when farmland is assessed at use value. The findings were similar to AFT's previous studies that analyzed only farmland in Agricultural Use Assessment Programs. These studies, taken together, suggest that residential land uses cost more in services than they generate in revenues, and that a mix of other land uses offsets this imbalance. The inclusion of vacant residential, commercial, and industrial parcels in the farmland and open space category in this study lessens the applicability of its results only to farmland.

The COCS studies analyzed the relationship of revenues and expenditures for selected land uses. The studies were general in nature and illustrated trends to local decision makers about the impact of various land uses on the local tax structure. Farm and open lands can subsidize those land uses that required more public service and infrastructure expenditures than those lands produced in revenues.

The COCS study methodology has some deficiencies concerning the allocation of both cost and revenues between the farmland and open space category, and other categories. Because this study did not contain all of the elements of a fiscal impact study, it could not answer the question of whether different types of residential development vary in terms of their ability to pay their own way. (A similar study was conducted by AFT in Loudoun County, Virginia in 1986 and again in Dutchess County, New York in 1989. Both studies had results similar to those reached in the Pioneer Valley study).

Farmland, when properly identified, is neither a large source of demands for local public services, nor a large generator of revenues, particularly when use assessments are involved. Other vacant land classes, such as commercial and industrial, may generate a larger net positive fiscal impact than farmland, due to higher assessed values and having no residences.

A Framework for Thinking About the Impacts of Growth in the Portland Metropolitan Area
Submitted to The State Council for Growth Management in the Portland Area
ECO Northwest, 1991

Summary and Applicability

This memorandum provided a synthesis of the professional literature on growth management to the Council as a basis for discussion and decision about growth policies for the Portland area. This memo, the first of a two-part study, focused on six questions about growth. These questions related to the causes and impacts of growth, the amount of growth possible in the metropolitan area, the effect of growth of public policy on growth, the effects on population and employment, and the inevitability of those effects. (The second part of the memo, not reviewed by CH2M HILL, was an investigation of key relationships and an evaluation of selected costs and benefits of growth.)

Two theories of growth were advanced in the memo: the conventional theory that people follow jobs and an alternate theory that jobs follow people and amenities. The authors of the memo acknowledged that growth has positive and negative impacts, but they submitted that the net effects of growth were difficult to estimate. Growth tends to have the following effects:

- Positive short-term effects on local and regional economies
- Mixed effects on the cost of public infrastructure in the short-run
- Negative effects on the cost of public infrastructure in the long run.
- Negative effects on the environment

Public policies can have a dramatic effect on the impacts of growth. Market-oriented economies often fail to provide efficient levels of public goods or to efficiently allocate costs and benefits from public resources. The existence of and the inequities involved with allocating external costs and benefits are presented as justifications for governmental regulation of land uses. Public policies, then, become important in the allocation of those resources. However, those public policies will, at times, be in conflict. Conventional policies are inefficient in large and growing urban areas. The effects of growth on the Portland area were predicted, given current policies.

The memo concluded by examining growth and declining livability. A region's growth rate was determined by how it compared with adjacent regions in terms of livability, wages, cost of living, location, presence of raw materials, skills and productivity of the labor force, and other factors that determined competitive advantage. A region's growth depended, to a significant extent, on the differences that existed in these factors across regions. Livability did not have to decrease to slow or stop growth. Improvements in livability attracted new residents, and increased the labor supply, which decreased wages and attracted new business. Growth in population and employment increased land demand and price. Equilibrium was re-established (rapid growth ends) when all of these factors were comparable among areas in the region.

High standards of livability may involve trade-offs between land prices and wage levels. Areas that had traded amenities for higher wages and higher land prices found the lost amenities more expensive to replace than if the cities simply had preserved them. Cities experiencing flight of the affluent (in search of greater amenities) to the suburbs were left without the fiscal or human resources to prevent the decay of their central areas.

This memo provided an interesting overview of the factors involved in determining how and why an area grows and provided some interesting areas to consider for policy formulation. This information is not directly applicable to the project outlined by the Subcommittee. Some of the most useful information in the memo addresses the difficulty of estimating the net effects of growth because of the complexities of the system of relationships linking development processes, quality of life, and the role of local government in planning for and providing services and infrastructure.

Encouraging Compact Development in Florida, Star Grant 88-053
Joint Center for Environmental and Urban Problems for the Department of Community Affairs and the Institute of Government

Summary and Applicability

The topic of this report was the encouragement of compact development in Florida. This report was commissioned by the Department of Community Affairs through the Institute of Government. The timing of the research for the report coincided with the creation of the Governor's Task Force for Urban Growth Patterns and the research was slightly refocused for its benefit. The report researched three major mechanisms for encouraging compact development: state-wide programs, regional efforts, and redevelopment.

The section on state efforts discussed state comprehensive plans that included incentives for encouraging compact development. The states reviewed included Oregon, New Jersey, Maine, and Vermont. The discussion of each state provided some background and history of the state's planning efforts. This section also included some explanation of major components of the plan and any supporting or associated legislation. The authors provided either reactions to the states' efforts or their own comments.

The third section of the report reviewed innovative strategies for achieving compact growth, including urban growth boundaries (UGBs), transferable development rights (TDR), point systems, and tax base sharing. The discussion of UGBs provided a brief description and means of implementation. Several examples from other states and from within Florida were provided. The authors compared issues–fixed boundaries to flexible boundaries. They highlighted some of the legal challenges, and the impacts on land and housing prices.

A similar description of TDRs included a brief history, examples of programs, the impacts of TDR systems on local economies and land development patterns, the problems with implementation, and examples from within Florida. The section about point systems began by comparing traditional vs flexible zoning techniques and then described point systems. The report described some of the effects of point systems on infill development and density, and provided local examples from within Florida and other states.

In the next section, the authors described the benefits of tax base sharing in fostering more efficient infill development. Competition for economic development among neighboring jurisdictions can contribute to urban sprawl. Tax base sharing was discussed as a means for equalizing tax base among jurisdictions, thereby reducing competition for commercial and industrial development. Tax base sharing also reduced the incentive not to zone for residential uses, which tended not to pay for themselves. Two examples were cited: The Hackensack Meadowlands District and Minnesota's Fiscal Disparities Program.

A discussion of infill and redevelopment included problems encountered at the local level, issues concerning governments and developers, public and private approaches to encouragement, and an overview of programs from Florida and other states. The authors included some lessons learned from other jurisdictions and a summary of implementation strategies for local governments. The report concluded with specific recommendations for encouraging compact development in the state of Florida.

This report was a review of state-level programs designed to encourage infill and redevelopment. It may be of the most use to the Subcommittee in the recommendations this report made for strategies by local governments to encourage infill and redevelopment. These strategies could provide assistance to the Subcommittee in formulating their own recommendations.

The Cost of Population Growth in the Patuxent River (Maryland) Basin: Population/Environment Balance

Summary and Applicability

This study identified the environmental impacts of population growth and the accompanying land use changes in the Chesapeake Bay watershed, and documented, in detail, the costs to taxpayers of expanding public facilities and services to accommodate growth. The Patuxent River Basin was selected because the researchers felt that it was representative of the major tributaries in the watershed. Two counties, Howard and Calvert, were selected from within the sub-watershed for detailed study. Population, housing, and land use trends were reviewed and the implications of their environmental and fiscal impacts on public infrastructure (water, sewer, education, and transportation) were examined. The report supports the objectives of the Patuxent River Policy Plan.

The report described the study area generally, discussed population growth and land use change trends, reviewed anticipated environmental impacts associated with the anticipated trends, and detailed the public costs of growth for Howard and Calvert Counties. Costs were provided for public infrastructure on a county-wide basis. Transferable Development Rights were discussed as a strategy for controlling the location of growth. The report concluded by reiterating the policies developed at the Maryland Department of State Planning conference entitled, "Land Use or Abuse?":

- Improve and strengthen local planning
- Concentrate development and prevent sprawl
- Enact effective agricultural zoning
- Provide zoning for dense residential development
- Provide public funding for public infrastructure
- Redirect growth into existing urban areas
- Continue programs for conservation and preservation
- Coordinate programs for conservation and growth management

This study provides some useful insight into past and expected development patterns in the Chesapeake Bay watershed area and the costs associated with trend development. However, the costs discussed in this report were too general to be utilized in the case studies envisioned by the Subcommittee. This study did not address the primary issue of interest to the Subcommittee: the cost differentiations between infill and sprawl development.

Growth Management and Economics: Developing Common Ground
National Growth Management Leadership Project, 1992

Summary and Applicability

The document produced for this conference contained articles and listed studies on costs of sprawl and the benefits of compact development. CH2M HILL obtained and reviewed these studies either directly or as they were reviewed by Frank in *The Costs of Alternative Development Patterns: A Review of the Literature.*

Most of the cost of sprawl studies in the conference materials are not directly applicable to the Subcommittee's project. Two studies reinforced the cost efficiencies of regional sewer planning. An article by Frank stated that average cost pricing of public utilities and services promoted sprawling patterns of development and created cross-subsidies in the local economy. Other effects were chronic under-investment in infrastructure capacity, over-investment in more costly-to-serve developments, and fiscal deficits. Frank recommended that states require that all public infrastructure be financed by full, marginal cost user charges and impact fees. An article by Nicholas and Pappas reviewed the average impact fees across the nation by type.

The other papers and articles spanned a wide variety of topics, ranging from rural area, natural resources, and tourism development; housing and transportation investments; and alternative world economies.

The Economics of Growth Management: A Background Reader
The National Growth Management Leadership Project; 1991

Summary and Applicability

The National Growth Management Leadership Project compiled a packet with reprints and excerpts from 27 journal and newspaper articles and studies that dealt with various aspects of growth management. *The Background Reader* was assembled without foreword or follow-up analysis. The articles and excerpts were grouped into the following seven categories:

- Costs and Benefits of Growth
- Growth Management as an Economic "Stabilizer"
- The Economic Advantages of Compact Development
- The Economic Importance of Growth Management: Protecting Resource Industries and Infrastructure Investment
- The Economic Advantages of Growth Management Planning

- The "Quality of Life" Benefits of Growth Management

- The Economic Advantages of Environmental Protection

Most of the articles were brief and discussed interesting topics regarding either a specific aspect of growth management or growth management efforts in a specific locality. The major studies cited in the document were reviewed independently by CH2M HILL. The information contained in the articles, while instructive, is of little direct benefit to the study being undertaken by the Subcommittee.

Economic/Fiscal Impacts of Development—Selected References **Urban Land Institute (ULI), Infopacket Number 386**

Summary and Applicability

ULI InfoPackets are packages of photocopied materials relevant to specific topics in real estate or urban development. The materials came from books, articles from magazines or newspapers, and published and unpublished reports. InfoPacket No. 386 included a bibliography of all of the references and sections from each reference included. The sections included were usually enough to give the reader enough information to determine whether he or she wanted to obtain the full document.

"Not in My Back Yard": Removing Barriers to Affordable Housing **Advisory Commission on Regulatory Barriers to Affordable Housing**

This book identified and described factors that affect affordable housing (for example, regulatory barriers, environmental regulations, the federal tax system, and the housing finance system). Regulatory barriers that were described included exclusionary zoning, fees that were not linked to the costs of providing services, slow and burdensome permitting, and building codes that raised housing costs and may have discouraged infill development. The book concluded with recommendations and implementation strategies for federal, state, local, and private actions.

Because the book's focus was on regulatory and institutional barriers to affordable housing, this book did not provide quantitative information that could be used to compare the costs of different growth patterns and intensities. However, the book provided a good overview of the regulations, policies, and attitudes that contributed to housing costs, and in some cases, discussed the linkage between them and growth patterns.

Greater Toronto Area Urban Structure Concepts Study Prepared for the Greater Toronto Coordinating Committee

The Greater Toronto Coordinating Committee was concerned about the long-term implications of the regional growth trends in the Toronto Metropolitan area. High rates of growth throughout the 1970s and 1980s had placed increasing pressure on regional infrastructure systems and had extended growth into the adjacent counties, raising the concern that large, future investments in infrastructure would be required. The committee decided that a long-term coordinated planning strategy was needed to ensure the efficient provision of infrastructure.

The Committee's concerns covered a wide range of issues but were primarily addressed at infrastructure requirements and capital costs for transportation, hard services (water, sewer, solid waste management), greening/environment, and human services. Other issues addressed by the study were environmental quality, energy consumption, economic development, and quality of life. The study defined and assessed three generic urban structure concepts for the metropolitan area. Each of these concepts defined the future spatial distribution of land uses, and future development densities.

Methodology

The study first defined the three generic urban structure concepts:

- Spread, a status quo concept consisted of a continuation of the existing pattern. This would result in low density suburban development, along with continuing commercial development within the Toronto CBD and adjacent subcenters. Under this concept, the transportation emphasis would be providing facilities for radial and suburb to suburb trips.

- Central consisted of future population growth, and accompanying increases in population and development intensity. This concept occurred primarily within metropolitan Toronto and other already developed urban areas. Under this concept, the future spread of urbanization outward from Toronto into adjacent areas would be significantly reduced. This concept would emphasize mass transit and trips between the suburbs and the central developed area.

- Nodal, an intermediate concept in which future growth occurred in and around existing developed communities. Relative to the central concept, the spread of growth into adjacent areas would be greater but would occur in compact nodes. The transportation emphasis here would be on trips between nodes, and on using mass transit to a greater extent than the spread concept.

The Committee had forecast that, by the year 2021, approximately 2 million additional residents would need to be accommodated within the Metropolitan area. The crucial choice was whether these new residents would be concentrated within the existing developed central area (Central concept) or outside of it. If the population was to be distributed outside of the central area, the population could be evenly distributed through low density development (Spread concept) or through concentrations in nodes (Nodal concept).

All three scenarios would accommodate the same total regional population of 6.02 million persons by the year 2010. Under the Central concept, 3.8 million of these people would live in the central built up area, under Spread there would be 2.428 million persons, and under Nodal there would be 2.8 million. The total urbanized area would be different for the three concepts, ranging from 463,800 acres under Central to 521,800 acres under Nodal, and up to 599,700 acres under Spread. Finally, all three concepts would have the same total employment of 3.44 million workers.

The study distributed the population, employment, and developed area within the study area, that consisted of metropolitan Toronto and four adjacent counties (Durham, Hamilton, Peel, and York). Once this was done, policies were adopted for each concept to determine the total amount and location of infrastructure. Eight criteria were defined:

- Urban structure
- Economic impetus
- Transportation
- Hard services
- Greening/environment
- Human services
- External impacts
- Overall infrastructure costs

Individual studies were performed to distribute the population employment, determine infrastructure and facility needs, estimate cost, and assess other impacts. As an example, overall population densities would be 16.9 persons per gross residential acre under Central, 14.9 under Nodal, and 12.6 under Spread. The current (1986) density figure for the study area was 12.9.

Results

The accompanying table, Table B-1 (Exhibit 7 from the Summary Report), presented the capital cost summary for the three concepts in evaluating the concepts for the last criterion listed above - Overall Infrastructure Costs. The absolute and percentage capital cost differences among the three concepts were relatively small. The differences ranged from 2 percent between the low cost for central and the low cost for nodal, to 7.4 percent between the low cost for Central and the cost for Spread. The differences between the cost categories were illuminating:

EXHIBIT 7

CAPITAL COST SUMMARY

(CUMULATIVE 1990-2021 TOTALS, IN BILLIONS OF 1990 DOLLARS)

	1. SPREAD	2. CENTRAL	3. NODAL
TRANSPORTATION			
TRANSIT	7.16	14.41	11.58
ROADS	19.93	13.20	17.04
SUB-TOTAL	27.09	27.61	28.62
HARD SERVICES			
WATER/SEWER	3.72	3.68	3.68
LOCAL SERVICES/ROADS	15.76	8.98	11.04
SUB-TOTAL	19.48	12.66	14.72
GREENING/ENVIRONMENT			
PASSIVE OPEN SPACE (LAND)	1.10	1.10-6.00	1.10-4.70
STORMWATER QUALITY	2.00	2.00	2.00
SUB-TOTAL	3.10	3.10-8.00	3.10-6.70
HUMAN SERVICES			
HOSPITALS	4.45	5.56	4.75
SOCIAL & OTHER HEALTH SERVICES	2.68	2.68	2.68
EDUCATIONAL FACILITIES	6.40	4.20	4.79
PROTECTION	2.83	2.83	2.83
CULTURE & RECREATION	10.90	10.90	10.90
PARKS (LAND)	2.32	4.22	2.82
SUB-TOTAL	29.58	30.39	28.77
TOTAL	79.25	73.76-78.66	75.21-78.81

NOTES:

IBI GROUP

- This table includes expenditures currently commited or announced by governments in the area as well as for longer range needs to 2021.
- The above costs do not include federal costs for new facilities serving the entire GTA, such as for airports, high speed interurban rail service or freight rail links, which would be similar for all concepts.
- If existing capital expenditure levels (averaged for the period 1984-88, see Exhibits 8 and 9 following) are extrapolated for the period 1990-2021 at expanded levels reflecting projected population growth, the total expenditure would be $73.97 billion in 1990 dollars. The estimated total of $79.25 billions for Concept 1, spread, is 7% greater than this extrapolated total, a relatively small increase attributable to assumed increased standards in this study.

- Overall transportation costs were very similar but their composition varied greatly between roads and mass transit

- Hard services showed the greatest variation, particularly for local services/roads, but surprisingly not for water and sewer. Costs were very similar for the three concepts.

- Greening costs (that is, acquisition of open space, stormwater management, and consumption of agricultural lands) were higher for the Nodal concept and were lowest for the Spread concept

- Human services, that is, education, recreation, social and health services, parks, and hospitals, were the largest expense item and were nearly the same for all three concepts

When the capital costs were converted to average annualized expenditures over the 1990 through 2021 period, they were almost identical: $2.55 billion for spread, and $2.54 billion each for Central and Nodal. The study noted that the future annual per capita capital costs (in 1990 dollars) would be only 7 percent above current levels. These expenditures assumed the maintenance of current service levels, although some of the expenditures would be needed to bring infrastructure systems up to the current standards.

The report produced annual operating cost estimates for transportation, including school busing and solid waste disposal. Qualitative descriptions about costs were provided for human services and water pumping costs. The total quantified annual operating costs were similar for spread – $12.96 million, and for Nodal, $12.09 million; these costs were lower for Central at $10.87 million (16.1 percent below the Spread figure and 10.1 percent below the Nodal figure).

The report summarized the effects for the three concepts for the other seven criteria:

- Urban Structure: The Nodal concept was preferred because it would have less impact on existing community character, although Nodal would consume more rural land than the Central concept. The Nodal concept would provide a wider range of community sizes, diversity, housing types, and a better mix of residential and job activity.

- Economic Impetus: The Central concept would have the lowest impact on agricultural lands, forests, and mineral resources. Central would have the lowest push effect on land development costs but had a risk of creating price increases for housing and land if growth was not properly managed.

- Transportation: The Central concept was preferred because it used mass transit more, resulted in shorter vehicle trips, and required less road capacity. The Nodal concept was only slightly less preferred for the same reasons. The Spread concept would produce a more detailed road network, provide better levels of service, and provide better inter-city and suburb to suburb connections. This would require greater transportation effort (long trips and more lane miles of roads) and would result in congestion in central areas because of the lack of mass transit.

- Hard Services: All three concepts were similar in terms of costs for and impacts of providing hard services. The Central concept had the lowest costs for servicing developed and redeveloped lands, with the Spread concept having the highest costs, and the Nodal concept somewhere in between.

- Greening/Environment: The Central concept was preferred because it required the least land consumption and produced the least impacts. The Spread concept would have the lowest need and costs for acquiring open space. Under the Central concept, residents would have to travel furthest for open space.

- Human Services: The Nodal concept rated highest in terms of quality of service, followed closely by the Central concept. The one exception is cultural/recreation services, whose quality would be maximized by the Spread concept.

- External Impacts: The Nodal concept was preferred because it would create the least pressure for spillover growth into surrounding areas. While the Central concept would have the most concentrated growth, its higher densities could create a desire for persons to move, ultimately, into the undeveloped adjacent lands.

The capital cost and operating cost impacts were similar for the three concepts but other types of impacts, such as quality of life, environmental, and quality of service, varied at least as significantly.

Summary and Applicability

Because this study was done in Canada, its findings may not be directly applicable to the U.S. because the governmental structure is different and because Toronto has a broad regional focus in providing government services. This study's multi-county regional focus means that the results do not apply to specific types and locations of residential development. This study's findings, when coupled with those from other reports reviewed in our study, do have some relevance to the Subcommittee's mission.

This study appeared to complete a continuum between the state-wide focus of the assessment of the New Jersey Interim State Development and Redevelopment Plan, the study in Virginia Beach, and local subdivision-specific studies. The clear message from these studies was that the larger the geographical focus, the more similar were the overall capital and operating costs for infrastructure and local government services. As the focus was refined, these cost differences became more pronounced. When considering a large regional area, such as the Chesapeake Bay watershed, the environmental and quality of life considerations are at least as important as the economic considerations in assessing alternative land use patterns.

"Population Growth, Density and the Costs of Providing Public Services"
Helen F. Ladd, *Urban Studies*, 1992

The relationship between population growth and local government spending on either a per capita or a total basis has long been of interest to local officials. Is a relationship between population growth in sparsely populated counties and local government spending? This paper investigated the affects that an increase in population density has on local government per capita spending to determine if it makes sense to encourage higher density development as a means to reducing per capita government expenditures.

The paper analyzed changes in per capita annual general fund or current account spending, per capita annual capital expenditures, and per capita annual spending for public safety cost as a function of an increase in population density. Two aspects of population growth were considered: increases in population density and the rate of population growth.

Methodology

The paper hypothesized that an increase in population density could affect public spending in two ways:

- An increase in population density would increase per capita spending because more services would have to be provided by the public sector, and because more of a given type of service (without increasing level of service) would be needed to serve the larger population

- Per capita costs could fall if there are economies of scale associated with increases in density

This paper used regression analysis to estimate the change in local government spending by 247 U.S. counties. Counties were selected because their boundaries are fixed over time, so as population increases, the population density increases; and because including all local governments within a county ensured that comparable bundles of services were being compared.

The paper made an, interesting distinction between the two outputs provided by local governments:

- The direct output, or the type of service provided. The paper noted police patrols as an example of a direct public output.

- The final output as perceived and demanded by the public. The paper identified protection from crime as the final output from the voting public's perspective.

The paper noted that the level of direct outputs required to provide a given level of final outputs will vary from county to county depending on a number of different factors. For example, an urban county may have to have more policemen on patrol (direct output) in order to achieve the same level of crime protection as another more rural county where the same final output can be provided by fewer policemen.

The paper focused on the costs of providing the final outputs as valued by local consumers (who express their service preferences through voting). The paper noted that the effect on an increase in population density may require a local government to incur more costs in the form of direct outputs to continue to provide the same level of final outputs.

The regression analysis used the natural logarithms of the variable, in which three dependent variables were used:

- Current per capita spending on operations
- Current per capita spending on public safety
- Per capita public capital outlays

A series of independent variables were used including:

- Gross population density of the county

- Average annual rate of population change between 1978 to 1985

- Demand, cost, and taste variables, such as the income of county resident, the residential share of total local assessed valuation, the educational attainment of residents, and the private sector manufacturing wage rate

- Intergovernmental relations variables, such as the ratio of local direct expenditures to total local and state expenditures within the county

Results

The regression of current per capita operations spending indicated the following for the independent density variables:

- The lowest per capita spending occurs for counties with population densities of about 250 people per square mile, defined as the base case

- Per capita annual operations spending rises steadily as population density increases from 250 persons/square mile to 1,250 people per square mile. At the higher density per capita, spending is about 19 percent higher than that for counties with population densities of 250 persons/square mile.

- For counties with the highest population densities of 24,000 people per square mile, per capita spending is 43 percent higher than that in the base case.

The regression using the population growth rate instead of population density as an independent variable yielded the following results:

- The faster the rate of population growth, the lower is the per capita spending. Specifically, per capita spending in counties with rapid growth rates of 5 to 8 percent annually is 12 to 13 percent below that of counties experiencing no population growth.

Counties appear to respond slowly to rapid increases in population growth, letting service standards fall as they try to serve more people with the same resources. In the short-run, as population growth surges, per capita spending may fall, but ultimately as population density increases, per capital annual operations spending increases.

The paper presented similar regression results using per capita annual capital spending and annual per capita expenditures on public safety as dependent variables. The results were not as statistically significant as those for the regression with annual per capita operations spending. The results did suggest that counties with population densities of about 500 people per square mile have the lowest per capita annual capital spending levels.

The regression of per capita capital spending using the population growth rate showed a stronger relationship than that between per capita operations spending and population growth. The major impact on the local budget from rapid population growth is felt in the capital budget, not in the current or general fund budget. Per capita public safety expenditures were also shown to increase as functions of both increases in population density and in population growth rates.

For counties with population densities between 250 and 1,250 persons per square mile, per capita annual operating expenditures increase as density increases. It is possible that per capita expenditures could decline for counties with densities of more than 1,250 persons per square mile, but that ultimately these expenditures would rise in very heavily populated counties. Focusing only on capital costs associated with residential growth as expressed by increases in population density would cause local officials to miss the fact that population density increases per capita operations spending.

One of its concluding statements said:

> "Higher density represents a harsher environment for providing public services which requires more public sector inputs to provide a given level of service. The surge effects of population growth work in the other direction; they tend to decrease per capita spending on current operations. However, this result suggests that local governments respond to rapid growth in part by allowing current service levels to decline. Thus, focusing on public sector burdens alone, established residents in moderately populated counties bear two forms of fiscal burdens from population growth; higher costs and reduced service levels. Only if the new development contributed significantly more than the average cost of providing services could it be said that development pays it fiscal way."

Applicability

This study did not analyze the cost of providing government services to residential development, rather it considered cost at the county level to all types of land uses within the county. The study is relevant because it indicates, for moderately populated counties, that population density produces an increase in annual per capita operations spending and, to a slightly lesser extent, increases in annual per capita expenditures for capital improvements and infrastructure. At least for moderately populated counties up to a density of 1,250 persons per square mile, it raises serious questions about policies that encourage growth as a means of lowering per capita service costs. The study makes a very important distinction between direct and final outputs as means of evaluating the true costs of providing local public services.

Table C-1
Sensitivity of Capital Costs for Intraneighborhood Services to Development Density

Service	Development Density	
	Gross Density	Net Density
Sanitary Sewer Collector Lines	Sensitive. Exception is standard site planning for single family detached units with no clustering or design efficiences where gross = net density.	Highly Sensitive. Spacing between individual dus determines the length of the collector system. Use of innovative site planning techniques and clustering increases net density vis-a-vis gross density.
Storm Sewer Collector Lines	Sensitive. Exception is standard site planning for single family detached units with no clustering or design efficiences where gross = net density.	Highly Sensitive. Spacing between individual dus determines the length of the distribution system. Use of innovative site planning techniques and clustering increases net density vis-a-vis gross density.
Water Distribution Lines	Sensitive. Exception is standard site planning for single family detached units with no clustering or design efficiences where gross = net density.	Highly Sensitive. Spacing between individual dus determines the length of the distribution system. Use of innovative site planning techniques and clustering increases net density vis-a-vis gross density.
Local Streets	Sensitive. Exception is standard site planning for single family detached units with no clustering or design efficiences where gross = net density.	Highly Sensitive. Spacing between individual dus determines the length of the collector system. Use of innovative site planning techniques and clustering increases net density vis-a-vis gross density.
Streetlighting	Sensitive. Exception is standard site planning for single family detached units with no clustering or design efficiences where gross = net density.	Highly Sensitive. Spacing between individual dus determines the length of the collector system. Use of innovative site planning techniques and clustering increases net density vis-a-vis gross density.
Sidewalks	Sensitive. Exception is standard site planning for single family detached units with no clustering or design efficiences where gross = net density.	Highly Sensitive. Spacing between individual dus determines the length of the collector system. Use of innovative site planning techniques and clustering increases net density vis-a-vis gross density.
Drainage Improvements	Moderately Sensitive. Capacity determined by relative amounts of impervious and pervious surface per du.	Sensitive. Use of site planning methods to increase net density increases the concentration of contiguous, impervious surface and lessens the potential for reducing runoff on-site.

Table C-2
Sensitivity of Capital Costs for Intraneighborhood Services to the Character of the Development

Service	Character of the Development	
	Lot Size and Shape	Type of Dwelling Unit
Sanitary Sewer Collector Lines	Highly Sensitive. Lot size determines the distance between individual dus and the length of the collector system—larger lots produce longer frontage lengths per du.	Moderately Sensitive. The type of dwelling determines the lot size and net density, which in turn determine the length of collector pipe per du. The generation of wastewater per capita is largely invariant by du type for the same socioeconomic level of residents.
Storm Sewer Collector Lines	Highly Sensitive. Lot size determines the distance between individual dus and the length of the collector system—larger lots produce longer frontage lengths of pipe per du. However, larger lot size increases the percentage of pervious surface on-site and the ability to attentuate runoff on the lot.	Moderately Sensitive. The type of dwelling determines the lot size and net density, which in turn determine the length of collector pipe per du. Type of du determines the amount of off-site runoff that must be accommodated. Larger the lots associated with single famile detached (sfd) dus contain a higher percentage of pervious surface on-site which produce more run-off.
Water Distribution Lines	Highly Sensitive. Lot size determines the distance between individual dus and the length of the distribution system—larger lots produce longer frontage lengths of pipe per du.	Sensitive. The type of dwelling determines the lot size and net density, which in turn determine the length of distribution pipe per du. The per capita consumption of water varies by type of du—sfd dus with yards have higher daily per capita demands for lawn watering, gardening, etc.
Local Streets	Highly Senstive. Lot size determines the distance between individual dus and the length of the collector system—larger lots produce longer frontage lengths.	Sensitive. The number of trips generated/day varies by type of du, with sfd units producing the most trips/day. This results in a need for more lane miles of street and road capacity.
Streetlighting	Highly Sensitive. Lot size determines the distance between individual dus and the length of the lighting system—larger lots produce longer frontage lengths per du.	Minimally Sensitive. The type of du determines net and gróss density, and the lot size, all of which determine the length of the lighting system.
Sidewalks	Highly Sensitive. Lot size determines the distance between individual dus and the length of the sidewalk system—larger lots produce longer frontage lengths of sidewalk per du.	Minimally Sensitive. The type of du determines net and gross density, and the lot size, all of which determine the length of the sidewalk system.
Drainage Improvements	Sensitive. Larger lot sizes allow stormwater flows to be attenuated on-site which can lessen need for off-site, large capacity, and centrally located facilities.	Moderately Sensitive. The type of du determines the amount of impervious and permeable surface per du, and, ultimately, the amount of off-site runoff that must be accommodated. Sfd dus have larger lots and contain a higher percentage of permeable surface on-site, allowing for on-site attenuation. Multi-family attached housing with a high percentage of impervious surface per du and with large, contiguous areas of impermeable surface will require large capacity, centrally located drainage structures.

Table C-3
Sensitivity of Capital Costs for Intraneighborhood Services to Population Characteristics

	Population Characteristics	
Service	**Total Number of Persons Served**	**Density**
Sanitary Sewer Collector Lines	Sensitive. Number of persons determines total flow to be conveyed to treatment facility. Capital cost is more a function of system length as opposed to pipe diameter.	Moderately Sensitive. Concentration of population means larger flows originating within a developed area. However, capital cost is more a function of system length as opposed to pipe diameter.
Storm Sewer Collector Lines	Minimally Sensitive. Total flow to be accommodated is more a function of development character and du type, and less a fuction of the number of persons served.	Moderately Sensitive. Increasing population density correlates with higher net development densities and more impermeable surface, which produces higher total flows coming from developed areas.
Water Distribution Lines	Sensitive. Number of persons determines total supply to be conveyed to service population. Capital cost is more a function of system length as opposed to pipe diameter.	Moderately Sensitive. Concentration of population means larger flows are needed to serve a developed area. However, capital cost is more a function of system length as opposed to pipe diameter.
Local Streets	Moderately Sensitive. Total number of persons determines to some extent the number of vehicle trips.	Moderately Sensitive. Concentration of population will mean larger numbers of trips within the developed area, which could translate to higher capcity roads being required.
Streetlighting	Minimally Sensitive.	Moderately Sensitive. Higher densities can be served more efficiently (that is, shorter length/capita).
Sidewalks	Minimally Sensitive. Capital cost does not depend on the number of persons served but rather on the development characteristics and development density.	Moderately Sensitive. Higher densities can be served more efficiently (that is, shorter length/capita).
Drainage Improvements	Minimally Sensitive. Runoff volumes to be accommodated are not determined by population but rather by development density and development characteristics.	Moderately Sensitive. Correlates with net development density which results in concentration of populations; implies greater percentage of impervious surface, which in turn requires larger capacity stormwater facilities.

Table C-4
Sensitivity of Capital Costs for Intraneighborhood Services to Locational Attributes

Service	Locational Attributes		
	Existing Service Area	**Employment Centers**	**Community Facilities**
Sanitary Sewer Collector Lines	Minimally Sensitive. The length and capacity of the collection system is not affected by the distance to a treatment facility rather but by development density and character of the area served.	Minimally Sensitive.	Minimally Sensitive.
Storm Sewer Collector Lines	Minimally Sensitive. Storm sewer collectors convey runoff to drainage facilities located at neighorhood or subdivision level.	Minimally Sensitive.	Minimally Sensitive.
Water Distribution Lines	Minimally Sensitive. The length and capacity of the distribution system is not affected by the distance to a treatment facility, but by development density and character of the area served.	Minimally Sensitive.	Minimally Sensitive.
Local Streets	Minimally Sensitive.	Moderately Sensitive. Longer distance to work means more vehicle trip miles/day/du, and requires more lane miles of street and road capacity. Impact will be more significant on arterials and highways than that on collection and subcollectors.	Moderately Sensitive. Longer distance to facilities means more local vehicle trips, as opposed to walking, and results in increased lane miles of capacity for local trips on collectors and arterials.
Streetlighting	Minimally Sensitive.	Minimally Sensitive.	Minimally Sensitive.
Sidewalks	Minimally Sensitive.	Minimally Sensitive.	Minimally Sensitive.
Drainage Improvements	Minimally Sensitive.	Minimally Sensitive.	Minimally Sensitive.

Table C-5
Sensitivity of Capital Costs for Intraneighborhood Services to Service Characteristics

Service	Service Characteristics		
	Capacity Utilization	**Service and Design Standards**	**Shape of Service Area**
Sanitary Sewer Collector Lines	Moderately Sensitive. Collector lines are sized to accommodate the flows from the development being served.	Sensitive. Design standard is primarily a function of required capacity, which is an engineering calculation based on expected flow.	Moderately Sensitive. Total length of collector pipe network is determined by shape of an area—circular or square areas minimize total system length.
Storm Sewer Collector Lines	Moderately Sensitive. Collector lines are sized to accommodate the flows from the development.	Sensitive. Storm water collectors have to be sized to accommodate a design flow that is based on a certain frequency storm event, and which considers the amount and percentage of impervious and permeable surface within the development being served. Regulatory standards specificy the frequency of the storm event as the design standard.	Moderately Sensitive. Total length of collector pipe network is determined by shape of an area—circular or square areas minimize total system length.
Water Distribution Lines	Moderately Sensitive. Distribution lines are sized to accommodate the flows to the development being served.	Sensitive. Design standard is primarily a function of required capacity, which is an engineering calculation based on expected flow.	Moderately Sensitive. Total length of distribution pipe network is determined by shape of an area—circular or square areas minimize total system length
Local Streets	Moderately Sensitive. Collector and subcollectors are designed based on traffic engineering considerations about vehicle movement, and are based less on capacity based on design flows at a desired level of service.	Highly Sensitive. Design standards, such as cartway width, and ROW width determine the capital cost/unit of distance. Use of narrower ROWs and cartways can substantially lessen costs.	Moderately Sensitive. Total length of local street network is determined by shape of an area—circular or square areas minimize total system length.
Streetlighting	Minimally Sensitive.	Moderately Sensitive. Design standards determine amount of illumination required, spacing of poles, and ability of poles to withstand vehicle impacts.	Moderately Sensitive. Total length of street light network is determined by shape of an area—circular or square areas minimize total system length.
Sidewalks	Minimally Sensitive.	Minimally Sensitive.	Moderately Sensitive. Total length of sidewalk network is determined by shape of an area—circular or square areas minimize total system length.
Drainage Improvements	Minimally Sensitive. Improvements are designed to accommodate a specific frequency storm.	Highly Sensitive. Stormwater facilities are designed to accommodate a particular frequency storm, usually the 100-year storm. Regulatory standards usually contain or reference the design standard	Minimally Sensitive. Capacity of facility is determined by the size of drainage area, not by its shape.

Table C-6
Sensitivity of Capital Costs for Interneighborhood Services
to Development Density

Service	Development Density	
	Gross Density	Net Density
Sanitary Sewer Trunk Lines	Highly Sensitive. Gross density across a service area of multiple neighborhoods or developments determines length of trunk line required.	Moderately Sensitive. Only to the extent that efficiencies in net density at the development level result in higher regional gross densities.
Storm Sewer Trunk Lines	Highly Sensitive. Gross density across a service area of multiple neighborhoods or developments determines length of trunk line required.	Moderately Sensitive. Only to the extent that efficiencies in net density at the development level result in higher regional gross densities.
Water Trunk Lines	Highly Sensitive. Gross density across a service area of multiple neighborhoods or developments determines length of trunk line required.	Moderately Sensitive. Only to the extent that efficiencies in net density at the development level result in higher regional gross densities.
Elementary and Middle Schools	Sensitive. The number and location of schools depends upon the gross density of all of the residential neighborhoods to be served.	Minimally Sensitive. Gross density and the number of school-age children are the major factors.
Police	Sensitive. Determines the number and location of precinct stations based on desired response times.	Minimally Sensitive. Gross density and the number of persons to be served are the major factors.
Fire	Sensitive. Determines the number and location of fire stations based on desired response times.	Minimally Sensitive. Gross density and the number of persons to be served are the major determinants.
Solid Waste Collection	Moderately Sensitive. Gross density determines the number and characteristics of the routes required to collect solid waste at homes and businesses, which are O&M costs. Low gross densities will increase the need to use regional transfer stations, a capital cost.	Minimally Sensitive. The use of higher net densities will produce efficiences in collecting waste (that is, reduce length and time required along collection routes per du served). While this is primarily an O&M cost, it also reduces the number of trucks needed.
Parks & Recreation	Moderately Sensitive. Gross density determines the number and location of facilities.	Moderately Sensitive. Higher net density increases demand for parks–particularly when more people reside within walking distance of them.
Emergency Medical	Sensitive. Determines the number and location of emergency medical squads based on desired response times.	Minimally Sensitive. Gross density and the number of persons to be served are the major determinants.
Arterial Streets	Highly Sensitive. Determines the length, location, and total capacity (that is, number of lane miles) of collectors and arterials.	Moderately Sensitive. Net density determines the costs of subcollectors.

Table C-7
Sensitivity of Capital Costs for Interneighborhood Services to the Character of the Development

Service	Character of the Development	
	Lot Size and Shape	Type of Dwelling Unit
Sanitary Sewer Trunk Lines	Moderately Sensitive. Cost size effects gross density to some extent within multiple neighborhood service areas.	Moderately Sensitive. The type of du determines the total population/du, which in turn determines total population to be served.
Storm Sewer Trunk Lines	Moderately Sensitive. Cost size effects gross density to some extent within multiple neighborhood service areas.	Moderately Sensitive. The type of du determines the amounts and proportions of impervious and permeable surface, which in turn determine the amount of off-site runoff to be accommodated.
Water Trunk Lines	Moderately Sensitive. Cost size effects gross density to some extent within multiple neighborhood service areas.	Sensitive. The type of du determines water consumption/capita, which in turn determines total flow required, pipe diameter, and capital cost.
Elementary and Middle Schools	Minimally Sensitive.	Highly Sensitive. The type of du determines the number of school-age children/du; sfd dus have higher numbers of school-age children/du than do other forms of dus.
Police	Minimally Sensitive.	Moderately Sensitive. The demand for services is higher for certain types of dus–specifically multiple family units. The socioeconomic characteristics of residents are also a factor.
Fire	Minimally Sensitive.	Moderately Sensitive. The demands for services is higher for certain types of dus–specifically multiple family units. The socioeconomic characteristics of residents are also a factor.
Solid Waste Collection	Minimally Sensitive.	Sensitive. Per capita generation of waste is higher for sfd dus due to the production of yard wastes.
Parks and Recreation	Minimally Sensitive.	Sensitive. Sfd dus have more children/du which translates into higher demand for recreational facilities, particularly those within walking distance.
Emergency Medical	Minimally Sensitive.	Moderately Sensitive. The demand for services is higher for certain types of dus–specifically multiple family units. The socioeconomic characteristics of residents are also a factor.
Arterial Streets	Minimally Sensitive.	Sensitive. The number of vehicle trips/du/day varies by type of du; sfd dus produce the largest number of trips/day, resulting in the highest demand for capacity, or total lane miles of roads and streets.

Table C-8
Sensitivity of Capital Costs for Interneighborhood Services
to Population Characteristics

Service	Population Characteristics	
	Total Number of Persons Served	Density
Sanitary Sewer Trunk Lines	Sensitive. The number of persons determines the total flow to be conveyed to treatment facility. Capital cost is more a function of system length as opposed to pipe diameter.	Moderately Sensitive. Concentration of population means larger flows originating within a developed area. However, capital cost is more a function of system length as opposed to pipe diameter.
Storm Sewer Trunk Lines	Moderately Sensitive. Total flow to be accommodated is more a factor of development character and du type, and is less a fuction of the number of persons served.	Moderately Sensitive. Increasing population density correlates with higher net development densities and more impermeable surface, which produces higher total flows coming from developed areas.
Water Trunk Lines	Sensitive. The number of persons determines the total supply to be conveyed to the service population. Capital cost is more a function of system length as opposed to pipe diameter.	Moderately Sensitive. Concentration of population means larger flows are needed to serve a developed area. However, capital cost is more a function of system length as opposed to pipe diameter.
Elementary and Middle Schools	Moderately Sensitive. The key factor is the number of school-age children, however, in general, higher population will mean more school-age children are likely to be present.	Sensitive. A more dense population creates efficiencies in busing students to school, a larger proportion of students will be able to walk in higher density areas, decreasing the number of buses required.
Police	Highly Sensitive. Service standards determining the number of stations and the number of personnel required are based on total population.	Sensitive. A dense population creates efficiencies in providing protection, which will decrease the number of vehicles and other equipment needed for providing protection.
Fire	Highly Sensitive. Service standards determining the number of stations and the number of personnel required are based on total population.	Sensitive. A dense population creates efficiencies in providing protection, which will decrease the number of vehicles and other equipment needed for providing protection.
Solid Waste Collection	Highly Sensitive. Total population determines the total residential solid waste flow; this, in turn, determines the number, capacity, and capital cost of transfer and disposal facilities required.	Sensitive. A dense population creates efficiencies in collecting waste which will lessen the number of vehicles and other equipment needed for the collection system.
Parks and Recreation	Highly Sensitive. Service standards determining the number of facilities and the desired amount of open space required are based on total population.	Sensitive. Higher densities mean more people residing within walking distance, increasing the demand for facilities. Land acquisition costs are higher in more densely populated areas.
Emergency Medical	Highly Sensitive. Service standards determining the number of stations and the number of personnel required are based on total population.	Sensitive. A dense population creates efficiencies in providing protection which will decrease the number of vehicles and other equipment needed for providing services.
Collector and Arterial Streets	Sensitive. A large population generates more vehicle trips, other things being equal, although other factors determine demand for total lane miles of capacity, such as trip characteristics and du type.	Sensitive. Densely populated areas produce more trips and require larger capacity roadways. Acquistition and construction costs for streets and roads these areas are higher.

Table C-9
Sensitivity of Capital Costs for Interneighborhood Services to Locational Attributes

Service	Locational Attributes		
	Existing Service Area	Distance to: Employment Centers	Community Facilities
Sanitary Sewer Trunk Lines	Highly Sensitive. The distance between residential areas served and the central sewage treatment plant determines the length of trunk lines.	Minimally Sensitive.	Minimally Sensitive.
Storm Sewer Trunk Lines	Minimally Sensitive. Stormwater is discharged at the neighborhood level and is not conveyed to treatment plants in modern systems.	Minimally Sensitive.	Minimally Sensitive.
Water Distribution Trunk Lines	Highly Sensitive. The distance between residential areas served and the central water treatment plant determines the length of trunk lines.	Minimally Sensitive.	Minimally Sensitive.
Elementary and Middle Schools	Minimally Sensitive. Schools are located where the residential areas are; scattered residential areas located beyond existing attendance zones would require more buses for transportation, not necessarily new buildings. Development beyond a certain size—producing about 500 or more elementary children—makes constructing a new school the most economical option.	Minimally Sensitive.	Minimally Sensitive.
Police	Minimally Sensitive. Stations are located where the residential areas are; scattered residential areas located beyond existing attendance zones would require more personnel and vehicles, not necessarily new precinct buildings. In areas with scattered population centers, constructing new branch facilities may be the most cost effective option as opposed to providing service from existing centers.	Minimally Sensitive.	Minimally Sensitive.
Fire	Minimally Sensitive. Stations are located where the residential areas are, scattered residential areas located beyond existing service areas would require more personnel and equipment, not necessarily new stations. In areas with scattered population centers, constructing new branch facilities may be the most cost effective option as opposed to providing service from existing centers.	Minimally Sensitive.	Minimally Sensitive.
Solid Waste Collection	Minimally Sensitive. Disposal and processing facilities are centrally located; scattered residential areas located beyond existing service areas would require more personnel and vehicles; transfer stations are an economical way to serve outlying population centers.	Minimally Sensitive.	Minimally Sensitive.
Parks and Recreation	Minimally Sensitive.	Minimally Sensitive.	Minimally Sensitive.
Emergency Medical	Minimally Sensitive. Stations are located where the residential areas are; scattered residential areas located beyond existing service areas would require more personnel and equipment, not necessarily new stations.	Minimally Sensitive.	Minimally Sensitive.
Arterial Streets	Minimally Sensitive.	Sensitive. The distance to employment centers determines the length of commuting trips and the required necessary lane miles of road capacity, particularly for arterials.	Highly Sensitive. The distance to community facilities determines the length of trips to local facilities and the required lane miles of road capacity.

Table C-10
Sensitivity of Capital Costs for Interneighborhood Services
to Service Characteristics

Service	Service Characteristics		
	Capacity Utilization	**Service and Design Standards**	**Shape of Service Area**
Sanitary Sewer Trunk Lines	Sensitive. Trunk lines are sized to accommodate the flows from the service area and are usually designed to have excess capacity, initially to accommodate flows from future growth. Higher utilization allocates capital costs among more users.	Sensitive. Design standard is primarily a function of required capacity, which is an engineering calculation based on expected flow.	Sensitive. Regularly shaped areas minimize the length and cost of trunk lines. Linear or star-shaped service areas increase length.
Storm Sewer Trunk Lines	Sensitive. Trunk lines are sized to accommodate the flows from the service area and are usually designed to have excess capacity, initially to accommodate flows from future growth. Higher utilization allocates capital costs among more users.	Sensitive. Storm water collectors have to be sized to accommodate a design flow which is based on a certain frequency storm event, which considers the amount and percentage of impervious and permeable surface within the area being served. Regulatory standards specify the frequency of the storm event as the design standard.	Minimally Sensitive.
Water Trunk Lines	Sensitive. Trunk lines are sized to accommodate the flows into the service area and are usually designed to have excess capacity, initially to accommodate flows from future growth. Higher utilization allocates capital costs among more users.	Sensitive. The design standard is primarily a function of required capacity, which is an engineering calculation based on expected flow.	Sensitive. Regularly shaped areas minimize the length and cost of trunk lines. Linear or star-shaped service areas increase length.
Elementary and Middle Schools	Moderately Sensitive. Schools are labor-intensive not capital intensive, excess capacity incurs low or zero marginal capital costs, and likely low O&M costs, if teachers do not need to be hired.	Sensitive. The design standard is based on regulations covering maximum class size and floor area standards for facilities, such as gyms and labs. Regulations often contain or reference the design standards.	Moderately Sensitive. Regularly shaped areas increase the percentage of walkers, decreasing capital costs for houses; irregularly shaped areas increase the percentage of riders, increasing the need for buses.
Police	Moderately Sensitive. Expansions in capacity are produced by adding personnel and equipment as opposed to new precinct stations. Large increases in population could require new precinct buildings.	Sensitive. Service standards are based on desired response times, sometimes also on the ratio of officers to population. This determines the number of stations and the number of personnel required by the population.	Minimally Sensitive.
Fire	Moderately Sensitive. Expansions in capacity are produced by adding personnel and equipment as opposed to new fire stations. Large increases in population could require new stations.	Sensitive. Service standards are based on desired response times, sometimes also on the ratio of firefighters to population. This determines the number of stations and the number of personnel required by the population.	Minimally Sensitive.
Solid Waste Collection	Moderately Sensitive. Expansions in capacity are produced by adding personnel and equipment to increase collection capacity.	Moderately Sensitive. The number of collections per week and type of wastes collected, including recycling, affect equipment required.	Minimally Sensitive.
Parks and Recreation	Moderately Sensitive. More capital-intensive at the neighborhood than at the regional level. Under use produces moderate marginal capital costs.	Sensitive. Service standards are based on the ratio of acres of open space or facilities to population. This determines the number and type of facilities required by the population.	Moderately Sensitive. Regularly shaped areas have more areas within walking distance; in a multineighborhood service area with an irregular shape, more facilities are needed to have neighborhood centers within walking distance.
Emergency Medical	Moderately Sensitive. Expansions in capacity are produced by adding personnel and equipment as opposed to new stations. Large increases in population could require new stations.	Sensitive. Service standards are based on desired response times, sometimes also based on the ratio of emergency staff to population; determines the number of stations and the number of personnel required by population.	Minimally Sensitive.
Collector and Arterial Streets	Highly Sensitive. Design standard is based on forecast utilization or level of service during peak hour flows.	Highly Sensitive. Lane miles of new roadway capacity are based on forecast design volumes at a specified level of service; design standards also specify pavement thickness and load capacity, etc.; all of which determine capital costs. Regulatory standards specify the construction standards, which determine the capital cost.	Highly Sensitive. Regularly shaped areas minimize length and cost of arterials; linear or star-shaped service areas increase length.

Table C-11
Sensitivity of Capital Costs for Regional Services to Development Density

Service	Development Density	
	Gross Density	**Net Density**
Wastewater Treatment Plants	Minimally Sensitive. Capital cost is based on the number of persons and businesses to be served, which determine design capacity required; low density may require smaller regional treatment plants as opposed to one large, centrally located plant.	Same as for gross density.
Water Treatment Plants	Minimally Sensitive. Capital cost is based on the number of persons and on the number and type of non-residential uses to be served, which determine design capacity required; low density may require smaller regional treatment plants or use of on-site wells instead of one large, centrally located plant.	Same as for gross density.
Water Supply	Minimally Sensitive. Capital cost is based on the number of persons and on the number and types of non-residential uses to be served.	Same as for gross density.
High Schools	Moderately Sensitive. The number, location, and size of schools depends on the number of pupils attending from the attendance area; this, in turn, is a function of regional gross density. Smaller, lower capacity facilities with higher unit capital costs may be needed in areas with low population densities. More buses may be used for high schools serving large areas, particultarly low density, rural areas.	Minimally Sensitive.
Solid Waste Disposal	Minimally Sensitive. The capacity depends on the number of persons, and on the number and type of non-residential uses. Several smaller, lower capacity facilities with higher unit capital costs may be needed in areas with low population densities.	Same as for gross density.
General	Minimally Sensitive.	Minimally Sensitive.
Highways	Sensitive. A major factor in determining the length and location of highways, capacity is determined to some extent by the amount of population in the areas that feed the highway. Capacity is also determined by the type of non-residential land uses, design standards, and amount of interregional traffic.	Moderately Sensitive. Gross density is the major factor.

Table C-12
Sensitivity of Capital Costs for Regional Services to the Character of the Development

Service	Character of the Development	
	Lot Size and Shape	**Type of Dwelling Unit**
Wastewater Treatment Plants	Minimally Sensitive.	Moderately Sensitive. The type of du determines the total population/du and the total residential population to be served, which determine total plant design capacity and total capital cost.
Water Treatment Plants	Minimally Sensitive. Larger lots result in higher per capita uses for lawn watering and gardening.	Sensitive. The type of du determines the total population/du and the total residential population to be served, which determine total plant design capacity and total capital cost; also per capita water use is higher for sfds (that is, lawn watering and gardening).
Water Supply	Minimally Sensitive.	Sensitive. Same reasons as those for water treatment plants.
High Schools	Minimally Sensitive.	Highly Sensitive. The type of du determines the number of school-age children/du; sfd dus have higher numbers of school-age children/du than do other forms.
Solid Waste Disposal	Minimally Sensitive. Larger yards will generate more yard wastes/capita, resulting in need for more capacity.	Moderately Sensitive. Per capita generation of waste is higher for sfd dus due to the production of yard wastes.
General Government	Minimally Sensitive.	Minimally Sensitive. Sfd dus have more children/du which translates into higher total demand for government services.
Highways	Minimally Sensitive.	Sensitive. The number of vehicle trips/du/day varies by type of du; sfd dus produce the largest number of trips/day, resulting in the highest demand for capacity, or total lane miles of roads and streets.

Table C-13
Sensitivity of Capital Costs for Regional Services to Population Characteristics

Service	Population Characteristics	
	Total Number of Persons Served	**Density**
Wastewater Treatment Plants	Highly Sensitive. Design capacity and capital cost are based on the number of persons and on the type of non-residential uses to be served.	Moderately Sensitive. Population density has little short-term impact on capital cost, if distribution system and facility have capacity. Over the long-term, increasing density will increase capital cost.
Water Treatment Plants	Highly Sensitive. Design capacity and capital cost are based on the number of persons and on the type of non-residential uses to be served.	Moderately Sensitive. Population density has little short-term impact on capital cost, if distribution system and facility have capacity. Over the long-term, increasing density will increase capital cost.
Water Supply	Highly Sensitive. Design capacity and capital cost are based on the number of persons and on the type of non-residential uses to be served.	Moderately Sensitive. Population density has little short-term impact on capital cost, if distribution system and facility have capacity. Over the long-term, increasing density will increase capital cost.
High School	Sensitive. The key factor is the number of school-age children. However, in general, higher population will mean more school-age children are likely to be present.	Sensitive. In general, both per capita annual capital and O&M costs increase with the population density at the county level.
Solid Waste Disposal	Highly Sensitive. Total population determines the total residential solid waste flow; this, in turn, determines the capital cost of disposal facilities required.	Sensitive. In general, both per capita annual capital and O&M costs increase with the population density at the county level.
General Government	Moderately Sensitive. Total service demands depend on population. However, this is a labor-intensive service, so the effect on capital cost is moderate.	Sensitive. In general, both per capita annual capital and O&M costs increase with the population density at the county level.
Highways	Sensitive. A large population generates more vehicle trips, other things being equal, although other factors determine demand for total lane miles of capacity such as trip characteristics and du type.	Sensitive. Densely populated areas produce more total trips and require larger capacity roadways. Acquistition and construction costs for streets and roads in these areas are higher.

Table C-14
Sensitivity of Capital Cost for Regional Services to Locational Attributes

Service	Locational Atributes		
	Distance to Existing Service Area	**Distance to Employment Centers**	**Distance to Community Facilities**
Wastewater Treatment Plants	Minimally Sensitive. Excessive distance to existing facility may require construction of new treatment plant.	Minimally Sensitive.	Minimally Sensitive.
Water Treatment Plants	Minimally Sensitive. Excessive distance to existing facility may require construction of new treatment plant.	Minimally Sensitive.	Minimally Sensitive.
Water Supply	Minimally Sensitive.	Minimally Sensitive.	Minimally Sensitive.
High School	Minimally Sensitive. Schools are located where the residential areas are: scattered residential areas located beyond existing attendance zones could require construction of new school; first option would be to expand bus fleet, if capacity exists.	Minimally Sensitive.	Minimally Sensitive.
Solid Waste Disposal	Minimally Sensitive. Disposal facilities may be centrally located, but difficulty in siting disposal facilities or resource recovery plants means they could be located anywhere. The first option, to serve new outlying residential development, if disposal capacity exists, is to expand collection fleet and possibly construct transfer stations.	Minimally Sensitive.	Minimally Sensitive.
General Government	Minimally Sensitive.	Minimally Sensitive.	Minimally Sensitive.
Highways	Minimally Sensitive.	Highly Sensitive. Distance to employment centers determines the length of commuting trips and the required necessary lane miles of road capacity.	Sensitive. Distance to community facilities determines length of trips to local facilities, and the required lane miles of road capacity.

Table C-15
Sensitivity of Capital Costs for Regional Services to Service Characteristics

Service	Service Characteristics		
	Capacity Utilization	**Design and Regulatory Standards**	**Shape of Service Area**
Wastewater Treatment Plants	Sensitive. Underutilized facility means high per capita capital costs for current users, but possibly low marginal capital costs for new users depending on how rate and user fees are designed.	Sensitive. Design standards along with capacity determine capital cost. Regulatory standards determine the quality of effluent which, in turn, determines treatment process and capital costs.	Minimally Sensitive.
Water Treatment Plants	Sensitive. Underutilized facility means high per capita capital costs, for current users, but possibly low marginal capital costs for new users, depending on how rate and user fees are designed.	Sensitive. The design standards along with capacity determine capital cost. Regulatory standards determine the quality of treated water, which in turn determines treatment process and capital costs.	Minimally Sensitive.
Water Supply	Sensitive. Underutilized facility means high per capita capital costs, for current users, but possibly low marginal capital costs for new users, depending on how rate and user fees are designed.	Sensitive. Engineering design and safety standards determine the capital cost of facility. Regulatory standards determine treatment required for water.	Minimally Sensitive.
High School	Moderately Sensitive. Schools are labor-intensive as opposed to capital-intensive; excess capacity incurs low or zero marginal capital costs, almost entirely O&M; given the larger enrollment service area and more specialized nature of high schools, a large population increase is needed to require a new school.	Sensitive. Design standards are based on regulations covering maximum class size and floor area standards for facilities such as gyms and labs.	Moderately Sensitive. The shape of the attendance area, along with its size and gross density, will determine the number of buses required.
Solid Waste Disposal	Moderately Sensitive. Underutilized facilities mean high per capita capital costs; although this can be offset to some extent because landfills are built as they are used.	Moderately Sensitive. Environmental regulations and design standards determine capital costs to some extent.	Minimally Sensitive.
General Government	Minimally Sensitive. Service is labor-intensive so capital cost effects are small.	Minimally Sensitive.	Minimally Sensitive.
Highways	Highly Sensitive. The design standard is based on forecast utilization or level of service during peak hour flows. Underutilized highways incur high marginal capital costs.	Highly Sensitive. Lane miles of new roadway capacity are based on forecast design volumes at a specified level of service; design standards also specify pavement thickness and load capacity, etc.; all of which determine capital costs. Regulatory standards specify the construction standards, which also effect the capital costs.	Sensitive. While the shape of region determines highway length, route, and cost, other factors also affect capital cost, such as inter-regional origins and destinations, location of employment centers, amount of pass-through traffic, and regional land use patterns (both residential and non-residential). In general, regularly shaped areas will require shorter lengths and impose lower costs.