Planning for Street Connectivity:

Getting from Here to There

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American Planning Association

Planning Advisory Service
Report Number 515

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This report reflects the hard work and important contributions of many others. Rachael Rawlins, then a member of the City of Austin Planning Commission and a lecturer in the Community and Regional Planning Program (CRP) at the University of Texas at Austin, initiated the original 1999 study on which this report is based and guided the Austin case study presented in Chapter 4. Several students from the CRP program are responsible for a substantial share of the research on which this report is based. Andrew DeGarmo completed most of the research in the original study, including the literature review and case studies, with the help of Christina Stanland. Judit Harscek worked on the housing cost analysis for Austin, presented in Chapter 4. Salila Vanka updated the case studies in 2002, and Kirk Scanlon drafted much of the historic overview and managed to compile the efforts of many different contributors into a draft report. Sam Shelton, a student at the University of California at Davis, helped with the final checks on the city ordinances and with the assembly of the graphics. Kevin Krizek, an assistant professor of urban planning and public affairs at the University of Minnesota, Marya Morris, APA senior research associate, and S. Mark White, an attorney with Freilich, Leitner, Carlisle & Shortlidge in Kansas City, Missouri, offered many constructive suggestions. Steve Tracy, staff research analyst at the Local Government Commission, provided last-minute tips on four additional communities with connectivity requirements. Last but not least, busy planners from all of our case study communities gave us valuable moments of their time to describe their efforts. We owe much credit and many thanks to all of them.

Funding for the original study was provided by the City of Austin, and later research was funded by a grant from the Mike Hogg Endowment for Urban Governance of the University of Texas at Austin.

Cover design by Lisa Barton; this report is printed on recycled paper.

Cover photo: A new development at the edge of Portland, Oregon, illustrating stub streets, interconnectivity, and existing cul-de-sacs in abutting development. Copyright by GlobeXplorer.

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Planning Advisory Service Reports are produced in the Research Department of APA. James Hecimovich, Editor; Lisa Barton, Design Associate; J.E. Luebering, Editorial Assistant; Toby Zallman, Design Assistant.

APA's publications office is at 122 S. Michigan Ave., Suite 1600, Chicago, IL 60603.
E-mail: pasreports@planning.org
APA headquarters office is at 1776 Massachusetts Ave., N.W., Washington, DC 20036.

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Preface

Connectivity is a system of streets with multiple routes and connections serving the same origins and destinations. . . . An area with high connectivity has multiple points of access around its perimeter as well as a dense system of parallel routes and cross-connections within the area.

—James M. Daisa
"Metro Regional Street Design Study," 1997

Look out the window as you fly into a major metropolitan region in the United States and you can easily identify the era during which different areas were developed. The most telling clue, besides the extent of the tree canopy, is the layout of the street network. Those areas with a regular, rectilinear street grid were almost certainly built sometime after the middle of the nineteenth century and before the middle of the twentieth (Figure P.1). Those areas with curvilinear, disconnected streets were most likely developed after World War II (Figure P.2). The stark differences between these areas reflect changes in the practice of planning and in the conventions of the development industry, and they have important implications for day-to-day life.

Susan Handy

Figure P.1. A typical street network developed before the Second World War.

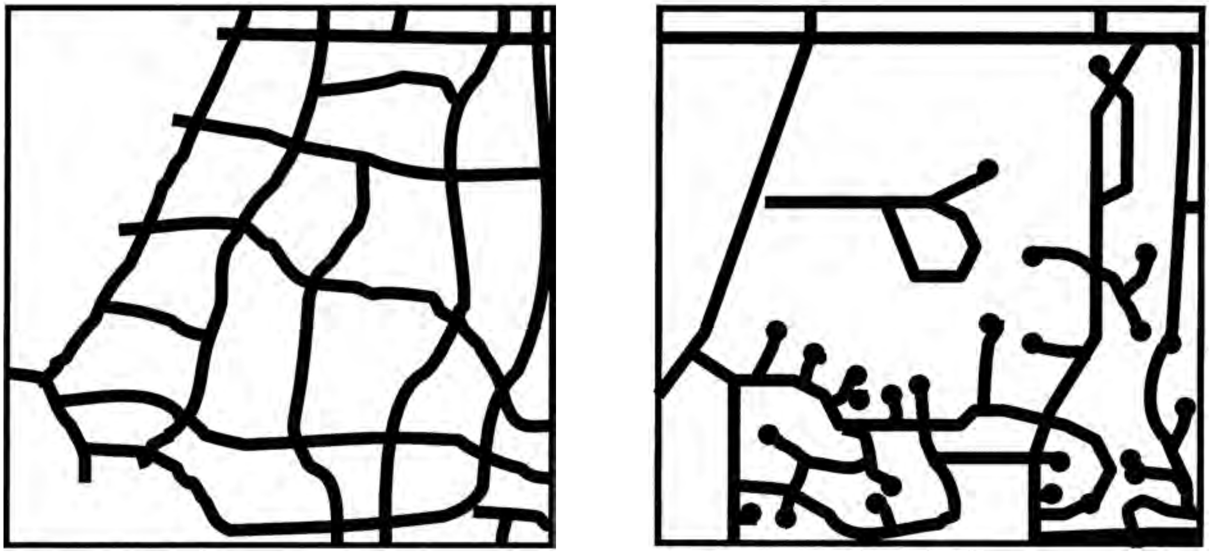
Susan Handy

Figure P.2. This street network is typical of those developed after the Second World War.

The "connectivity" of the street network has important implications for travel choices, emergency access, and, more generally, quality of life.

The purpose of a street network is to connect spatially separated places and to enable movement from one place to another. With few exceptions, a local street network connects every place in a community to every other place in the community. But, depending on the design of the network, the quality of those connections will vary. The network may provide one connection or many connections, direct connections or indirect connections, connections for all modes or for selected modes of travel. The quality of connections—the "connectivity" of the street network—influences the accessibility of potential destinations in a community and has important implications for travel choices, emergency access, and, more generally, quality of life.

After decades of promoting residential street networks characterized by low connectivity (Figure P.3), a growing number of U.S. cities are beginning now to consider the potential benefits of improved street connectivity (Figure P.4). Many have adopted ordinances that require the street networks in new residential subdivisions to provide a higher level of connectivity. The motives for adopting such ordinances are largely similar across these communities: reduce traffic on arterial streets, provide for continuous and more direct routes, provide greater emergency vehicle access, and improve the quality of utility connections. But the methods these cities have chosen differ in important ways. These efforts have begun to reshape residential development, although they are so recent that their full implications cannot yet be assessed. The Congress for New Urbanism is also promoting the concept of connectivity as a part of its efforts to create more livable and sustainable communities, and the Smart Growth Network recommends that communities "plan and permit road networks of neighborhood-scaled streets . . . with high levels of connectivity and short blocks" (Smart Growth Network 2002, 63). Reid Ewing included connectivity in his guide to best development practices (Ewing 1996).



Adapted from City of Eugene, Oregon, 1996b

Figures P.3 and P.4. (Left) A high-connectivity street network. (Right) A low-connectivity street network.

The purpose of this report is to provide an overview of efforts by communities across the United States to increase street connectivity. It is aimed at communities struggling with this goal themselves. The report looks at the motivations behind such efforts, the wide variety of issues these efforts have raised, and the different approaches that communities have taken to resolve them. These requirements are too new to have yet produced evidence on their effectiveness, however, and so no overall assessment is offered here. Questions that remain at the end of this report include:

- What is the most appropriate way to measure connectivity?
- How much connectivity is the right amount?
- What is the best network design for achieving the desired level of connectivity?
- What does street connectivity mean for nonautomobile modes?
- How can connectivity in commercial areas be improved?
- What can be done about existing street networks?

Planners, decision makers, and residents should gain from this report a better understanding of the concept of connectivity as well as ideas about how best to address the goal of connectivity in their own communities.

Nevertheless, planners, decision makers, and residents should gain from this report a better understanding of the concept of connectivity as well as ideas about how best to address the goal of connectivity in their own communities.

The report is organized as follows. Chapter 1 describes the history of street network design, including the emergence of the concept of a street hierarchy after World War II. Chapter 2 discusses the arguments for and against increased street connectivity. Chapter 3 includes summaries of efforts by 11 U.S. cities and one regional agency to increase connectivity; it also describes the jurisdictions' ordinances and the political processes that resulted in their adoption. Chapter 4 compares the case of Raleigh, North Carolina, where the city succeeded in adopting increased connectivity standards, with that of Austin, Texas, where various parties have been negotiating a connectivity requirement for several years; these cases illuminate the importance of a cost-benefit analysis of connectivity standards during the adoption process. The Afterword concludes with a discussion of the larger issues that need further attention as efforts to promote street connectivity evolve.

CHAPTER 1

History of Street Patterns and Standards

The street layout determines, in a very large degree, how the people shall live, how they shall travel to and fro, how they shall work and play; it has a direct influence upon the character of the home and its surroundings, upon the safety, comfort, and convenience of the people, and upon the efficiency of government and the public service. . . . The modern city . . . requires a layout of its streets quite different from that of any city of the past.

—B. Antrim Haldeman
"The Street Layout," 1914

The differences in metropolitan street patterns reflect changing ideas about how best to design a street network. The rectilinear grid emerged as a way to rationally subdivide land and enable the regular outward growth of a city. Growing use of the car prompted a move away from the rectilinear grid—or "gridiron"—in the 1920s. This shift in the philosophy of street network design is an important backdrop to today's efforts to increase street connectivity. This chapter provides a brief overview of the history of street patterns and standards.

THE RECTILINEAR GRID

From antiquity, human settlements provided rights-of-way for public circulation.

Wheeled traffic shared space with children at play, adults conducting business, and foraging livestock. Streets provided market space and entertainment sites. In 450 B.C., Hippodamus, considered the father of Greek town planning, developed a system of straight and parallel streets. This design became known as the gridiron system.

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While the Greeks created the grid, the Romans elevated the science of street design, construction, and traffic regulation to forms we recognize today. The modern elevated sidewalk is an example. Constructed of stone and built on both sides of the street, Roman sidewalks occupied as much as half of a street's width and provided a safe, dry area for pedestrian traffic. The Romans also established a number of design criteria for the width and construction of roads. The first street standard was established in 100 B.C.; it mandated street widths of 15 feet, which accommodated two passing carts (Jackson 1985). In 15 B.C. Augustus expanded street standards by creating a hierarchy of street widths for the gridiron network: the width of the decumanus, a town's processional road running west and east, was to be 40 feet; that of the cardo, the main north-south road, was to be 20 feet; and that of the cincinae, or side roads, was to be 15 feet (Southworth and Ben-Joseph 1997, 9-10).

Outside the cities, the viae militares, or military roads, were the pride of the Roman transportation system. They served as the prototype for modern street design and construction:

> [t]he typical Roman road was constructed of four layers: flat stones, crushed stones, gravel, and coarse sand mixed with lime. . . . Roads were usually about 35 feet wide, with two central lanes 15.5 feet wide for two directions of traffic, and were lined by freestanding curbstones two feet wide and 18 inches tall. . . . [They set] the standard for road construction in Europe until the late eighteenth century. (Southworth and Ben-Joseph 1997, 12)

The Romans also pioneered traffic regulation. For example, the city diverted refuse and rubble collection to evenings in order to ease traffic congestion on roads outside of the city. Building heights and setbacks along streets were regulated to provide light and air and to facilitate mobility. And, in perhaps the first documented case of traffic calming, Romans placed stone blocks at the entrances of streets to discourage chariot traffic (Homburger et al. 1989).

The decline of the Roman Empire brought a movement away from the grid network. Roman cities were transformed during the Middle Ages: roadways deteriorated, long-distance vehicle travel stopped, public spaces shrank, and walls were built to protect and enclose cities. The clear, regular grid became an irregular design with no major streets moving traffic from the gates to the loci of the town. Internal streets were also constricted by the loss of building setbacks; they thus became "narrow passageways defined by the building walls and overhead arches" (Southworth and Ben-Joseph 1997, 13).

The population and economic booms that accompanied the Renaissance in the 1500s signaled a time of architectural reform for many cities across Europe. Simultaneously, technological advances in warfare techniques rendered the medieval city wall obsolete. In response, sections of the walls were removed and new gridiron-based suburbs for the growing merchant class were attached to existing urban outlays. Straight, parallel streets were praised for their pure form and the dramatic perspectives on civic or religious landmarks they offered; they also provided the military with increased mobility through cities to meet civil unrest or invasion (Southworth and Ben-Joseph 1997, 16).

In the late 1600s, the grid first appeared in American cities. In 1682, Philadelphia adopted the grid, modeling its network after London's. Savannah, Georgia, in 1733 and New York City in 1811 followed. These early American street networks standardized street widths so that all streets had the same right-of-way and carried the same amount of traffic. Exceptions included downtown Manhattan, where some streets were built with a greater right-of-way to allow for future expansion (Homburger et al. 1989, 5)

The benefits of the gridiron system were multiple and concrete. The grid was a simple, efficient, and economically beneficial method of subdividing land. It simplified surveying, maximized the number of houses facing a street, minimized legal boundary disputes, and allowed for standardization of lot sizes (Jackson 1985, 75). Kenneth Jackson also argues that the grid provided psychological comfort to a growing nation:

> The pervasive right-angled plot, which enabled such efficient speculative subdivision . . . personified the antinaturalism that influenced nineteenth-century urban form. Rectangular streets testified to man's capacity to overcome the hostility of the land and to civilize a continent. . . . Early planners associated the grid system with success and refused to make any deviation, even when the configuration of the terrain suggested it. (Jackson 1985, 74)

The grid so swayed American leaders of the late 1700s that conformance was mandated by the Northwest Ordinance of 1787 for all trans-Appalachian expansion. The result of that legislation is the ubiquitous influence of the gridiron on urban form from coast to coast.

CURVILINEAR STREETS

By the early nineteenth century, however, the monotony of the grid, in conjunction with insufficient building setbacks and myriad social and economic factors, created intolerable tenement conditions in industrial cities around the world. In 1875, the English government responded to these conditions by instituting the Bye-Law Street Ordinance, which promoted light, air, and freedom of movement through increased street widths of 40 to 50 feet, a standard still used today, and a gridiron pattern of very long, straight streets. Despite improving sanitary conditions and traffic flow, however, the overall effect was more monotony and a sterile landscape disliked by residents. "The street space is swept so clean as to approach emotional emptiness and complete negation," noted a London resident the time (as quoted in Southworth and Ben-Joseph 1997, 37).

The gridiron thus came under increasing scrutiny by architects and planners late in the century. The grid's weaknesses, they argued, included architectural monotony and disregard for topological variables:

> Surveyors, who ignored the existence of hills in their unswerving faith in gridirons, sometimes laid out streets which could never be constructed, such as in San Francisco, where the pattern even extended under water into the Bay, or in Philadelphia, where the grid was intended to cross steep bluffs and ravines. (Homburger et al. 1989, 5)

London's Bedford Park and Hampstead Garden were two neighborhoods planned in the wake of this critique. Bedford Park, considered the world's first "garden suburb," introduced curved streets, visual anchors at the termini of streets, reduced street widths, and planting strips for trees. The effect "inspired succeeding suburban street designers to question authoritative prescriptions. It has stood the test of time and today it is still one of London's more delightful and livable neighborhoods" (Southworth and Ben-Joseph 1997, 42).

Bedford Park, considered the world's first "garden suburb," introduced curved streets, visual anchors at the termini of streets, reduced street widths, and planting strips for trees.

The Hampstead Garden suburb, designed by Raymond Unwin and Barry Parker in 1904, was, at its inception, an experiment in social engineering. Co-opting garden city ideals from suburban guru Ebenezer Howard, Unwin and Parker sought to create healthful environs for the working poor through a synthesis of urban and rural amenities and a variety of housing choices designed to integrate economic classes. They received a reprieve from the strictures of the Bye-Law Ordinance through a private bill entitled the Hampstead Garden Suburb Act. Passed in 1906, this bill allowed for a street pattern that, as a contemporary commentator noted, "avoids regularity in every way. [The streets] meander about aimlessly comfortably, following the natural contour and advantages of the land. Nor are they of equal width. The residential streets are narrow. They are designed to discourage traffic and keep it on the main thoroughfares" (as quoted in Southworth and Ben-Joseph 1997, 45). Hampstead Garden was the first planned development to systematically use cul-de-sacs and open courts to create a quiet, pedestrian-oriented environment. Pedestrian connectivity was enabled through pedestrian walkways at midblock or at the end of cul-de-sacs. Through these innovations Hampstead Garden became an exemplar of subdivision street design and road planning.

Radburn was unique in its separation of the pedestrian network from the automobile infrastructure and its rigid hierarchy for street use.

In the early 1900s, Fredrick Law Olmsted and Calvert Vaux mirrored in the United States Unwin and Parker's curvilinear street patterns. Their avant-garde designs, however, had relatively little effect on the mainstream, rectilinear American subdivision street patterns. Not until the 1920s did the curvilinear evolution of the suburban landscape begin in earnest, with the escalation of automobile ownership serving as the prime motivator. In 1900, there were only 8,000 motor vehicles on the roads; in 1920 there were 8 million, and in 1930 there were 23 million (Southworth and Ben-Joseph 1997, 56). Automobiles enabled the decentralization of American cities and forced planners to cope with growth patterns on a regional level.

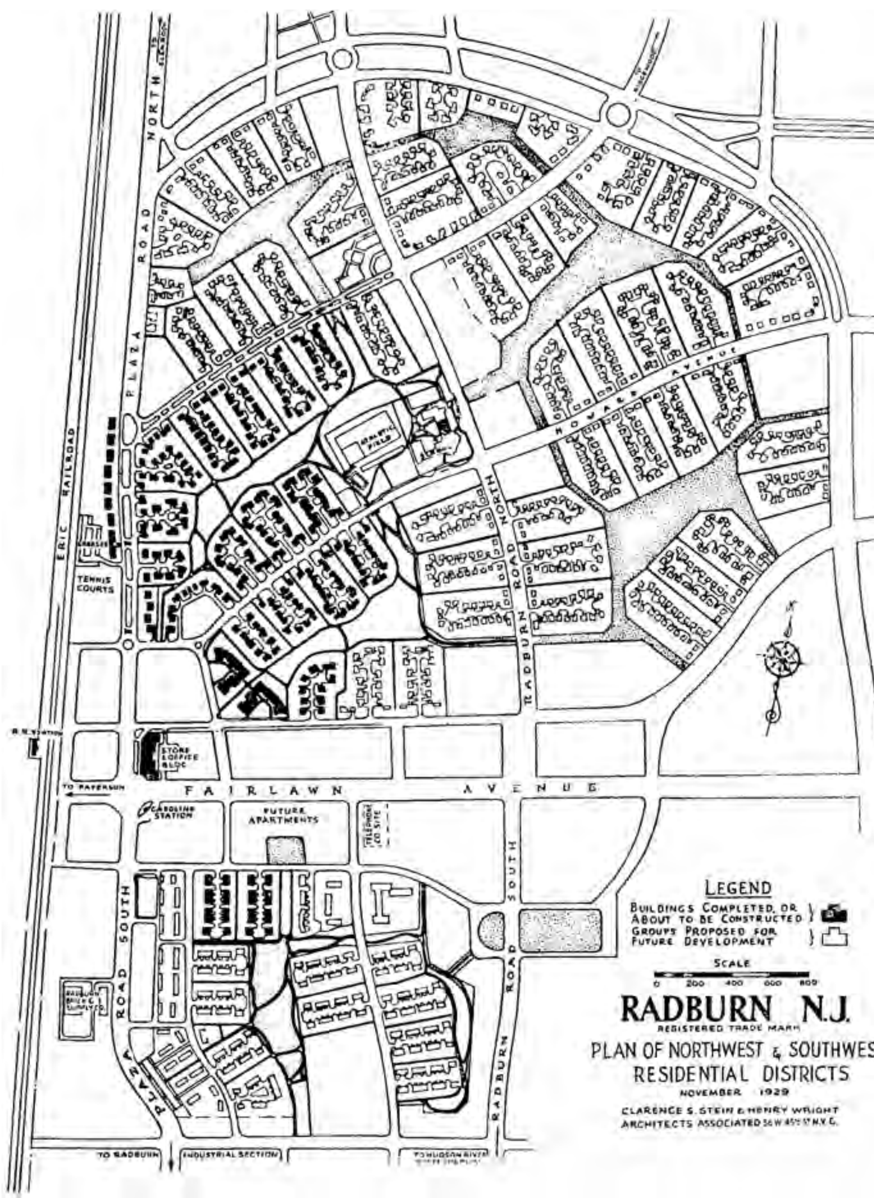
THE STREET HIERARCHY

In 1923, the newly formed Regional Planning Association of America (RPAA) was charged with creating metropolitan and regional planning guidelines and with developing principles for quality residential development. Among the founders of the RPAA were Clarence Perry and Clarence Stein. Perry established a set of principles that proved to be the foundation for modern suburban design. He envisioned the model community as a neighborhood unit with distinct boundaries in the form of major streets. A school would be placed at the center of the development, and all sectors of the development would be within easy walking distance of the school. The walking distance and the population would define the extent of the unit and its density (Homburger et al. 1989, 8). Perry also promoted the use of road hierarchy to match traffic load and usage.

In 1928, Stein and Henry Wright wove Perry's principles into the design for Radburn, a two-square-mile development in New Jersey. Radburn was unique in its separation of the pedestrian network from the automobile infrastructure and its rigid hierarchy for street use. Stein's observations on the nefarious influence of automobiles upon development illustrate the impetus behind his planning innovations:

> The flood of motors had already made the gridiron street pattern, which had formed the framework for urban real estate for over a century, as obsolete as a fortified town wall. . . . The checkerboard pattern made all the streets equally inviting to through traffic. Quiet and peaceful repose disappeared along with safety. Porches faced bedlams of motor throughways with blocked traffic, honking horns, noxious gases. Parked cars, hard gray roads, and garages replaced gardens. (Stein 1957, 41)

Stein integrated several existing techniques and some new ones to both accommodate the automobile and mitigate its effects in Radburn (Figure 1.1). He borrowed from Hampstead Garden the use of superblocks—blocks of 35 to 50 acres surrounded by wide streets—as well as cul-de-sacs, narrow streets, planting strips, and 15-foot setbacks. Among his innovations was a road hierarchy that separated commercial from residential uses by creating narrow residential streets for local traffic. At the time, popular real estate and planning wisdom viewed the separation of residential and commercial uses as impractical. But Stein argued that narrow residential streets would curtail automobile traffic. In addition, he argued, with narrow streets "the area in streets and the length of utilities is 25 percent less than in the typical American street plan" (Stein 1957, 48). The resulting savings paid for the acquisition of land for parks within the development. Stein also created a network of pedestrian trails and bridges that thoroughly separated the automobile from the pedestrian.



Source: Stein 1957

Figure 1.1. Radburn, New Jersey, Residential Street Plan, 1929.

Over time the Radburn plan has come to represent a milestone in the design of residential communities. Although the internal network of greenways and pedestrian paths was not widely copied, the concept of a hierarchy of streets first articulated by Stein at Radburn quickly became the prevailing standard for new suburban subdivisions. The rectilinear grids found in older residential areas were often modified to create a hierarchy through the installation of barriers and diverters to discourage traffic through the neighborhood and to concentrate traffic on designated streets; Donald Appleyard describes several of these "neighborhood protection" efforts in his widely cited book Livable Streets. The street hierarchy concept today still dominates the design of street networks, owing largely to its entrenchment in street design standards.

STANDARDS

The standardization and subsequent proliferation of the modern residential suburb pattern occurred when the Federal Housing Administration (FHA) was created through the National Housing Act of 1934. The FHA was established to stabilize the mortgage market, improve housing, increase access to home loans, and alleviate unemployment during the Depression. It was successful on all counts, garnering substantial power through its financial successes and unprecedented acceptance by the private sector.

The FHA recommended that developers and builders create a hierarchy of streets, place major thoroughfares outside of developments, eliminate wide intersections, discourage through traffic, and reject the grid pattern. . . . the FHA emphasized the use of cul-de-sacs.

Before long, the FHA exceeded its role as a stabilizing influence on the housing market by exerting significant influence on the regional distribution of suburban developments, the economic and racial composition of communities, and the standardization of subdivision design. The FHA threatened to refuse guaranteed loans in areas identified as risky or in noncompliance of subdivision design standards prescribed by the administration, although it denied that it was regulating development:

> [t]he Administration does not propose to regulate subdividing throughout the country, nor to set up stereotype patterns of land development. . . . It does, however, insist upon the observance of rational principles of development in those areas in which insured mortgages are desired. (As quoted in Southworth and Ben-Joseph 1997, 83)

In 1935, the FHA published its first booklet of standards for subdivision design, Standards for the Insurance of Mortgages on Properties Located in Undeveloped Subdivisions – Title II of the National Housing Act. These standards established the precedent for suburban street patterns and specified that subdivision layout should fit the topography of the site, that blocks should range from 600 to 1,000 feet in length, and that density for semidetached dwellings should not exceed 12 units per acre, among other requirements (Southworth and Ben-Joseph 1997, 83).

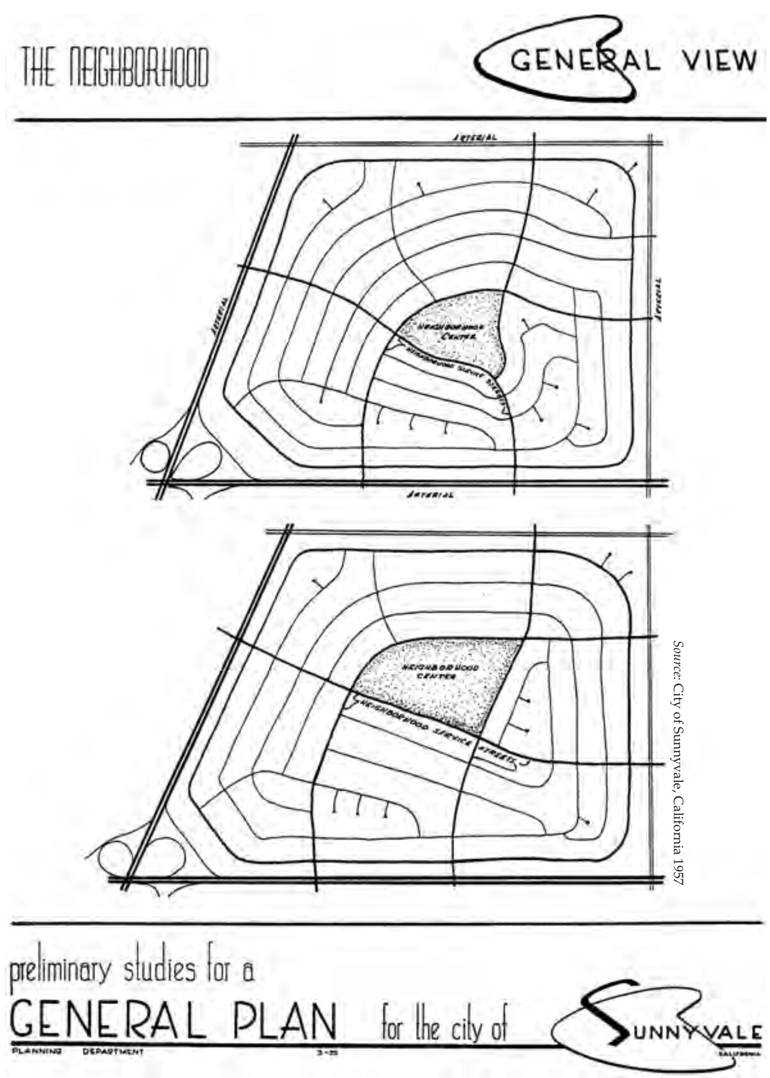
In 1936, the FHA published Planning Neighborhoods for Small Houses, which offered design standards based on the work of Unwin, Perry, and Stein. The FHA recommended that developers and builders create a hierarchy of streets, place major thoroughfares outside of developments, eliminate wide intersections, discourage through traffic, and reject the grid pattern. In addition to the use of curvilinear streets and courts, the FHA emphasized the use of cul-de-sacs:

> Cul-de-sacs are the most attractive street layout for family dwellings; street construction costs are thereby reduced since an 18-foot pavement with a minimum 30-foot radius turnaround are sufficient. (As quoted in Southworth and Ben-Joseph 1997, 84)

In 1932, the Hoover administration brought 3,700 housing experts together at a special Conference of Home Building and Home Ownership to provide ideas on how to kick-start the building industry during the Depression. One recommendation was to grant local governments subdivision control for the first time. By 1941, 32 states had passed legislation granting this power to municipalities. Despite the geographic, cultural, and economic differences between the municipalities, the standards enforced were strikingly similar:

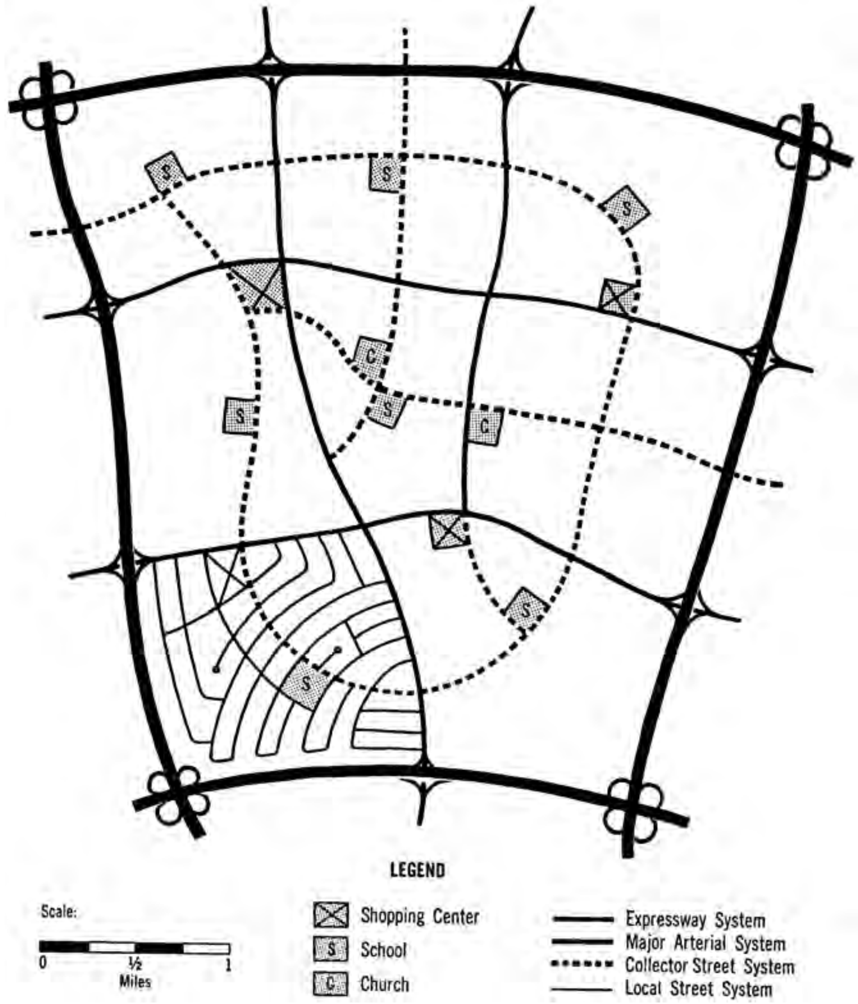
> Local planning commissions, once authorized and empowered by the community, adopted rules and regulations governing subdivision procedures largely based on federal criteria, in particular those of the FHA. A nationwide survey of more than two hundred cities' requirements by the Public Administration Service in 1941 found them to be similar. (Southworth and Ben-Joseph 1997, 88)

Examples of Stein's concepts of a neighborhood unit and a street hierarchy can be found in general plans of the era throughout the country. For example, the 1957 general plan for Sunnyvale, California, defined a neighborhood as consisting of a neighborhood center within a network of low-traffic residential streets, all surrounded by high-traffic arterial streets. The examples shown in the plan use cul-de-sacs, curvilinear streets, and only five or six connections between the neighborhood and the arterial streets to achieve



Source: City of Sunnyvale, California 1957

Figure 1.2. Neighborhood Street Concept for Sunnyvale, California, 1957.



National Committee on Urban Transportation 1958

Figure 1.3. Street Network Concept from National Committee on Urban Transportation, 1958.

the desired effect (Figure 1.2). A diagram from the National Committee on Urban Transportation published by the Public Administration Service in 1958 shows the concept of a hierarchy carried out at a community scale (Figure 1.3). The hierarchy concept still pervades local transportation plans. The current land development code for Austin, Texas, for example, shows a strikingly similar diagram for the street network system (Figure 1.4).

In 1961, an influential study by Harold Marks furthered the national standardization of subdivision street design. Marks' study compared the accident rates between gridiron developments and those of FHA neighborhood units between 1951 and 1956. The results demonstrated that the FHA model reduced accident rates. The gridiron developments had 77.7 accidents per year, compared to 10.2 accidents per year in an equivalent area of the FHA subdivisions. Similarly, 50 percent of intersections in the gridiron developments but only 8.8 percent of intersections in FHA subdivisions had at least one accident (Southworth and Ben-Joseph 1997, 92). However, this study did not control for differences in traffic volume, land-use mix, housing density, population density, socioeconomic conditions, intersection density per square mile, lighting, and other factors that might also explain differences noted in aggregate accident rates.

Nevertheless, based on these results, the Institute of Transportation Engineers (ITE) published Recommended Practice for Subdivision Streets in 1965. This document further promoted the concept of a street hierarchy and increased the recommended right-of-way for residential streets to a mini-

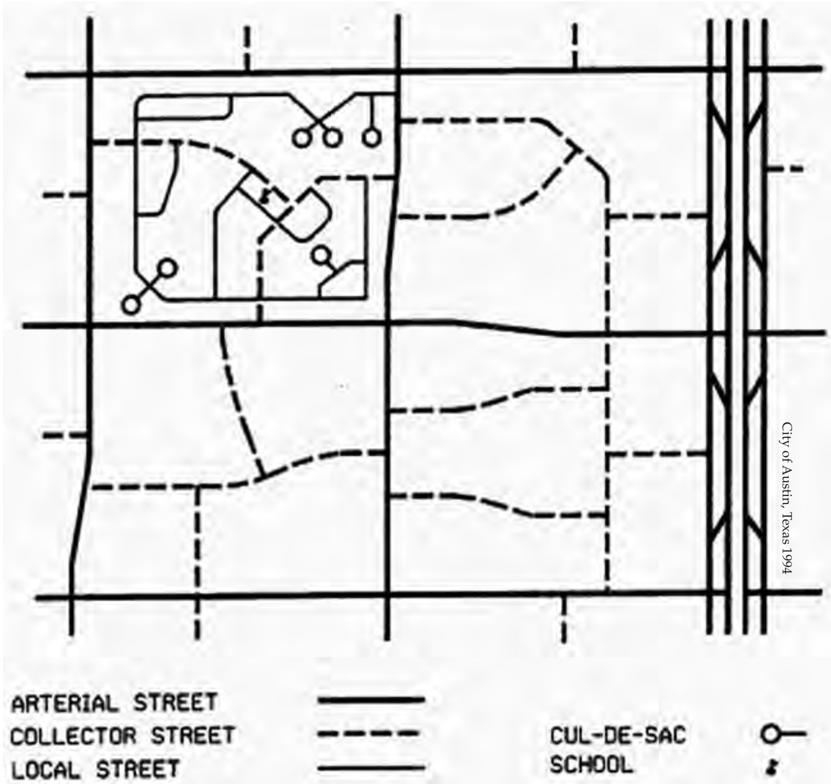


Figure1.4. Austin, Texas, Street Network Concept, 1994.

mum of 60 feet with a pavement width of 32 to 34 feet (Southworth and Ben-Joseph 1997, 94). ITE later published two more guidebooks, Recommended Guidelines for Subdivision Streets (1984) and Guidelines for Residential Subdivision Street Design (1990), each changing the standards in minor ways but perpetuating the concept of a hierarchy of streets (Figure 1.5)

The concept of a street hierarchy is imbedded in the street classification system that still dominates traffic engineering and transportation planning

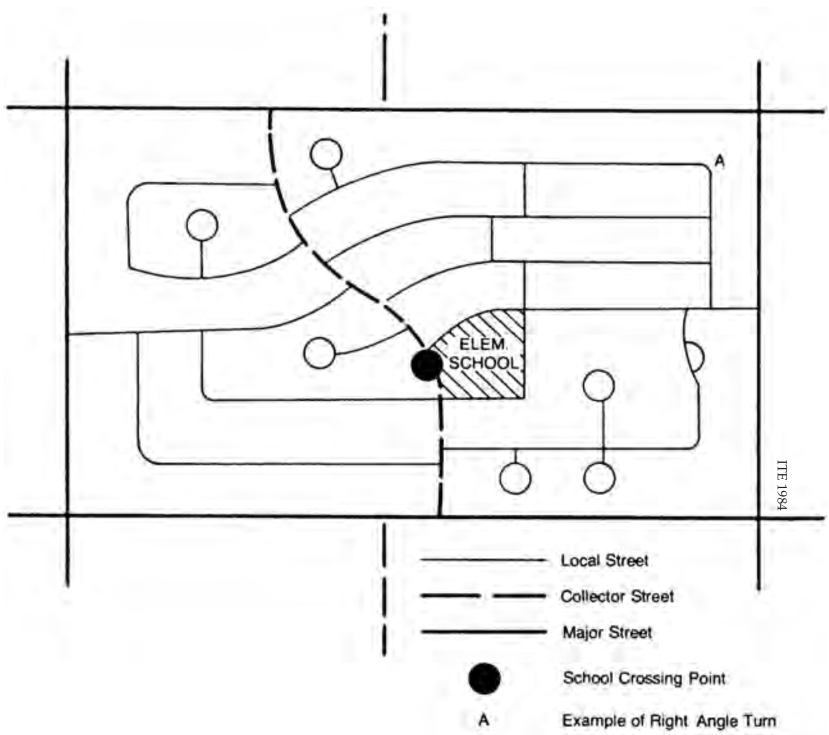


Figure 1.5. Institute of Transportation Engineers Street Layout Principles, 1984.

One of the guiding principles of traffic engineering and transportation planning practice is that the design of a street should match its function.

practice. In this system, streets are differentiated by the degree to which they serve access or movement functions. Cul-de-sacs, at one end of the hierarchy, serve almost entirely an access function; freeways, at the other end, serve solely a movement function (Figure 1.6). Standard street classifications include access streets, collector streets, and arterial streets (e.g., ASCE et al. 1990), although other classifications are sometimes also defined (e.g., Figure 1.7). One of the guiding principles of traffic engineering and transportation planning practice is that the design of a street should match its function. Thus, standards for street design are defined according to this street classification; requirements for street widths, curbs, sidewalks, speed limits, and parking provision are established so as to match the projected level of use of each facility. This principle has had important implications, both positive and negative, for the design of residential areas.

IMPLICATIONS

The American Society of Civil Engineers argues in Residential Streets that "the street's contribution to the neighborhood environment is as important as the street's role as a transportation conduit" (ASCE et al. 1990, 22). The minimization of through traffic on residential streets has been one of the primary means of improving the neighborhood environment, and disconti-

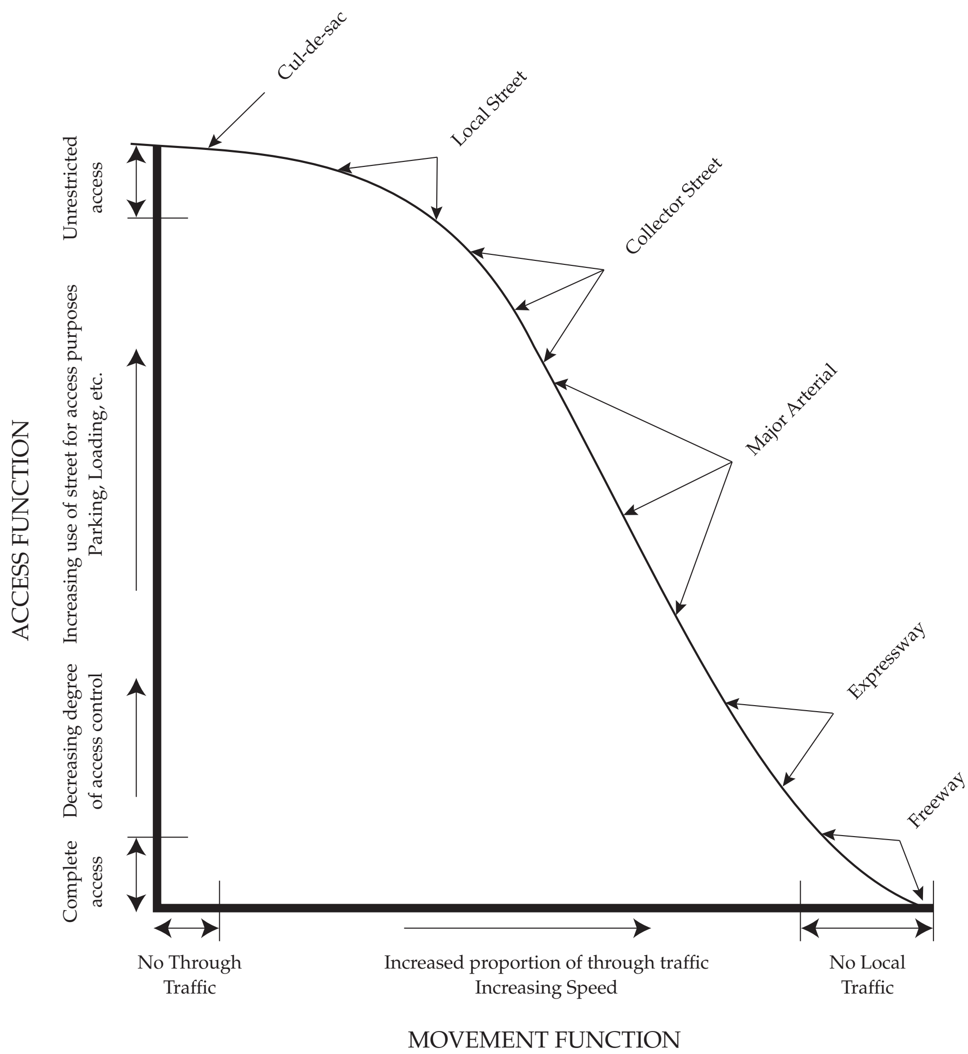
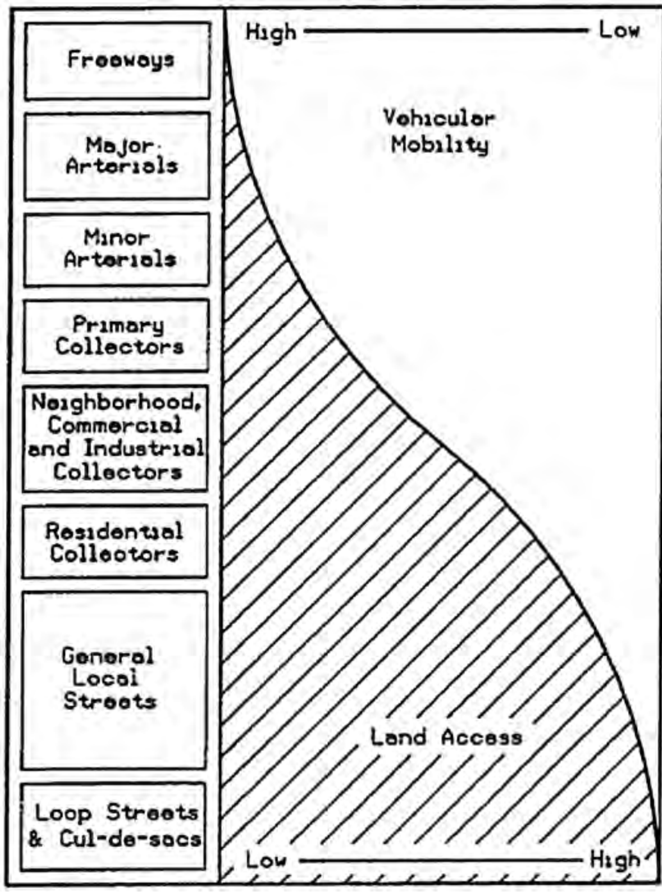


Figure 1-6. Standard Street Hierarchy Classifications.

Source: Adapted from Homburger and Kell 1977



Source: City of Austin, Texas 1994

Figure 1.7. Street Hierarchy Concept for Austin, Texas, 1994.

nuities in the street network have been one of the primary techniques used to minimize through traffic. In other words, the decline in street connectivity over the twentieth century reflects a conscious effort to improve quality of life in residential areas.

Although this effort has largely succeeded in reducing through traffic on residential streets, it has affected quality of life in residential areas in other unintended and not always positive ways (Handy 1993). First, most applications of the hierarchy concept produce residential areas bounded by high-speed arterials, with limited entrances from those arterials, an idea that clearly has its roots in the Radburn design. As a result, residential areas are often separated from surrounding development, with low connectivity between neighborhoods. Second, street networks within residential subdivisions are dominated by T-intersections and cul-de-sacs, which are designed to slow speeds and reduce through traffic. But these designs also tend to reduce connectivity within the neighborhood, leading to indirect, inefficient routes from one location to another. Both of these characteristics have the potential to increase travel distances and reduce the viability of walking.

Concerns about these negative side effects have contributed to growing interest in efforts to increase street connectivity by moving away from a rigid hierarchy concept and returning to something more like the traditional gridiron. As the next chapter shows, however, the available evidence on the relative merits of high-connectivity grids is surprisingly thin, and the importance of connectivity continues to be debated. Despite the skimpy evidence, however, more cities continue to adopt connectivity ordinances, and if the trend continues, the history of residential street design may take another important turn.

CHAPTER 2

The Debate

Proposed connectivity ordinances, designed to increase connectivity in new residential subdivisions, have met varied receptions, quietly accepted in some communities and vigorously opposed in others. Reaction is typically divided between two camps: those for often include designers and planners while those against often include developers, financers, and real estate professionals. Planners in communities studied in this report offer the following motivations for increasing street connectivity, which will be analyzed at length in this chapter. They say increasing street connectivity will:

- decrease traffic on arterial streets;
- provide for continuous and more direct routes that facilitate travel by nonmotorized modes such as walking and bicycling and that facilitate more efficient transit service;
- provide greater emergency vehicle access and reduced response time, and, conversely, provide multiple routes of evacuation in case of disasters such as wildfires; and
- improve the quality of utility connections, facilitate maintenance, and enable more efficient trash and recycling collection and other transport-based community services.

The opposition to connectivity can come from different sources, most obviously developers faced with meeting the new requirements and residents of existing neighborhoods faced with changes in the distribution of traffic. Those opposed to connectivity ordinances often argue that they will:

- raise levels of through traffic on existing residential streets;
- increase infrastructure costs and impervious cover;
- require more land to develop the same number of units;
- decrease the affordability of housing; and
- threaten the profitability of developments.

The opposition to connectivity can come from different sources, most obviously developers faced with meeting the new requirements and residents of existing neighborhoods faced with changes in the distribution of traffic.

Unfortunately, not all potential benefits and costs have yet been adequately studied, and some remain more contentious than others. This chapter reviews the available evidence on the debates surrounding these potential benefits; it also discusses the role of street widths in the debate over street connectivity. The concerns over cost are examined in more detail in Chapter 4.

DECREASE TRAFFIC ON ARTERIAL STREETS

The published research on street connectivity tends to support the argument that greater connectivity will reduce traffic volumes on arterials. This reduction can be attributed to two factors: the dispersal of vehicle trips throughout the network, and a decrease in the total amount of vehicle travel. The latter is more difficult to test than the former, which is essentially a function of route choice. Connectivity might reduce vehicle travel by reducing trip distances, reducing the number of trips, or encouraging a shift to transit or nonmotorized modes. Existing studies seem to agree that average trip distance and congestion (relative to the intensity of land uses) will be lower in areas with a rectilinear grid street pattern than in areas with conventional suburban street patterns only if the number of trips made by car does not increase. This caveat, however, is an issue of particular contention.

The results of several simulation efforts support the theory that greater street connectivity will reduce traffic volumes on arterials. Michael G. McNally and Sherry Ryan (1993) used a travel demand forecasting model to predict traffic in two hypothetical neighborhoods, one a conventional planned unit development with a curvilinear network and the other a traditional rectilinear grid. While limited by its hypothetical nature, the simulation showed significant decreases in vehicle miles of travel, trip lengths, and travel time in the traditional grid. Although it showed streets operating at higher ratios of volume to capacity in the traditional grid, none operated at congested levels, in contrast to the conventional street pattern. However, the model also showed a slight increase in the total number of trips in the grid neighborhood and did not show any significant change in level of service at major intersections. In a similar simulation study conducted in Portland, Oregon, analysts found that total vehicle miles traveled (VMT) were 43 percent less in a traditional neighborhood with a highly connected street pattern than in a conventional suburban neighborhood with a largely hierarchical street pattern (as cited in Proft and Condon 2001).

Metro, the regional government in the Portland, area, undertook a more realistic study several years ago based on forecasted travel demand for 2015 (Kloster et al. 2000). The study, which helped to refine connectivity requirements, used Metro's regional travel demand forecasting model to compare the results for varying levels of street connectivity in five neighborhoods in the Portland area. The study defined connectivity as the number of intersections per mile of arterial streets. It did not evaluate the performance of the transportation system for modes other than personal vehicles. In each neighborhood, the study varied the street layout in the model to achieve low, medium, and high numbers of connections per mile (ranging from six to 20), using existing highways and natural features as constraints where necessary.

The study found that medium and high levels of connectivity improved traffic flow on arterials. Overall, vehicle hours of delay, vehicle miles traveled, and average trip lengths declined in each area: when connectivity increased from low to medium levels, delay dropped by an average of 14 percent while both vehicle miles traveled and average trip length fell by an average of 2 percent. Traffic volumes approaching key intersections also declined by 10 percent. Results for individually selected segments of particular arterials were mixed, but, on average, traffic volumes decreased by 9 percent when connectivity increased from low to medium. The researchers attribute the mixed results to the fact that local trips made up a very small percentage of total traffic on arterials at the start, on average about 4 percent for the low-connectivity scenario. The one study area that did have a substantial amount of local traffic on its selected links (13 percent in the low scenario) showed the largest decreases—about 50 percent—in the proportion of local traffic as connectivity increased.

In all cases, the model found that a moderate level of connectivity yielded greater improvements per c onnection than the high level.

Portland Metro's results also suggest that greater connectivity could have negative impacts on both residential streets and on arterials. Although the model predicted that most longer-distance traffic would remain on the arterials, it showed some use of local streets to bypass congested intersections and/or arterial sections when doing so yielded equal or better travel times. In addition, the researchers noted that arterials might lose some capacity due to the increased number of intersections. However, they found evidence that might suggest decreased arterial traffic volumes could improve travel times for through traffic even with more intersections. In all cases, the model found that a moderate level of connectivity yielded greater improvements per connection than the high level. The researchers interpreted this result to mean that the optimal level of connectivity falls in the range of 10 to 16 connections per mile (one connection every 330 to 530 feet) for local and arterial streets. Additional connections beyond this range yielded diminishing returns in traffic improvements.

These studies have not adequately addressed the possibility that an increase in connectivity will increase the frequency of trips. Other researchers have offered theoretical and empirical support for this possibility. Using economic theory, Randall Crane (1996a) examined the likely impact of grid networks on vehicle travel; he concluded that grids would tend to increase car trips and that, as a result, total vehicle travel could also increase, even if trip lengths decreased. Susan Handy (1996) found evidence in a study of neighborhoods in the San Francisco Bay Area that improved accessibility can lead to greater trip frequencies. Her findings suggest that if a grid network reduces travel distances to destinations like supermarkets and shopping malls, it will tend to increase the frequency of trips to those destinations and may increase total travel. Reid Ewing and Robert Cervero (2001) completed a comprehensive review of studies that tested the link between street networks and vehicle travel and concluded that the evidence is inconclusive. Given the ambiguities of the impact of connectivity on total vehicle travel, it is safer to assume that reductions in traffic on arterials will result from changes in route choice.

However, changes in route choice may create additional problems. If traffic is declining on the arterials but not declining overall, it must be increasing on residential streets. With high levels of connectivity, the traffic on residential streets may be sufficiently dispersed that the impact on any one street is negligible. However, high levels of connectivity increase the opportunities for cut-through traffic—traffic that passes through the neighborhood but does not originate there or stop there. The Metro study, for example, provides evidence of the widely observed tendency of drivers to cut through neighborhoods to avoid congested intersections on arterials. As the previous chapter discussed, street standards for curvilinear subdivisions effectively reduced connectivity for the explicit purpose of reducing through traffic on residential streets, and many cities with grids added barriers and diverters for the same purpose.

Citizens have often expressed concern over cut-through traffic that might result from increased connectivity. A message posted on the Transportation for Livable Communities listserve (TLC-net) in June 2002 exemplifies the concerns of residents over attempts to increase connectivity in existing neighborhoods:

High connectivity may reduce traffic on arterials but will do so only at the cost of increasing traffic on residential streets. The challenge for communities is to find an appropriate balance between these potentially competing goals.

> We have approximately 40 homes for sale and/or replacing renters on just two streets in our historic neighborhood, many more turning over nearby, and thousands more trips being added [due to increases in connectivity] right away despite the obvious blighting and disinvestments. They are killing this part of town with traffic connectivity. Do other cities have a mechanism to limit the cut-through problems once the streets are connected?

Residents may also express concern over crime. They may fear that increased connectivity provides potential criminals with easy access to a neighborhood, where they are unlikely to be noticed because of the constant flow of nonresidents through the area. Multiple points of access also mean multiple escape routes for criminals, residents may argue. At least a handful of communities, including Los Angeles and Houston, have used barriers and diverters on residential streets to decrease connectivity in the interest of reducing crime (Handy 2003; Elizer and Lalani 1994). But others have countered that connectivity aids police pursuit of criminal suspects fleeing on foot who can more easily escape law enforcement in an area with dead-ends or cul-de-sacs (e.g., Berkeley-Charleston-Dorchester Council of Governments 2001). Empirical evidence on street connectivity and property crime rates is currently lacking. However, several studies have compared crime rates with measures of the fear of crime within gated communities and within non-gated communities. Three separate studies found no decrease in crime rates in neighborhoods with gates or street barricades (Blakely and Snyder 1997; Fowler and Mangione 1986; Wilson-Doenges 2000), but one study found a significant reduction in the rate of property crimes (Atlas and LeBlanc 1994). However, these studies also show that residents of gated or barricaded neighborhoods generally feel safer whether or not they actually are safer.

What all of these issues suggest is that high connectivity may reduce traffic on arterials but will do so only at the cost of increasing traffic on residential streets. The challenge for communities is to find an appropriate balance between these potentially competing goals. Techniques to reduce the impacts of traffic on residential streets, including narrower streets and other traffic calming approaches, can help communities achieve this balance.

FACILITATE NONMOTORIZED TRAVEL

Another potential benefit of greater connectivity is an increase in nonmotorized travel. Proponents argue that shorter travel distances resulting from higher connectivity will encourage walking and bicycling, and, because of shorter walking distances to bus or rail stops, will also increase the attractiveness of transit. If so, additional benefits will accrue to the community. For example, public health officials are increasingly concerned with the poor physical condition of American youth and the growing rates of obesity in the population as a whole. In order to increase physical activity, they argue, communities must be designed to facilitate walking and bicycling (e.g., Frumkin 2002). Other proponents point to the damaging environmental consequences of automobile dependence or to the social inequity that results in communities with few transportation alternatives to the car (e.g., Nadis and MacKenzie 1993). Finally, a growing number of proponents point to the pernicious effects auto dependence has upon the social fabric of communities as reason enough to increase connectivity and otherwise redesign suburban development (e.g., Duany et al. 2000).

Yet the available empirical evidence on the impact of street connectivity on walking and bicycling is ambiguous. Few studies have focused on the street network specifically; instead, most have examined the link between travel behavior and a variety of neighborhood characteristics, including the street network, land-use patterns, and design characteristics. In addition, these studies have focused primarily on the question of whether neighborhood characteristics can reduce levels of automobile use rather than on whether neighborhood characteristics can increase walking and bicycling. This distinction is important: it is possible that neighborhood characteristics like street connectivity increase walking and bicycling without decreasing automobile use. In other words, street connectivity has the potential to generate additional trips in all modes.

Limited research, however, has not yet shown that this potential has been realized. Ewing and Cervero (2001, 100) conclude that “it is hard to say which modes gain relative advantage as networks become more grid-like, let alone to predict the impacts that this may have on travel decisions.” Other studies have found that rates of walking to retail areas are higher in traditional neighborhoods than in newer suburban neighborhoods, but the determining factor was distance to the store rather than the street network per se (Handy 1996; Handy and Clifton 2001). The interconnected networks found in traditional neighborhoods helped to reduce distances but did not guarantee that a store would be within walking distance, these researchers found. This finding points to the importance of land-use planning in conjunction with connectivity requirements.

PROVIDING GREATER EMERGENCY ACCESS AND IMPROVING SERVICE EFFICIENCY

Emergency medical service, trash collectors, police, and other municipal service providers have been strong supporters of greater connectivity. One issue in particular binds the group: the cul-de-sac. Dispatch practices for emergency services typically determine the order in which the vehicles arrive, but on cul-de-sacs, the first vehicle on the scene is blocked in by subsequent arrivals (West and Lowe 1997, 50). Trash collectors and police also find that the “doubling back” or “dead heading” that occurs on dead ends adds time and cost to their service. All service providers find discontinuous transportation networks difficult to navigate. Greater connectivity can help to improve the quality and efficiency of emergency and other municipal services.

While emergency providers like greater connectivity, they may not necessarily like the narrower street standards that may accompany it. In fact, minimum required street widths have crept up over time in part to accommodate larger emergency vehicles. As discussed in the next chapter, most cities that

Greater connectivity can help to improve the quality and efficiency of emergency and other municipal services. While emergency providers like greater connectivity, they may not necessarily like the narrower street standards that may accompany it.

have adopted connectivity ordinances have also changed their codes to enable or require narrower streets. To address concerns over narrower streets, Portland, Oregon, tested different street widths in older neighborhoods to determine the minimum width necessary to provide what they considered an acceptable level of accessibility for fire trucks, which was found to be 18 feet (Bray and Rhodes 1997). Also, the city's requirement of either two access points or short cul-de-sacs made the Portland Fire Department comfortable with narrower street standards. The guidelines for narrower streets published by the American Society of Civil Engineers, National Association of Home Builders, and the Urban Land Institute (ASCE et al. 1990) will likely encourage more cities to adopt narrower street standards, whether or not they adopt connectivity ordinances.

THE ROLE OF STREET WIDTHS

Street widths play an important role in the debate over street connectivity. As noted above and discussed in the following chapter, most cities that have adopted street connectivity ordinances have also reduced minimum required street widths and rights-of-way. The reasons for adopting these narrower standards are twofold: to improve the quality of life in the community and to reduce the potential cost of connectivity requirements for developers.

The traditional gridiron and the conventional curvilinear street pattern both have strengths and weaknesses. The best of both may be achievable through hybrid street patterns that provide greater connectivity but avoid clear, fast routes for non-local traffic to cut through residential neighborhoods.

The community potentially benefits in several ways from narrower street standards (Ewing 1996). Narrow streets tend to discourage through traffic by promoting slower speeds. By reducing speeds and reducing traffic, they may also increase the attractiveness of walking and bicycling. They likewise help to ensure that the connectivity standard does not increase impervious cover and its negative impacts on water quality and neighborhood aesthetics. As Jim West and Allen Lowe show,

> [a]n interconnected street system has the potential disadvantage of increasing impervious surface area. However, a trial application of the new standards to an existing subdivision showed an actual reduction in paved area. Although the linear feet of street increased, both street paving and sidewalk paving decreased, resulting in an overall decrease in impervious surface of 16 percent. (West and Lowe 1997, 49)

From the developer's standpoint, narrower street standards help to minimize the expense that will likely result from the increase in linear feet of street that a connectivity ordinance may necessitate. The amount of space devoted to streets is especially important to developers, both because street pavement costs them money and because street space does not produce revenues. Narrower streets may also ensure that the number of lots in a subdivision does not decline when a developer meets higher connectivity requirements. As discussed further in Chapter 4, narrower street standards may thus prove essential to the successful implementation of connectivity standards.

CONCLUSIONS

The traditional gridiron and the conventional curvilinear street pattern both have strengths and weaknesses. The best of both may be achievable through hybrid street patterns that provide greater connectivity but avoid clear, fast routes for non-local traffic to cut through residential neighborhoods (Ewing 1996). While much of the discussion of street layout seems to compare the extremes of strict gridirons versus pure cul-de-sac neighborhoods, it is important to remember that these two extremes are not the only choices. The cities and towns presented in this report emphasize connectivity without requiring strict adherence to a rigid, unwavering grid. All have provisions that allow cul-de-sacs where natural or built features prevent connections.

None prohibit streets from curving but instead, to varying degrees, encourage street patterns that avoid long, straight, uninterrupted routes that might invite cut-through traffic. The goal of these jurisdictions is to increase connectivity without significantly increasing through traffic in residential areas, and their provisions strive to achieve an appropriate balance between these competing objectives.

CHAPTER 3

Street Connectivity in Practice

This chapter examines the street connectivity measures adopted by a growing number of U.S. cities in recent years. The purpose of the case studies presented here is to understand every aspect of these measures, from preliminary studies to final impacts. The case studies therefore examine the context in which the connectivity standards were adopted, the criteria built into the standards and the important features of their application, the issues that arose during the development and implementation of the standards, and the performance of the standards in terms of their impacts on new developments in these communities. The case studies describe these facets of connectivity efforts for 12 cities in Oregon, Colorado, North Carolina, Delaware, and Florida. More detailed case studies of Raleigh, North Carolina, and Austin, Texas, are presented in Chapter 4.

These cities were identified through a snowball process that started with a posting on the Transportation for Livable Communities (TLC) listserve in May 1999. All communities identified through that process were included as case studies. Since the completion of the case studies, seven other communities with increased connectivity standards have been identified— Knoxville, Tennessee; McKinney and San Antonio, Texas; Hercules, California; Hillsborough County, Florida; and Concord and Davidson, North Carolina (Tracy 2003; White 2003a)—and it is likely that still more exist. The case studies presented here are based primarily on phone interviews with planning officials in 1999 and 2002. At the time of the first round of interviews, most of these cities were either in the process of implementing or had just adopted street connectivity ordinances. Most did not yet have examples of completed development projects that reflected their newly established connectivity criteria. The second round of interviews followed up on the experiences of these cities in adopting and implementing their connectivity ordinances. In addition to the interviews, the ordinances themselves and other relevant documents were reviewed, when available. Draft versions of the case studies were sent to the communities for their review, and about half responded.

Two approaches have been used most frequently to address the issue of connectivity in the cities studied: block length requirements and connectivity indexes.

Two approaches have been used most frequently to address the issue of connectivity in the cities studied: block length requirements and connectivity indexes. With a block length requirement, the city controls the spacing between local streets, thereby creating a relatively predictable and evenly distributed network of streets. A connectivity index is calculated as the number of street links divided by the number of nodes or link ends. The higher the number of links relative to nodes, the greater the connectivity. A third technique, the ratio of the travel distance via the network to the straight-line distance between points, has also been used as a performance measure. These techniques will be illustrated in the case studies that follow. Important differences in the definition and measurement of block length and connectivity are summarized at the end of the chapter.

In addition to choosing an approach to defining and measuring connectivity, communities must address issues about:

- increasing connectivity between residential areas and arterials;
- planning for future street connections through stub-out requirements;
- decreasing minimum street widths;
- promoting the use of traffic calming devices;
- restricting the use or length of cul-de-sacs;
- prohibiting gated communities;
- promoting pedestrian and bicycle connectivity;
- allowing for flexibility through performance standards and incentives;
- giving appropriate consideration to topography, floodplains, and dense drainage networks and to other factors that might limit connections; and
- establishing processes for the granting of variances and exceptions.

The communities studied here have addressed these issues in different ways and to differing degrees, although important similarities are also evident. The chapter concludes with a summary of both similarities and differences in the adoption of connectivity standards around the United States.

METRO, REGIONAL GOVERNMENT FOR THE PORTLAND, OREGON, AREA

In 1997 Metro established street connectivity standards for residential and mixed-use areas in its Urban Growth Management Functional Plan, which all local government units in and around Portland, Oregon, within Metro's jurisdiction must follow. Each community must adopt connectivity requirements but has some flexibility in designing them. The Functional Plan provides two options for complying with the connectivity requirements: a set of design requirements or a performance option (Metro 1997). The motivation for establishing street connectivity standards arose from a perceived need to reduce reliance on major arterial streets and to promote bike and pedestrian movement as well as transit options (Kloster 2002). Although its transportation responsibilities do not include local streets, Metro's conclusion that the configuration of local streets affects the performance of regional arterials prompted it to adopt these connectivity standards. The process of designing the standards was initiated by Metro with the cooperation of local governments.

Although its transportation responsibilities do not include local streets, Metro's conclusion that the configuration of local streets affects the performance of regional arterials prompted it to adopt these connectivity standards.

Criteria

The design option requires street connections (including connections with arterials) to be no more than 530 feet apart except where physical conditions make them impossible. Connections spaced at less than 330 feet are recommended for the highest-density, mixed-use areas. These spacings correspond to the optimal level of 10 to 16 connections per mile that Metro's study found most conducive to efficient connectivity, as described in Chapter 2. However, no connections are allowed within 400 feet of major intersections because long turning queues would interfere with the safe operation of nearby connections (Kloster 1999). Where street connections are impossible, accessways for pedestrians, cyclists, and/or emergency vehicles should be provided, if not prevented by physical conditions, with spacing of no more than 330 feet. The requirement also calls for cities and counties to prepare maps of potential future street connections necessary to meet Metro's connectivity standards. The design option also encourages direct routes for nonmotorists, narrower local streets (no wider than 28 feet of pavement), and increased connectivity in existing areas where possible. Finally, it restricts cul-de-sacs to 200 feet in length and allows their use only where street connections are impossible.

The performance option also requires local street spacings of 530 feet or less, but its remaining two requirements are performance based. One mandates that local traffic on each regional street may not exceed the 1995 median level for all regional streets by more than 25 percent. The other includes two parts linked to trip distances: (1) for motor vehicles, the shortest distance from any local origin over public streets to a street categorized as a collector or higher should not be more than twice the straight-line distance, and (2) for pedestrians, the distance should be no more than 1.5 times the straight-line distance. The performance criterion for pedestrian routes is thus stricter than for motor vehicle routes, reflecting the importance that Metro places on pedestrian connectivity.

These standards were only one part of a larger transportation component in Metro's Functional Plan, which implements the region's 2040 Growth Plan. As described in Chapter 2, Metro conducted a modeling study to determine optimal connectivity standards. The agency provided the performance option in response to local desires for such a measure, but, according to Tom Kloster, transportation planner for Metro, no jurisdiction has used this option because none (including Metro) has the data to assess whether localities are achieving the standard for traffic composition on arterials (Kloster 1999).

Metro measures connectivity by intersection spacing because that is the measure used in the 2040 Growth Plan. Kloster prefers intersection spacing to intersection density (e.g., intersections per square mile) because density measures could allow high intersection density in one part of a development but very low density in another part. This lack of uniformity would not provide as much benefit to alternative modes, which increase with more frequent intersections.

Metro made some changes to its connectivity requirements in early 2001 to address the issue of stream crossings in subdivisions (Kloster 2002). It is not uncommon to find fish-bearing streams and creeks running through existing or proposed subdivisions in Oregon. The presence of endangered species such as the native salmon and steelhead in some of these streams made it necessary for Metro to give special consideration to their connectivity standards at sensitive stream crossings. In response, Metro created new standards in its Green Streets program. That program provides guidelines for negotiating stream crossings responsibly through the use of bridges instead of box culverts and through separate spacing standards that vary between 800 and 1,200 feet for streets crossing streams. The Green Streets requirements also allow flexibility in the location of the stream crossings so that the most sensitive sections of the stream are left undisturbed while regular connections are provided at more urbanized sections of the stream.

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Issues

In most communities in the Portland region, adopting the ordinance was not as controversial as implementing it. According to Kloster (2002), elected officials in the area approve of the ordinance, but debates over its requirements have been contentious. One area of contention is the loss of saleable land due to the greater street area required in networks with greater connectivity. Even with narrow streets, developers may face a decrease in saleable land, although they may be able to create the same number of lots as they would with lower connectivity. Without narrow streets, the loss of saleable land is more significant. Kloster noted that the loss may not be as great as it might seem because lots around cul-de-sacs tend to be inefficiently sized in order to meet minimum frontage requirements.

Exceptions for environmental constraints and the required connections for pedestrians and bicycles where street connections are not feasible have also attracted controversy. The connections for alternative modes have been unpopular because local officials often believe that such connections promote crime and are unsafe for residents, although Kloster believes that proper design can alleviate these concerns. The Portland area has few gated communities, so there is almost no resistance to connectivity based on desires for gated access. Most streets in the region are public, although some in mixed-use areas are privately maintained though not obviously different or separated from the public streets.

Emergency service providers have been strong supporters of greater connectivity, but they have objected to the narrower street standards that may accompany it. (Metro's provisions allow for skinny streets but do not require them.) Narrower streets have also drawn some controversy because of the perception that they lead to higher accident rates. However, Kloster does not believe that any data support that contention; he argues instead that narrow streets decrease vehicle speeds and thus improve safety.

Controversy also arose over the requirement to prepare a map of future street connections. Some communities were concerned about possible changes in their neighborhoods in the future. Others opposed the provision of street stubs in their neighborhoods in the meantime. In a small number of cases, realtors misled prospective clients by passing off the stubs as cul-de-sacs. To avoid such problems, some city agencies started posting signs at street stubs, thus indicating to local residents that they should be prepared for the stub to be extended in the future (Kloster 2002).

Performance

According to Kloster (1999), the arterials that perform best in the Metro area are those in central Portland and to the east, areas with a grid pattern of streets. The least functional arterials are in the west, where conventional suburbs with curvilinear streets and cul-de-sacs are located. He attributes the difference in performance to the local street patterns. He also noted that Metro's study of connectivity showed that higher numbers of connections to arterials did not significantly affect the level of service on those arterials, contrary to common transportation engineering assumptions. Again, he pointed to the performance of arterials in the areas of Portland with rectilinear grids as empirical evidence of this conclusion.

The communities in the region have been fairly active in implementing connectivity standards in their new land development projects. In the last two years, nearly all new developments have adopted the connectivity standards (Kloster 2002). According to Kloster, the best examples were those projects that previously had no connections from the subdivisions to arterials. In several such cases, implementing Metro's bike/pedestrian spacing requirements helped to create accessways to transit locations that are located at the intersections of the bike/pedestrian routes and major streets.

Kloster attributes the general acceptance of Metro's connectivity standards to their consistent application across the region. In his words,

> Having a regional government has been an advantage in that Metro's rules apply uniformly to all jurisdictions in the region, and thus all the local jurisdictions had to adopt the connectivity standards. If some cities adopted the standards while others did not, then cities that adopted the standards would have been anxious that they would lose their economic base to their less restrictive neighbors. (Kloster 2002)

Kloster also emphasizes the importance of having good data on the benefits of increased street connectivity to popularize the concept. Metro's technical analysis and connectivity modeling was based on case studies of communities around the region. Using these case studies, Metro officials were able to demonstrate that increased street connectivity reduced the amount of local traffic on local streets and that longer-trip traffic primarily used the major streets. The modeling also provided the basis for establishing the spacing standards so as to maximize the benefits but minimize the downsides of increased connectivity.

Kloster attributes the general acceptance of Metro's connectivity standards to their consistent application across the region. . . . He also emphasizes the importance of having good data on the benefits of increased street connectivity to popularize the concept.

PORTLAND, OREGON

In 1998, Portland, Oregon, began the process of updating the city's code to comply with Metro's Functional Plan and to simplify the city's existing connectivity requirements (Portland 1998). Although Metro's requirements provided the impetus for this effort, the city already strongly supported the goal of increased connectivity, as evidenced throughout the city's transportation planning efforts. The Portland Transportation System Plan (TSP), adopted in October 2002, includes a policy on connectivity to "support development of an interconnected, multimodal transportation system to serve mixed-use areas, residential neighborhoods, and other activity centers" (Portland 2002a, 2-28). The TSP argues that street connectivity improves arterial street system capacity, enhances mode choice, improves emergency response times, reduces traffic volumes on other streets by spreading traffic over a denser network, and results in slower traffic speeds because of the increased number of intersections (p. 11-1). After a lengthy process in which several drafts were considered, the city council adopted the final requirements in December 2002.

Criteria

The purpose of the connectivity requirements, as specified by the city's planning and zoning code, is to "ensure provision of efficient access to as many lots as possible, and enhance direct movement by pedestrians, bicycles, and motor vehicles between destinations." Through streets and pedestrian connections in open space, residential, commercial, and employment and industrial zones are required "where appropriate and practicable." Rather than establishing a specific maximum for the spacing of through streets, the code also suggests that "through streets should generally be provided no more than 530 feet apart, and pedestrian connections should generally be provided no more than 330 feet apart" (Portland 2002b, 654-1). In addition, the connections should take into account the street network in the surrounding area, characteristics of the site such as terrain, and the directness of pedestrian connections.

The purpose of the connectivity requirements, as specified by the city's planning and zoning code, is to "ensure provision of efficient access to as many lots as possible, and enhance direct movement by pedestrians, bicycles, and motor vehicles between destinations."

Decisions about the connections required in a particular development are also shaped by master street plans and by the city engineer. Adopted for many areas of Portland through the TSP and incorporated into its comprehensive plan, master street plans show street and pedestrian/bicycle connections at both the conceptual level and at a more precise level where possible (Duke 2003). The code specifies that master street plans be considered before the approval of any proposed connections. In addition, when it adopted the TSP the city council also expanded the authority of the city engineer to include the authority to require public streets and pedestrian/bicycle connections at the same spacing through large sites that are not subdivided, such as a shopping center or a university campus (Duke 2003).

The code does not establish minimum street widths but instead states that "the width of the local right-of-way must be sufficient to accommodate expected users, taking into consideration the characteristics of the site and vicinity, such as the existing street and pedestrian system improvements, existing structures, and natural features" (p. 654-3). The width of right-of-way for pedestrian connections must also "be sufficient to accommodate expected users and provide a safe environment" (p. 654-4). Dead-end streets are allowed where through streets are not required, according to the code, but may not be longer than 200 feet. The code also encourages public streets but allows private streets and gated developments; nonconnected streets and alleys may be private.

This ordinance provides an unusual degree of flexibility for the planning staff, although staff tries to avoid variances to the recommended standards. The staff makes initial judgments about whether connections are necessary and adequate based on an analysis of the features of the surrounding natural or built environment that might prevent or discourage connections. Because of the code's flexibility, staff can consider features such as steep slopes, ravines, railroads or freeways, existing lot patterns, and environmental protection areas in determining necessary connections. The city has formalized a process by which developers have the opportunity to appeal the decision of a hearings officer to the city council (Duke 2002).

Issues

Portland already had requirements for through streets before the rewrite effort, and much of the city is already built out on a connected system of streets (Duke 1999). The fact that most current development in the city is infill raises different issues than if the development were mainly subdivisions in new areas. For example, most of the subdivisions in the city are very small—three to four lots—so the city must consider the extent to which such a small subdivision can contribute to the construction of a public street. In addition, these subdivisions raise the question of how much increased traffic infill brings to surrounding neighborhoods.

The city did not face any opposition in adopting its new connectivity standards. Since these standards were codified only recently, the city does not have many examples of projects to which the standards have been applied, but so far developers have generally met them (Duke 2003).

BEAVERTON, OREGON

Several forces together led to the adoption of connectivity standards in Beaverton, Oregon, in 1998. The most obvious and direct incentive was Metro's required connectivity requirement, but other factors contributed as well. The traditional neighborhood design movement was one while another was the city's desire to give residents more transportation choices in order to avoid local arterials. Beaverton's Draft Comprehensive Plan Amendments cite a "lack of local street system connectivity" as one reason for the poor performance forecast for some of the city's arterials (Beaverton 1998b). The regional urban growth boundary, in place since 1979, provided yet another incentive as the city struggled to determine how to accommodate its projected future growth within that boundary. Also, in advance of the construction of two light rail stations, the city completed a study of its downtown to determine how it could enhance its grid to improve the accessibility of these stations.

Criteria

Beaverton, a suburb of Portland located within Metro's jurisdiction, drafted connectivity requirements in 1998 that closely followed those established by Metro. The requirements have since been incorporated into the city's development code (Middleton 2002). With exceptions for physical constraints, Beaverton's code requires that, "in new residential, commercial, and mixed-use development, local street connections shall be spaced at intervals of no more than 530 feet" (Beaverton 1998a). In addition, the code specifies that "local street connections at intervals of no more than 330 feet shall be considered in areas planned for the highest density of mixed-use development" (Beaverton 1998a).

The code specifically requires connections to collector streets at spacings between 220 and 440 feet and connections to arterials at intervals of 660 to 1,000 feet. Street stubs are required where development is likely to occur in the future on neighboring properties, and the city keeps an updated inventory of those stubs (Middleton 1999). In addition, the city's comprehensive plan includes a map of recommended street connections. Where full connections are not possible, the code requires connections for pedestrians, bicycles, and/or emergency vehicles at intervals of no more than 330 feet, except where physical conditions make such connections impossible. Short and direct routes for pedestrians and bicyclists to neighborhood services are encouraged.

Cul-de-sacs are allowed when connections are impossible. According to the ordinance, "[a] cul-de-sac design may be used when there is no opportunity for connection to another public street due to development or topographic constraints" (Beaverton 1998a). Cul-de-sacs must be as short as possible and no more than 200 feet long. The code requires streets and rights-of-way to be public, but it provides a waiver mechanism where developments will not significantly affect off-site traffic flow. Gated streets are not allowed (Middleton 1999). The code also establishes narrowed street standards, with a minimum width for "infill through streets" of 25 feet (paved) in a 42-foot right-of-way, as long as traffic does not exceed 200 vehicles per day at build-out. These narrower standards respond to the fact that Beaverton is nearly built out and that site constraints often necessitate narrower streets (Middleton 2003). Parking is allowed on one side. In general, "traffic calming may be required in a design of the proposed street through the development review process" (Beaverton 1998a).

Cut-through traffic has been a major issue of concern. The city responded with a traffic calming program, which includes criteria for determining the eligibility of streets and selecting an appropriate calming plan.

Although the city allows exceptions to the connectivity requirements, they rarely grant them. According to Margaret Middleton, a senior transportation planner for the city, a proposed development application must include a detailed analysis of whether specific connections identified and recommended in the city's comprehensive plan and otherwise necessary to meet the connectivity requirements can be accommodated (Middleton 2003). The application must include a recommendation on whether the connection can be made and whether it should be a multimodal connection or a bicycle/pedestrian-only connection. This analysis provides important information for city staff and the development review committee. "Staff coordinates closely with the applicant and negotiations can take place during application review and staff report development," Middleton said. If the staff recommendation is appealed, it is forwarded to the planning commission, whose decision on the recommendation and conditions of approval are then sent to the city council; without an appeal the board of design review makes the final decision. "Because of the extensive work that goes into the development of the comprehensive plan," she added, "the city does not often eliminate planned connections."

Issues

According to Middleton (1999), developers have not been particularly upset by Beaverton's connectivity requirements. She attributes their low-key reaction to the fact that they are bound by state law and Metro's requirement, which presumably developers recognize as beyond the city's control. In addition, the city gave a committee of developers the opportunity to review and comment on a draft of the requirements.

Cut-through traffic has been a major issue of concern. The city responded with a traffic calming program, which includes criteria for determining the eligibility of streets and selecting an appropriate calming plan. For one new connection, the city installed speed humps at the same time as the connection. Middleton believes that the city's narrower street standards also help address this issue (Middleton 1999).

Performance

In general, the city's connectivity requirements have been reasonably effective and well followed by local developers (Gustafson 2002). The city staff interacts with local developers and residents at neighborhood meetings and other similar forums. By doing so, staff learns the concerns of the neighborhood residents and educates local residents about connectivity issues. As Middleton (2002) put it, "A lot of it is education. [Residents] need to know that fewer people will be cutting through their neighborhoods if they have more streets to travel on."

EUGENE, OREGON

In Eugene, Oregon, the Local Street Plan provides a detailed rationale for its connectivity requirements and for the city's restriction on private streets (Eugene 1996b). Primary motivations are improved emergency access and

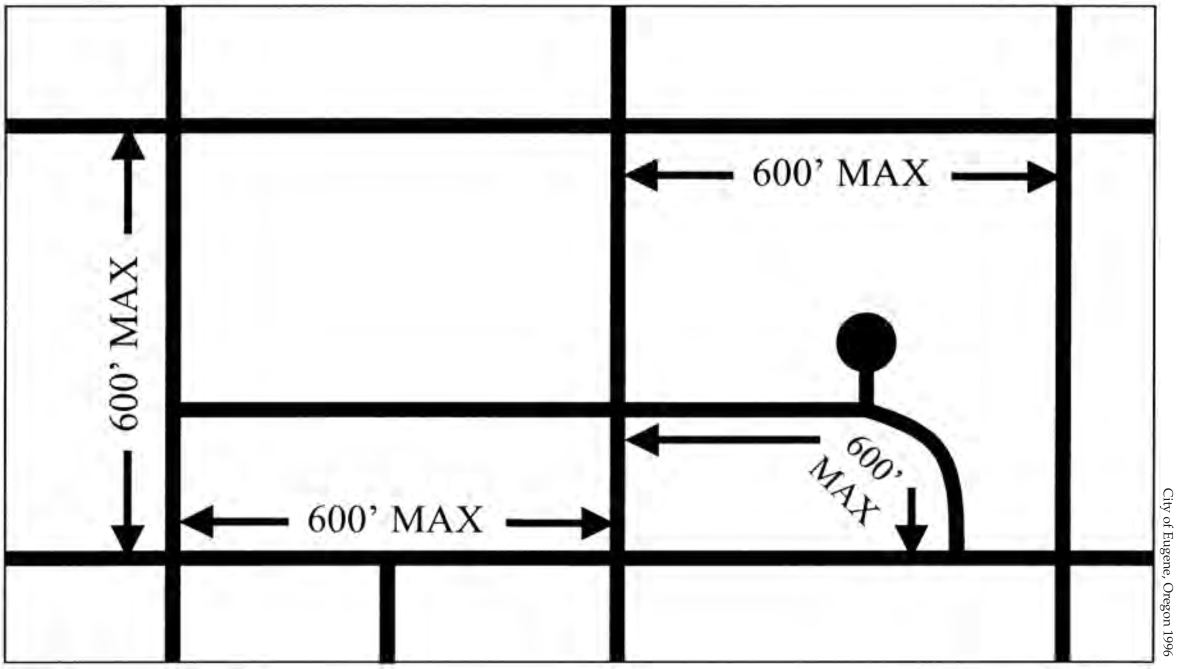


Figure 3.1. Definition of Block Length Requirements in Eugene, Oregon (defined as the distance along a street between the centerline of two intersecting through streets, including "T" intersections, but excluding cul-de-sacs).

response times, lower utility distribution costs, increased utility interconnections (for back-up), and more efficient mass transit service. The plan also cites increased personal travel options, reduced trip lengths, more evenly distributed traffic, and decreased use of arterials and collectors for local trips. Lack of connections between residential areas was one reason for the plan's sharp restrictions on private streets; other motivating concerns include inadequate design for safety and drainage, inadequate emergency vehicle access, and conflicts where public easements and private streets coincide.

Allen Lowe, the planner who guided the development of the Local Street Plan, said that the city addressed the issue of connectivity in the context of addressing a number of "smoldering problems" with streets, including speeding and poorly designed private streets (Lowe 1999; West and Lowe 1997). In addition, Oregon's Transportation Planning Rule requires cities to address fragmentation and connectivity in the transportation system, but the impetus to address the connectivity issue mainly came from the planning staff. When staff brought up the issue of connectivity, there was little public interest because the public was heavily focused on other street issues. Developers likewise showed little interest in the connectivity issue (Lowe 1999).

Oregon's Transportation Planning Rule requires cities to address fragmentation and connectivity in the transportation system, but the impetus to address the connectivity issue mainly came from the planning staff.

Criteria

Eugene's ordinance requires connectivity in all residential developments over one-half acre (Eugene 1996a). Block lengths must be no more than 600 feet, and exceptions may occur only if physical conditions or adjacent development (including subdivided but vacant property) prevent connections (Figure 3.1). Block length requirements apply only to local streets. The code is silent on the issue of intersection spacing on arterials, although Eugene's Draft Arterial and Collector Street Plan calls for eight to 12 pedestrian or street connections per mile where fencing separates buildings from the street for more than 600 feet (Lowe 1999; Eugene 1998). Blocks are defined by intersections with through streets, as illustrated in Figure 3.1.

According to the ordinance, "A public street connection shall be provided to any existing or approved public street or right-of-way stub abutting the development" unless physical conditions or neighboring developments make it impossible (Eugene 1996a).

Street stubs are also required to provide for future connections to neighboring, developable property. Instead of a strict grid, the code requires that the street layout suit the local topography and other physical attributes. The code allows narrower local street widths, ranging from 20 to 34 feet. Private streets are not permitted unless "the developer can demonstrate that a public street or alley is not necessary for compliance." In all cases, "secondary access for emergency fire and medical vehicles shall be required" (Eugene 1996a). Cul-de-sacs may be no longer than 400 feet. Gates are allowed only for very small enclaves of six or fewer houses, and since the city made that restriction, no development has used gates (Lowe 1999). Developments must have plans demonstrating connectivity for pedestrians, especially where cul-de-sacs are allowed. The conditions for exceptions are relatively strict:

Street stubs are also required to provide for future connections to neighboring, developable property. Instead of a strict grid, the code requires that the street layout suit the local topography and other physical attributes.

> Exceptions to the connectivity requirements are allowed if natural or human features prevent connections. Connections are required . . . unless it is demonstrated that a connection cannot be made because of one or more of the following conditions:
>
> a. Physical conditions that preclude development of a public street. Such conditions may include, but are not limited to, topography or the existence of natural resource areas such as wetlands, ponds, streams, channels, rivers, lakes or upland wildlife habitat area[s], or a resource on the National Wetland Inventory or under protection by state or federal law.
>
> b. Buildings or other existing development on adjacent lands, including previously subdivided but vacant lots or parcels, that physically preclude a connection now or in the future, considering the potential for redevelopment. (Eugene 1996a)

The code includes a provision that allows developers to prepare and present an alternative means of meeting the intent of the street connectivity requirements other than the block length requirement. The plan must not only meet the connectivity needs of the immediate development but also the needs of adjoining properties. This section is mainly used for small developments in which connections could be made but where equal or greater benefit would come from connections through adjacent developable land. The description in the code of the purpose and intent of the requirements is helpful in making decisions under this section (Kulby 1999). The planning director makes the final decision on whether exceptions or alternative plans will be allowed (Lowe 1999; Kulby 1999). Subdivision approvals always have a hearing before a hearings officer; the planning commission is involved only if a developer appeals the planning director's decision.

Kent Kulby (1999), a planner in the city's subdivision review section, said the staff is very strict about enforcing the connectivity requirements, so few exceptions are allowed. In one case, a developer could not meet the standards in his own development because of steep topography and a wetland, so in order to meet the standards, he had to build an off-site connection (for which the city already owned the right-of-way). Obstacles to connections must be on-site; the staff does not allow exceptions to the requirement for street stubs for topography on adjacent properties if there is any potential for those properties to develop. The future developers of those sites will have the responsibility of showing that they cannot complete those connections (Kulby 1999). To help address the concerns of developers, the city also adopted a skinny streets policy, which set 28 feet as the standard width; streets can be even narrower in some situations.

Issues

When the city first began implementing the connectivity requirements, developers "did not get it," Lowe (1999) said, but now they comply without much enforcement from the staff. Kulby (1999) reported that most objections are made by developers building higher-end, large-lot subdivisions who do not want to connect to existing, less expensive, smaller lot neighborhoods. Lowe has not heard any problems with selling houses on streets built with the new connectivity standards. The city's policy on skinny streets also helped reduce some of the cost for developers.

For the public, however, the issue has become "a nightmare" where infill development is occurring (Lowe 1999). New areas cause no problem, but the infill areas result in new connections on streets that formerly were dead-ends. Many residents on dead-end streets did not realize that they lived on street stubs rather than on cul-de-sacs, and they are outraged by traffic increases that, though usually very small in absolute numbers, may be large in percentage terms. The city has won two court challenges on the issue of connecting previously unconnected streets via infill, and the planning commission and city council are upholding the requirements. Nonetheless, the issue is politically difficult.

The city has won two court challenges on the issue of connecting previously unconnected streets via infill, and the planning commission and city council are upholding the requirements. Nonetheless, the issue is politically difficult.

The city also had considerable difficulty working with the county in a particular unincorporated area adjacent to the city. The county is not interested in dealing with these street issues, according to the city's planners, and because many of the 30,000 residents in the area consider themselves to be living in a rural community, they do not want features that they perceive as urban, including street connectivity. Since the area is growing rapidly and the city periodically extends its boundaries through annexation, the controversy presents a major difficulty for the city.

Performance

According to Kulby, the Local Street Plan has been successful in forcing developers to make connections (Kulby 1999). Before the plan, in other words, planning staff had to perform a Dolan test for each development to demonstrate that the connections were in the public interest. The justification presented in the plan that connections are in the public interest now allows the city to forego this procedure. Connectivity has become "a bedrock principle" in the planning department (Lowe 1999).

The plan also addresses cut-through traffic and impervious cover, two potential problems associated with greater connectivity. The plan recommends the use of "three-way or 'T' intersections, 'dog leg' alignments, parks, and other community facilities to discourage use of the streets by nonlocal traffic" (Eugene 1996b). The plan also mentions traffic calming devices as additional means to discourage cut-through traffic. To test whether impervious cover would increase, city staff applied the connectivity and street-width standards contained in the 1995 Draft Plan to an existing subdivision. The analysis showed that these standards actually decreased the amount of impervious cover. "Although linear feet of street increased, both street paving and sidewalk paving decreased, resulting in an overall decrease in impervious surface of 16 percent" (West and Lowe 1997, 49).

The planning staff believes that connectivity will reduce traffic on the arterials as well as provide benefits for utilities and emergency services. In fact, the fire department was a strong supporter of connectivity requirements, although the department was somewhat uncomfortable with street-width issues. In response, the city kept the standard local street width at 28 feet rather than narrowing it to 26 feet. In addition, after a situation where the city placed speed humps on a fire response route, causing slower responses and maintenance problems for the fire trucks, planners worked with the fire department to designate primary fire response routes and to avoid placing traffic calming devices, other than friction devices, on those routes. The fire department then agreed that more intrusive calming devices (i.e., vertical displacements, like speed humps) could be placed on local streets.

Principal Planner Jerry Jacobson's favorite connectivity example is a project in Eugene, where a developer built a subdivision on a large vacant lot abutting an older subdivision (Jacobson 2002). City standards required the developer to provide a street connection between the two developments. The residents of the older subdivision opposed the new connection, which they thought would cause cut-through traffic from the new subdivision. They even appealed to Oregon's Land Use Board of Appeals (LUBA) to change the plan. (LUBA is a state hearings board in Oregon that hears all land-use appeals in local jurisdictions that have exhausted all local remedies.) Their appeal was rejected, however, and the connection was built. The new subdivision lies between the older subdivision and a neighborhood commercial center, which residents had accessed previously by a circuitous route. After the new subdivision was built, the residents of the older neighborhood started using the new street connection to cut through the new subdivision to access the commercial center. Thus the residents of the older neighborhood also benefited from the shorter alternative route.

To educate residents, staff went to public forums across the city where they presented their plans. . . . The public education process lasted nearly two years, but it was well worth the time and effort.

—Jerry Jacobson
Principal Planner
Eugene, Colorado

While Eugene's Planning Council was satisfied with the connectivity standards from the onset, staff perceived much opposition from local residents (Jacobson 2002). In many instances, they found that the public's resistance to the standards stemmed from not knowing enough about connectivity and its ramifications. To educate residents, staff went to public forums across the city where they presented their plans. Local residents also attended the public hearings at which the city staff presented their plans to the planning council. The public education process lasted nearly two years, but Jacobson says it was well worth the time and effort.

With time, both developers and residents in Eugene have shown a growing acceptance of the connectivity standards. The developers are now accustomed to applying the standards; local residents also see the dispersal of formerly congested traffic, and "hence there is far less resistance to the connectivity standards in recent times" (Jacobson 2002). Jacobson argues that "selling" the concept of connectivity by articulating its benefits to the community is far more effective than "shoving the concepts down people's throats." He warns communities that are currently implementing connectivity standards that the concept may not find immediate popularity in the community, but he suggests that local support can be best gained through dialogue between city staff and citizens. By doing so, the city can learn more about residents' concerns and expectations while residents better understand the city's goals. Through listening to residents, he has found, city staff also gains opportunities to address local concerns and to generate more acceptable solutions for all concerned.

FORT COLLINS, COLORADO

Fort Collins, Colorado, rewrote its land-use code to conform to its new comprehensive plan in 1999. The new comprehensive plan was revised to reverse trends toward disconnected suburban development served by a winding street system that was dominated by cul-de-sacs (Mapes 2002). During the comprehensive plan process, the city's planning department undertook a public visioning process with citizens, council members, and project consultant Peter Calthorpe. During this process, residents decided they want Fort Collins to be a city rather than a suburb. As a result, the revised code implements their vision of a walkable city with frequent, direct connections that provide multiple choices to pedestrians, bicyclists, and motorists. The vision includes neighborhoods that are "knitted together," without barriers to traveling between them.

Criteria

The city uses a unique three-pronged approach to ensure connectivity by limiting the size of blocks, establishing maximum intervals between local and collector connections to arterials, and requiring specific traffic shed patterns in new developments. The code defines block size as a maximum number of acres, from seven to 12 acres depending on the zoning of the parcel. Natural or built features, such as a railroad, may form up to two sides of a block, but in general blocks are defined by surrounding streets (Fort Collins 1999). The code requires full-movement intersections every 1,320 feet (i.e., one-quarter mile) along arterial streets and limited-movement intersections every 660 feet between full-movement collector or local street intersections. Developers must complete street connections shown in the comprehensive plan, and they must connect to or build street stubs to adjacent property. A development must shed traffic to at least three arterials in three directions within a surrounding square-mile area, and in city neighborhoods it must provide a pedestrian connection at least every 700 feet.

Fort Collins uses a unique three-pronged approach to ensure connectivity by limiting the size of blocks, establishing maximum intervals between local and collector connections to arterials, and requiring specific traffic shed patterns in new developments.

Exceptions to the requirements are allowed if connections are "rendered infeasible due to unusual topographic features, existing development, or a natural area or feature" (Fort Collins 1999). Planning staff decides whether to allow exceptions; that decision is included in its report on the development plan submitted to the Planning and Zoning Board for review and approval (Mapes 1999). In addition, a developer may submit an alternative plan to modify the code in order to use a different street layout that meets the intent of the connectivity section as well as the city's requirements; however, no one has used this provision yet. The decision maker for the project would decide whether the alternative plan is acceptable. (Fort Collins has different decision processes with different decision makers, either the planning director or the Planning and Zoning Board, depending on the type of project and decisions to be made.)

The city prohibits gated communities, but it allows cul-de-sacs, provided that any development with cul-de-sacs still meets all other connectivity requirements. The city's requirement that all streets over 660 feet have two outlets limits the length of cul-de-sacs. Only non-through streets may be private. The city reduced local street widths to 24–36 feet in conjunction with the other street changes (Mapes 1999). Use of the narrowest standard is limited to short block lengths and low daily traffic volumes.

Issues

Developers expressed some concerns but did not vehemently oppose the connectivity standards. One developer concern was that the market alone should dictate development. Some developers also suggested that connectivity is only important for pedestrians and bicyclists and that street connections are not necessary. The city council decided to provide a variance process for developers to propose alternative ways of meeting the intent of the code, but otherwise they stuck to their vision for the city and did not make any significant changes in response to developers' concerns. Cost has not been a major concern, possibly because it is marginal relative to the overall costs of new houses.

Fort Collins's fire department supported the connectivity requirements, and no other city departments opposed them. The fire department believed that an interconnected street system would be easier and faster to navigate than current layouts, where they occasionally have had trouble finding addresses on circuitous streets. Although the police department did not openly express support, the planning staff believes street connectivity will assist them as well.

The fire department believed that an interconnected street system would be easier and faster to navigate than current layouts, where they occasionally have had trouble finding addresses on circuitous streets.

The planning department has encountered some difficulty in implementing the street stub requirements of the code, largely caused by adjacent property owners who will not cooperate. In these cases, the neighboring property is usually a farm, and the owners resist the implication that their property will be developed. In addition, the city's requirement of two connections for streets more than 660 feet long has in some cases delayed a project until the developer can obtain an easement over the neighboring property.

Performance

Since the connectivity plan was introduced in 1999, several new housing and mixed-use projects have been built using the plan as the starting point. Clark Mapes, a planner with Fort Collins, says that the street networks are one of the best features of these new developments. In some projects, intersecting streets form spaces for compact parks, which are more visually pleasing than the leftover open spaces that tend to occur in conventional subdivisions (Mapes 2002). The city has had more success in implementing the standards in new subdivisions than with infill projects.

BOULDER, COLORADO

Boulder, Colorado, adopted a new transportation master plan in 1996. A main goal of the plan was to connect neighborhoods both internally and externally. The city initiated the process of adopting connectivity standards so as to reduce pressure on the arterial system, achieve a better sense of community, and encourage alternate modes of transportation, including bike and pedestrian activity (Durian 2002).

Criteria

Most of Boulder's development now is infill, so the city has not found it necessary to codify a requirement for street spacing, although city staff tries to space local streets 300 to 350 feet apart (Hinkelman 1999). The city allows cul-de-sacs but discourages them in favor of loops. Cul-de-sacs may be unavoidable in some infill situations, but they may not be longer than 600 feet without secondary emergency access. Private streets are not allowed, except for drives serving no more than three single-family houses. Gated streets, likewise, are not allowed.

Issues

The city's connectivity efforts encountered no major objections from developers or citizens, although, as in Eugene, some residents were opposed to connecting existing neighborhoods to new development (Hinkelman 1999). One of the incentives for the city's efforts was improved emergency access. To satisfy residents opposed to new connections to existing neighborhoods, the city shifted its focus in these areas from full streets to pedestrian and bicycle connections, which were popular with the residents.

Although connectivity has not occurred in infill development as staff had hoped, their efforts work well in new development on the northern edge of Boulder. The North Boulder Subcommunity Plan, which was created for this fast-developing area of the city, identifies all streets with future connections and other desirable connectivity features in that area (Durian 2002). Developers have not had a problem with the connectivity initiatives, and the new developments sell very well in Boulder's strong housing market.

Cut-through traffic has been an issue in Boulder in the past. Individual property owners often oppose the replacement of an existing cul-de-sac with a through street because they see it as danger to their children. According to Transportation Engineer Steve Durian, "It becomes a conflict of property owner interest versus public interest. We find it challenging to explain to the private owner in such cases that we have to look out for the community goals and interest" (Durian 2002). The city has focused on site design to discourage cut-through traffic. In addition, the city allows narrower streets—as narrow as 20 feet in some situations—in less dense neighborhoods, which helps to slow traffic (Hinkelman 1999).

Durian believes that it is essential to educate the local community and local leaders about the benefits of street connectivity. In communities considering connectivity requirements, he recommends that local planning board and council members be made aware of the benefits of street connectivity since they make the final decisions on planning developments. Additionally, Durian stresses the need for strong local leadership that is not swayed by pressure from individual special interests on decisions about projects that do not meet the city's goals for street connectivity (Durian 2002).

"It becomes a conflict of property owner interest versus public interest. We find it challenging to explain to the private owner in such cases that we have to look out for the community goals and interest."

—Steve Durian
Transportation Engineer
Boulder, Colorado

CARY, NORTH CAROLINA

Cary, North Carolina, first adopted a connectivity ordinance in 1999 as a way of meeting the goal of the town's growth management plan: to "improve vehicular circulation in residential and non-residential subdivisions" (Parajon 1999a). In addition to establishing connectivity requirements, the city also wanted to control the use of cul-de-sacs and require the provision of street stubs to adjoining properties. According to the ordinance, the purpose of these requirements is to

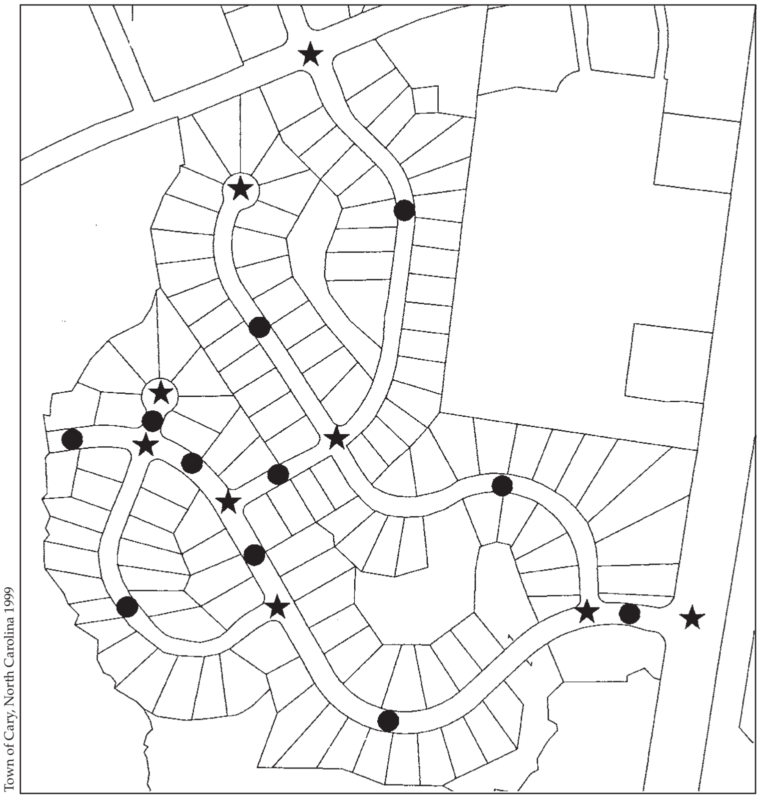
> support the creation of a highly connected transportation system within the Town in order to provide choices for drivers, bicyclists, and pedestrians; promote walking and cycling; connect neighborhoods to each other and to local destinations such as schools, parks, and shopping centers; reduce vehicle miles of travel and travel times; improve air quality; reduce emergency response times; increase effectiveness of municipal service deliver; and free up arterial capacity to better serve regional long distance travel needs. (Cary 2003)

The town's land development ordinance, adopted in 2003 as an update of its unified development code, did not change the original connectivity requirements.

Criteria

Cary has taken a different approach to requiring connectivity than the other communities discussed above: it uses a connectivity index. The index is calculated by dividing the number of street links (street sections between intersections, including cul-de-sacs) by the number of street nodes (intersections and cul-de-sacs); the calculation, illustrated in Figure 3.2, does not include existing adjacent streets (Cary 1999). The town's ordinance requires an index value of at least 1.2. The ordinance also requires connections to compatible adjacent uses spaced no more than 1,250 to 1,500 feet apart for each direction, a requirement that ensures a minimum level of external connectivity. The town limits cul-de-sacs to 900 feet, somewhat less than

Figure 3.2. Calculation of Connectivity Index in Cary, North Carolina.



Town of Cary, North Carolina 1999

● Links – 11
★ Nodes – 9
Connectivity Index = 11/9 = 1.22

its prior limit of 1,000 feet. Private streets are allowed, but gated streets are not. The required width of a typical local street is 27 feet.

The standards may be waived if meeting them is "impractical due to topography and/or natural features," but in those cases pedestrian connections are required between cul-de-sacs (Cary 1999). The city works with the developer to make changes necessary to meet the requirements, but the planning director can waive the requirements if the developer can document why the requirements cannot be met. If the staff and the developer cannot agree, they turn the matter over to the planning commission. If the commission waives the index, the developer must provide pedestrian connections to all of the cul-de-sacs in the project. Although the connectivity index is too new to have a long record, other waivers are rare in Cary; only about one in 15 plans needs a waiver of some sort.

Cary, North Carolina, chose to use a connectivity index in order to give developers the flexibility to respond to site-specific issues arising from the topography of the surrounding natural and built environment.

The city chose to use a connectivity index in order to give developers the flexibility to respond to site-specific issues arising from the topography of the surrounding natural and built environment. Planning staff members recommended the index value of 1.2 as a compromise between what they thought would provide maximum connectivity benefits and what they thought was politically feasible. They originally wanted an index of 1.5, but because most of the city's 85,000 residents live on cul-de-sacs, the staff decided that an index of 1.2 was more realistic. Likewise, staff analysis found that the index values of 20 existing or approved subdivisions in Cary averaged 1.0, within a range from 0.8 to 1.8 (Parajon 1999a). The city has also considered adding a second phase to the ordinance that would establish incentives for exceeding the connectivity requirement, such as a reduction in transportation development fees.

Issues

The town's fire and public works departments supported the higher connectivity standard. The deputy fire marshal supported further restrictions on cul-de-sacs due to concern about the fire department's ability to access them in emergencies (Parajon 1999a). The public works department raised several operational and maintenance issues about cul-de-sacs. The water distribution system provides poor quality water to cul-de-sacs because the system usually dead-ends on these streets, creating stagnant water in the pipes. In a memo, the department states that "about 90 percent of all our water quality trouble calls come from cul-de-sacs and dead-end streets" (Parajon 1999a). The department pointed out that because these dead-end systems are not looped, damage to the water lines might cause serious interruptions of service. Furthermore, repairing water lines on these streets may necessitate closing off the cul-de-sacs, inconveniencing residents and potentially hampering emergency access. The department also noted that solid waste collection and snow removal are inefficient on these streets.

Planning Manager Jim Parajon (1999b) found that the benefits from connectivity for trash collection, utilities, emergency response times, and transportation were fairly compelling. Several years earlier, a hurricane had knocked down many trees, blocking access to a number of cul-de-sacs. That experience helped residents understand the benefits of connectivity. Parajon also mentioned that the need to travel on arterials in areas with low connectivity increases travel distances and times. To educate residents, the city's planning department used examples at public meetings of high-connectivity neighborhoods already considered by most residents to be desirable places to live.

The proposal met almost no opposition. When staff presented the proposal to the city council, one member objected to the possibility of cut-through traffic, but staff emphasized that the requirements sought to make local trips more efficient, not through-traffic. City council approved the measures with little resistance, although Parajon (1999b) noted that other local issues distracted attention from the connectivity issue at the time.

The new subdivision designs allow greater efficiency in delivery of services and more interaction among residents. Applying cross-access standards in commercial l and use has helped to reduce curb cuts and thus to improve the efficiency and safety of arterial systems.

Performance

Implementing the standards has helped Cary optimize the existing infrastructure and prepare for future growth. Parajon (2002) said that developers now adhere to the connectivity standards as they would a parking or setback standard. The new subdivision designs allow greater efficiency in delivery of services and more interaction among residents. Applying cross-access standards in commercial land use has helped to reduce curb cuts and thus to improve the efficiency and safety of arterial systems, he said. The street stub requirements also enable easy access to future subdivisions. "We are a growing community," Parajon said, "and if we do not provide for such future growth, there is no way we can sustain it."

Parajon believes that city planners should try to quantify the benefits of street connectivity in order to make the standards acceptable to their citizens and leaders. For instance, Cary's planning staff was able to demonstrate that the costs of solid waste management in well-connected subdivisions were 20 percent lower than in poorly connected subdivisions. He suggests that planning professionals should change their argument "from just saying that street connectivity is something planners recommend or want to promote it in terms that decision makers will understand" (Parajon 2002).

According to Parajon, the existing connectivity index of 1.2 has a significant impact on local street networks but not on the major arterials. The city is hoping to update the ordinance in the near future by increasing the connectivity index from 1.2 to 1.4 in order "to utilize the existing local system better without having to widen the major arterials into six-lane roads to accommodate the traffic" (Parajon 2002).

HUNTERSVILLE, NORTH CAROLINA

Huntersville, a rapidly growing town on the north side of Charlotte, North Carolina, adopted a comprehensive new development ordinance based on neotraditional design principles in 1996. The town's connectivity requirements are just one element of the extensive changes made. Stuart Mullen, land development coordinator for the town, called Huntersville's approach "intent-oriented," one that maintains flexibility so that individual projects can be tailored to site-specific characteristics (Mullen 1999).

The town's ordinance grew out of concern beginning in the late 1980s about the rapid growth of the town and the potential loss of its character (Mullen 1999). The primary motive for the connectivity requirements was concern about traffic levels on arterial and collector streets. Huntersville began the process of developing its ordinance in 1995, when it enacted a 12-month growth moratorium. During that year, the town used an intensive public input process and established a 22-member committee to develop its ordinance. The effort culminated in adoption of the ordinance in November 1996.

According to the code, cul-de-sacs "shall be allowed only where topographical and/or lot line configurations offer no practical alternatives for connections" and may be no longer than 350 feet.

Criteria

In keeping with its intent-oriented approach, the code both describes desired street characteristics and provides specific requirements. One of the descriptive elements of the code states that "all streets should connect to help create a comprehensive network of public areas to allow free movement of automobiles, bicyclists, and pedestrians" (Huntersville 2003). The code emphasizes the role of streets as public spaces and the need for streets to provide access for nonmotorized traffic.

Huntersville prohibits cul-de-sacs and private streets, requires street stubs for future connections, and calls for relatively short block lengths. According to the code, cul-de-sacs "shall be allowed only where topographical and/or lot line configurations offer no practical alternatives for connections" and may be no longer than 350 feet.The town also has a blanket prohibition against private streets: "Private streets are not permitted within any new development" (Huntersville 2003). The only exception is for clusters of up to six houses in open space zones that may share a private driveway (Mullen 1999).

Block lengths, however, are not rigidly defined: "under most conditions . . . [they] may range from 250 to 500 linear feet between cross streets" (Huntersville 2003). The goal of the block length guidelines is to achieve block circumferences of approximately one-quarter mile (Mullen 1999). The code also attempts to prevent the unintended creation of routes for cut-through traffic by stating that "segments of straight streets should be interrupted by intersections designed to: a) disperse traffic flow and reduce speeds . . . and b) terminate vistas" (Huntersville 2003). The code allows but does not require traffic calming measures.

Exceptions to the connectivity requirement are allowed when topography or lot lines prevent connections. Staff makes recommendations to the town's planning board on this issue when it brings a development plan to the board for approval. Exceptions are fairly rare. A recent 250-acre subdivision, for example, had only three cul-de-sacs. Waiving the limit on cul-de-sac lengths is a more formal process, requiring approval by the town's council.

To offset the cost to developers of providing increased connectivity, the city allows narrower streets: travel lanes on residential streets may be as narrow as nine feet, with a minimum total width of 18 feet (or 25 to 26 feet if on-street parking is necessary to accommodate multifamily housing). The city is considering changes to the code that would increase the minimum lane width to 10 feet with seven feet for on-street parking, for a minimum of 27 feet for streets with parking on one side (Simoneau 2003). For all residential streets, the town requires a 40-foot right-of-way to provide for trees and sidewalks.

To offset the cost to developers of providing increased connectivity, the city allows narrower streets: travel lanes on residential streets may be as narrow as nine feet, with a minimum total width of 18 feet (or 25 to 26 feet if on-street parking is necessary to accommodate multifamily housing).

Issues

The connectivity ordinance was not highly controversial. Developers said that increased connectivity would drive up housing costs, although the flexibility to build narrow streets helped to alleviate this concern. Mullen suggested that because Huntersville is in a high-growth part of the Charlotte area and near a lake, higher costs do not seem to deter developers or buyers. As he put it, "Developers who are really interested in building in Huntersville will take the time to learn the new ordinance—including the other aspects of the [traditional neighborhood development] requirements—and will work with it. Those who are less motivated, especially those who have been in the business longer and are used to traditional rules, tend to resist more" (Mullen 1999). Some developers have complained that the standards prevent them from meeting perceived market demands for subdivisions with limited access and cul-de-sacs (Simoneau 2002).

The Huntersville fire department has supported the greater connectivity requirements overall because it believes that greater connectivity will provide it with more direct routes to reach emergency sites. But it is also currently concerned about access to alleys that are planned as part of new developments.

Performance

Huntersville has approved a considerable amount of development since the new ordinance was adopted in 1996, including both residential and commercial projects, but as of 2002 the first projects were still under construction, with only some structures completed. Mullen (2002) said that the new developments are selling just as well as conventional developments.

Huntersville Planning Director Jack Simoneau (2002) said that the community seems to have accepted the standards pretty well. Though the development community may not always be happy with the standards, they construct stub outs for future streets and other features that promote connectivity as required. He believes the town has had success in implementing the standards in both infill projects and new subdivisions on the town's outskirts.

"It is a challenge just getting everyone to share the vision, since it presents a whole new way of looking at things," Simoneau said. "Educating people on concepts that say that a) by providing more local access, we can promote safety and efficiency of traffic flow and services, and b) it is beneficial to the natural environment to cluster land development, can be a challenge." However, he said the town's spirit of cooperation helps to resolve any differences without much conflict.

Simoneau (2002) also attributes Huntersville's success in implementing the connectivity standards to its effort to forge a common vision for its future growth. He said the credit lies mainly with the town's planning staff that in 1994–95 "demonstrated the capacity to seize and utilize opportunities to integrate connectivity standards as part of the town's vision." By espousing the concept of street connectivity, the city's staff was able to present the town with a wider range of options for shaping their community, he explained, and now Huntersville is reaping the benefits of those efforts.

CORNELIUS, NORTH CAROLINA

Cornelius, North Carolina, adopted its connectivity standards in October1996 as part of a larger rewrite of its land development code designed to require traditional neighborhood design (Floyd 1999). The University of North Carolina and the town's planning division worked together to create the standards. The ordinance grew out of a visioning process and was encouraged by a new planning director, who had just developed a similar code for Belmont, North Carolina. The land development code was amended in August 2002 to change street dimensions and classifications.

Criteria

The final decision on which streets will be allowed to exceed the block lengths or end in cul-de-sacs rests with the planning commission at the time it decides whether to approve the development plan with or without conditions.

The criteria used in Cornelius are similar to those in neighboring Huntersville, with notable exceptions. The Cornelius code emphasizes the community and pedestrian aspects of streets and has general requirements that streets "interconnect within a development and with adjoining development." The code also requires that "[a] properly designed street network, unless prohibited by the existing street layout or topography, should provide at least two routes of access to a given location. This affords a high level of accessibility for emergency vehicles and appropriate service routing for school buses and transit vehicles" (Cornelius 2002).

The code encourages on-street parking and traffic calming devices. It allows streets within developments to be privately maintained, but it strictly prohibits closed or gated streets and requires streets to be accessible to the public. The town does allow features such as guardhouses. Cul-de-sacs are only allowed where topography or "exterior lot line configurations" prevent street connections. Alternatives to cul-de-sacs are encouraged, and the length of cul-de-sacs is restricted: "Where practical, a close should be used in place of a cul-de-sac. Cul-de-sacs, if permitted, shall not exceed 250 feet in length from the nearest intersection with a street providing through access (not a cul-de-sac)" (Cornelius 2002).

Cornelius requires block lengths between 200 to 500 feet but allows for exceptions "due to topography, environmental protection, preservation of existing buildings, and similar considerations" (Cornelius 2002). Arterials are regulated by the state department of transportation, so the town does not control intersection spacing on those streets. Cornelius classifies streets as boulevards, parkways, avenues, main streets, residential main streets, local streets, minor streets, rear lanes, rear commercial alleys, and rear residential alleys (Cornelius 2002). Main streets are roughly equivalent to collectors and are meant to serve high-density mixed-use or residential areas.

In order to gain approval for longer block lengths, a developer must prove that a hardship makes meeting the standards impossible (Floyd 1999). Planning staff decides whether the hardship is legitimate. The final decision on which streets will be allowed to exceed the block lengths or end in cul-de-sacs rests with the planning commission at the time it decides whether to approve the development plan with or without conditions. Exceptions occur fairly frequently, with typically one or two short cul-de-sacs allowed per subdivision.

Issues

The politics related to the entire ordinance revision have been contentious, but the connectivity requirements themselves seem to be fairly well accepted.

Karen Floyd, planning director for Cornelius, said that the town council is "pretty convinced" of the benefits of higher connectivity (1999). Some local conditions contribute to this attitude, including the large number of peninsulas that extend into the lake bordering the town. Without the connectivity requirement, the town could have many very long cul-de-sacs extending onto these peninsulas. The presence of a nuclear power plant nearby heightens concern about having good connectivity to provide multiple evacuation routes to and from developments on these peninsulas.

According to Floyd, developers in the area are indifferent to the connectivity requirement as long as they know about it in advance and have the rationale explained to them (Floyd 1999). In general, Floyd said, developments built under the new ordinance simply require different marketing. She noted that a builders' coalition fought the ordinance, but other builders went ahead with developments, including tract builders that simply modify their designs. The high demand for relatively expensive housing in the area may mute controversy. Floyd described the town as wealthy and attractive to residents of all ages.

Because Cornelius is a fairly small town, it does not have a problem with cut-through traffic. However, the town does encourage on-street parking in the design of new developments, and new local streets are required to be 20 feet wide, with curb radii of 15 feet, to help reduce speeds on local streets. Overall, the code has been well received by the local community. Several residential and mixed-use developments reflect the connectivity standards. At the same time, there continues to be opposition from some residents to any kind of change in their neighborhoods (Floyd 2002).

Developers in the area are indifferent to the connectivity requirement as long as they know about it in advance and have the rationale explained to them.

—Karen Floyd
Planning Director
Cornelius, North Carolina

CONOVER, NORTH CAROLINA

In the early 1990s, growing traffic congestion and poorly designed subdivision plans motivated the planning staff in Conover, North Carolina, to revise its subdivision ordinance in order to avoid such problems in the future. Before adopting the ordinance, staff members went through a long but fruitful process of educating themselves and the community about the benefits of connectivity. They studied examples such as Celebration and Seaside in Florida, and also looked at other older towns such as Annapolis, Maryland, and Davidson, North Carolina. To their advantage, Conover already had good examples of old neighborhoods with high levels of connectivity and other traditional design features. The staff showed the local community good and bad textbook examples of good and bad connectivity as well as the real local examples in Conover. The revised subdivision ordinance, adopted in 1994, requires street connectivity in residential areas, except in situations where it is not possible for the developer to meet the connectivity requirements due to the unique characteristics of the land.

Criteria

The city subdivision ordinance has a maximum block length requirement of 400 feet by 1,200 feet. The ordinance requires street stubs to be created for the construction of future roads. While cul-de-sacs are allowed, their use is restricted. Private and gated streets are not allowed. The city uses traffic calming methods to address cut-through traffic. In a subdivision development design, the ordinance requires that streets not be straight for their entire length; they should instead be curved or have T-intersections in order to slow vehicular traffic.

Conover does not have a similar ordinance for commercial land use, but it has a policy instead that requires parking lots in commercial lots to be connected through private drives or joint easements. The city tries to work out these details with the developers during the design review process of commercial developments.

Issues

There was some opposition to the connectivity standards from developers who did not believe that connectivity was the best practice. Some residents who have lived in Conover all their lives at the end of cul-de-sacs are also opposed to the concept of connectivity (Williams 2002). But in general, the standards have been accepted by the community.

Randy Williams, Conover's planning director, emphasizes that education and knowledge of the benefits of street connectivity are crucial for the widespread acceptance of the concepts. The process of introducing the concepts of connectivity to the community went on for over two years (Williams 2002). "We tried to educate not only the citizens but also the professionals from other departments," Williams said. "We did it slowly and kept introducing the issues in phases, instead of dumping all that information on them at once."

"We tried to educate not only the citizens but also the professionals from other departments. . . . We did it slowly and kept introducing the issues in phases, instead of dumping all that information on them at once."

—Randy Williams
planning director
Conover, North Carolina

Williams stressed the importance of showing local built developments to the public rather than just using textbook examples. The city staff took local planning board and planning council members on site visits to show them already existing examples of good connectivity in Conover, and this effort played a vital role in securing the support of local decision makers (Williams 2002). Williams also said the good working relationship between city departments allowed successful implementation of the subdivision ordinance.

Conover has been successful in establishing the connectivity standards in residential and commercial areas alike in all but one situation during the past four years (Williams 2002). Today the city has several examples of new subdivisions and old infill projects that incorporated the connectivity standards in their design. City planners seem pleased with the results of the increased connectivity standards, although they have not yet studied the impacts.

MIDDLETOWN, DELAWARE

Middletown, Delaware, adopted its connectivity standards as part of a 1998 rewrite of its development code to require traditional neighborhood design. The revisions included requirements for greater connectivity and restrictions on the use of cul-de-sacs. This effort was galvanized by a state mandate that required Middletown—which Delaware's governor designated as a "Growth Center"—to prepare a comprehensive plan (Deputy 2002). The town worked with the state and the University of Delaware in preparing the new plan and code.

Criteria

Like Cary, North Carolina, Middletown uses a connectivity index to define its requirements, with a required value of 1.4. The city allows cul-de-sacs of up to 1,000 feet long but discourages their use in favor of loops. According to Town Engineer Morris Deputy, "The cul-de-sacs form the most important aspect of our code" (Deputy 2002). Street stubs must extend to neighboring, developable land. The code prohibits private streets in residential developments and prohibits gated streets. The code also provides for narrower local streets (24 to 32 feet wide) to slow traffic and reduce impervious cover, and it requires street trees, also in an effort to slow traffic.

Issues

Developers did not resist the new code, but the city did make some changes to accommodate emergency vehicles. Developers were primarily concerned about whether they would be able to maintain the same number of house lots. By clustering houses in higher densities, the code did not change the overall numbers of lots. All new subdivisions have adopted the connectivity standards. The town does not have any infill developments.

There was no significant reaction from local residents to the standards. Deputy attributes this absence of reaction to a lack of awareness and understanding of the concept of connectivity. He adds that the only instances in which there has been resistance from local residents were in situations where the town tried to create connections with other towns in the vicinity and residents feared increases in through traffic (Deputy 2002).

ORLANDO, FLORIDA

In 1999, Orlando, Florida, adopted an incentive-based approach to encouraging connectivity in its Southeast Orlando Sector Plan: Development Guidelines and Standards (Orlando 1999). The policy set forth in the sector plan, which the planning staff anticipates extending to the rest of the city, provides a discount on impact fees if a developer meets or exceeds a connectivity index value of 1.4, with an allowance for topographic or other constraints (Gallagher 1999). Orlando's connectivity index calculation differs slightly from those of Cary and Middletown described above, however, in that it incorporates intersections and links on existing perimeter streets: "to properly calculate the connectivity index, you must include the first link beyond the last nodes" (Orlando 1999).

The policy set forth in the Southeast Orlando sector plan, which the planning staff anticipates extending to the rest of the city, provides a discount on impact fees if a developer meets or exceeds a connectivity index value of 1.4, with an allowance for topographic or other constraints.

In 1999, the planning staff also presented a proposal to address the issue of connectivity in gated, multifamily developments. These developments tend to have only one entrance onto an adjacent arterial, so the staff proposed to require perimeter roads and entrances to these roads on each side of a development. The entrances may still be gated, but, if adopted, this requirement would provide a more developed street network and would allow residents of these communities to exit in different directions. The developments would also receive impact fee reductions for complying with the requirements.

City staff is currently working towards incorporating the connectivity standards into Orlando's land development code (Klasky 2002). The city's Growth Management Plan as amended in 2002 states that "the City shall continually implement residential development roadway connection standards which promote convenient access to adjacent residential developments and nearby uses yet discourage cut-through traffic" (Orlando 2002). The plan also proposes that "by 2005, the City shall develop bicycle and pedestrian connection standards for residential and nonresidential developments" (Orlando 2002). In the meantime, the city's connectivity requirements remain primarily administrative rather than regulatory.

Criteria

The city's land development code requires several basic, but generally unquantified, elements of connectivity. It requires, for example, that "all subdivisions shall be designed to allow for dispersal of residential traffic and to minimize the impact of residential traffic" on surrounding streets (Orlando 1993). Street stubs to adjacent developable property and connections to existing adjacent streets are required. Cul-de-sacs may not serve more than 30 single-family houses or be longer than 700 feet in other residential areas. The minimum width of local residential streets is 24 feet. The code also suggests that "to discourage excessive speeds, traffic calming techniques such as street design with curves, medians, textured pavement, changes in alignment, short lengths and other special designs shall be required" (Orlando 1993). The city does not permit gated single-family residential communities unless there is no possibility of future extensions of the local street system.

The city's Growth Management Plan as amended in 2002 includes a number of goals related to connectivity (Orlando 2002). Policies tied to the objective of implementing "residential development roadway connections standards" require the city to ensure connectivity of roadways, bikeways, and pedestrian systems in existing and new residential neighborhoods and between neighborhoods. In new residential developments, the plan encourages maximum stub spacing of 660 feet, consistent with the city's access management policies. New developments must also align their roadways to connect with street stubs in adjacent developments. In addition, the plan calls for increased connectivity between multifamily developments and for the preservation of existing roadway connections. Residential developments, according to the plan, should be designed to discourage speeding and cut-through traffic, and private and gated communities should be discouraged.

Issues

Dan Gallagher, chief planner for Orlando, said that the city's Municipal Planning Board has supported efforts in 1999 toward greater connectivity. Gallagher noted that residents seem to think very favorably about neotraditional design, which receives significant attention because of local developments such as Disney's Celebration. The importance of local examples of high-connectivity communities in shaping public opinion was also stressed by Nhur Klasky, a planner for the city. Baldwin Park, where a former naval training center is being redeveloped into several mixed-use neighborhoods, will provide another local example of a high-connectivity development when it opens in 2003 (Klasky 2002). Gallagher pointed out that Orlando's rejuvenated, grid-based downtown area is now a very popular place for people to live, as reflected in part by high property values, another indication, he said, that residents recognize the desirable qualities of grids. The success of these neighborhoods give him confidence that developers will still want to build in Orlando even with more stringent connectivity requirements (Gallagher 1999). Because the city staff had not taken the connectivity standards through the public process as of early 2003, it did not have direct evidence of public opinion about the connectivity requirements.

SUMMARY

Each of these communities has adopted a somewhat different approach to increasing connectivity. Their requirements are summarized in Tables 3.1 and 3.2 (which include the criteria for Raleigh, described in the next chapter), and excerpts from the requirements for selected cities are included in Appendix B. Besides differences in the techniques used to measure connectivity, these communities have used widely different approaches to addressing the issues of connectivity to arterials, requirements for stub-outs, minimum street widths, traffic calming, cul-de-sacs, gated communities, bicycle and pedestrian accessways, variances and exceptions, and adoption and implementation. The communities surveyed have increased connectivity requirements to varying degrees, based in part on the prevailing level of connectivity in each city. There is certainly no one-size-fits-all approach to street connectivity requirements; each community must develop an ordinance that fits its particular context. However, their efforts are so new that these communities are still working to develop an effective approach, and they have much to learn from the experiences of other communities.

Efforts are so new that these communities are still working to develop an effective approach, and they have much to learn from the experiences of other communities.

As experience with street connectivity ordinance accumulates, clear best practices will likely emerge.

TABLE 3-1
SUMMARY OF REQUIREMENTS FOR INTERSECTION SPACING AND CUL-DE-SACS

	Max Intersection Spacing for Local Streets (feet)	Max Intersection Spacing for Arterials	Are Street Stubs Required?	Are Cul-de-Sacs Allowed?	Max Cul-de-Sac Length (feet)
Block-Length (by city)					
Metro, Oregon	530	530	No	No (with exceptions)	200
Portland, Oregon	530	530	Yes	No (with exceptions)	200
Beaverton, Oregon	530	1,000	Yes	No (with exceptions	200
Eugene, Oregon	600	None	Yes	No (with exceptions)	400
Fort Collins, Colorado	See Note 1	660–1,320[2]	Yes	Limited	660
Boulder, Colorado	See Note 3	None	Yes	Yes, discouraged	600
Huntersville, North Carolina	250–500	No data	Yes	No (with exceptions)	350
Cornelius, North Carolina	200–1,320	See note 4	Yes	No (with exceptions)	250
Conover, North Carolina	400–1,200	No data	Yes	Yes	500
Raleigh, North Carolina	1,500[5]	No data	Yes	Yes	400–800[6]
Connectivity Index (by city)					
Cary, North Carolina	Index = 1.2	1,250–1,500	Yes	Yes	900
Middletown, Delaware	Index = 1.4	None	Yes	Yes, discouraged	1,000
Orlando, Florida[7]	Index = 1.4	None	Yes	Yes	700 (30 units)

Notes:

(1) Maximum block size is 7 to 12 acres, depending on zoning district.

(2) Limited movement intersections required every 660 feet; full movement intersections required every 1,320 feet.

(3) Not specified by code, but staff tries to achieve 300 to 350 foot spacing.

(4) Intersection spacings on arterials is regulated by the state Department of Transportation.

(5) Within a Mixed-Use Center, no street block face shall exceed 660 feet in length.

(6) 400 feet in residential areas, 800 feet in commercial areas; Transportation Director may approve up to 10% longer.

(7) Requirements in place for Southeast Sector and under consideration for rest of city.

As experience with street connectivity ordinance accumulates, clear best practices will likely emerge.

Cul-de-sacs are usually restricted to 200 to 300 feet and are allowed only in places where connections would be impractical.

Techniques for Measuring Connectivity

The communities studied have used two primary approaches to requiring connectivity. Ten of the 13 communities have established maximum block lengths and significant restrictions on the use of cul-de-sacs. (In addition, four of the communities with connectivity standards identified since the completion of the case studies also use block length requirements.) Typical block length requirements fall in the range of 300 to 600 feet (although a few cities allow substantially longer blocks, at least under certain circumstances), and cul-de-sacs are usually restricted to 200 to 300 feet and are allowed

TABLE 3-2
SUMMARY OF OTHER REQUIREMENTS RELATED TO STREET CONNECTIVITY[1]

	Max Spacing Between Bike/Ped Connections (feet)	Local Street Widths (Paved, in feet)	Are Private Streets Allowed?	Are Gated Streets Allowed?
Block-Length (by city)				
Metro, Oregon	330	<28 encouraged	See Note 2	See Note 2
Portland, Oregon	330	See Note 3	Limited	No
Beaverton, Oregon	330	20–34	Limited	No
Eugene, Oregon	See Note 4	20–34	Limited	Limited
Fort Collins, Colorado	700	24–36	Limited	No
Boulder, Colorado	See Note 5	24–36	No	No
Huntersville, North Carolina	None	18–26	No	No
Cornelius, North Carolina	None	18–26	Yes	No
Conover, North Carolina	None	22	No	No
Raleigh, North Carolina	None	26	Limited	Discouraged
Connectivity Index (by city)				
Cary, North Carolina	If Index waived	27	Yes	No
Middletown, Delaware	No data	24–32	No	No
Orlando, Florida[6]	None	24 minimum	Yes	No

Notes:

(1) Traffic calming incorporated into connectivity requirements; city may have separate traffic calming program.

(2) Not regulated.

(3) Width must be sufficient to accommodate expected users.

(4) No maximum distance, but each development must have a plan showing pedestrian connections to cul-de-sacs.

(5) No requirements, but staff suggests spacing similar to local streets (300 to 350 feet).

(6) Requirements in place for Southeast Sector and under consideration for rest of city.

only in places where connections would be impractical. The block length approach is easily visualized and understood by developers and residents, and it produces a relatively predictable and evenly distributed network of streets.

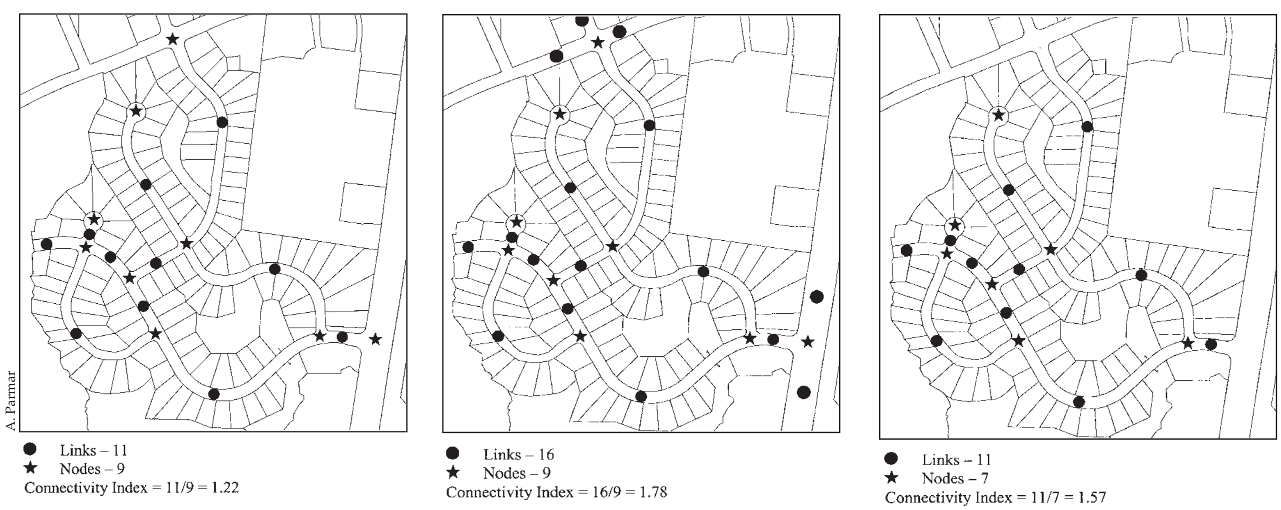
It is important to note that different communities have defined the block length rule in slightly different ways. Some communities specify the requirement in terms of the length of the block, while others specify the requirement in terms of the spacing of intersections or connections. The effect is essentially the same, but the exact measurements may vary depending on the width of streets and rights-of-way. The codes often do not specify exactly how these dimensions are measured, although several options exist (Tracy 2003). Eugene, for example, defined its requirement in terms of block length, measured as the distance between centerlines for intersecting streets. McKinney (an excerpt of whose code is included in Appendix B) measures block length as the distance from curb face to curb face of intersecting streets. The length of a given block under the Eugene rules will be longer than under the McKinney rules because it includes the width of the intersecting streets. A variation on the block length or intersection spacing requirement is block size, measured as width by length (as in Conover), number of acres (as in Fort Collins), or block perimeter (as in Knoxville, excerpts of whose code is included in Appendix B). Portland has chosen to specify a suggested block length, allowing for flexibility to account for topography and other factors.

A second, less-used approach to connectivity requires compliance with a specified value of a connectivity index, defined as the ratio of links to nodes. This approach, used by three of the case study communities (and three of the communities with connectivity standards identified since the completion of the case studies), allows developers greater flexibility while still ensuring a higher degree of connectivity. This flexibility enables developers to account for constraining topographic features and design unique neighborhood layouts more readily than established block lengths. The connectivity index approach also provides an incentive to developers to reduce cul-de-sacs and include more four-way intersections but does not dictate specifics of the network layout. To provide a minimum level of connectivity for all areas, a loose block length requirement may supplement the index, as in the case of Cary. Cary has a lower index requirement, at 1.2, while Middletown and Orlando have higher requirements at 1.4.

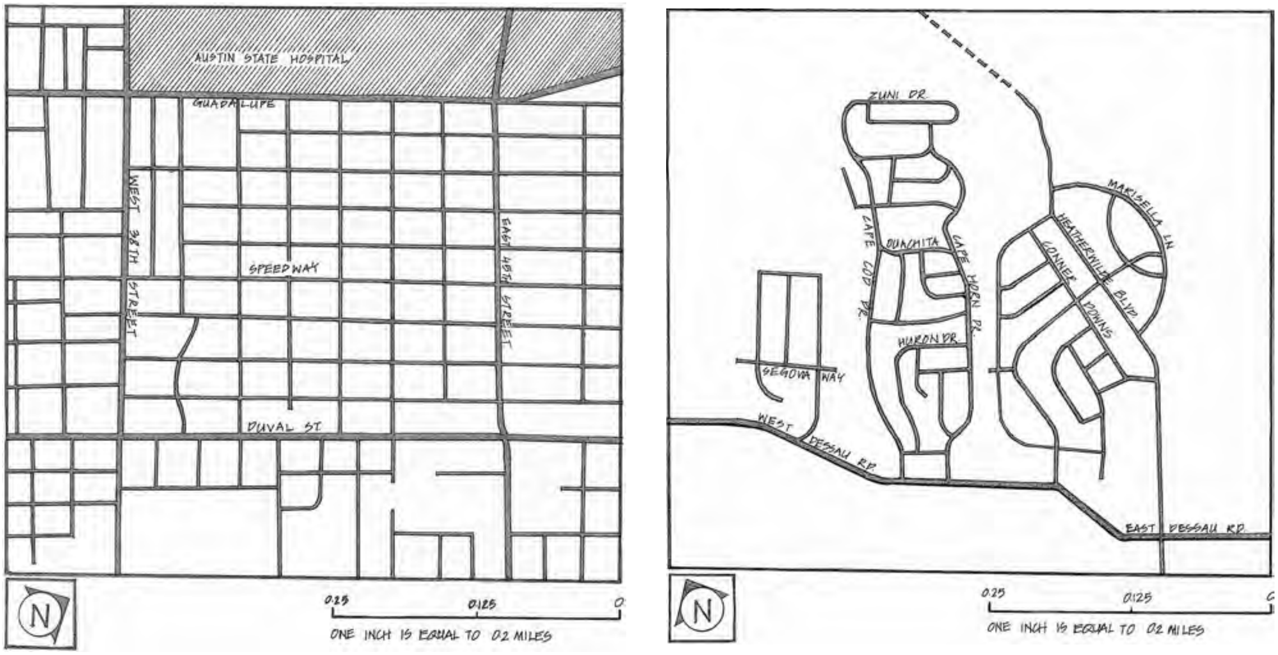
The connectivity index approach also provides an incentive to developers to reduce cul-de-sacs and include more four-way intersections but does not dictate specifics of the network layout.

It is important to note that different communities use slightly different rules for counting nodes and links (Figure 3.3). The rule in Cary is that the intersections of residential streets with the arterial that borders the development are counted as nodes, but only the residential street is counted as a link. In Orlando, the first links beyond this last node are counted as links, thus increasing the number of links relative to nodes and increasing the connectivity index for the same development. In San Antonio, Concord, and Hillsborough County, excerpts of whose codes are included in Appendix B, intersections of residential streets with the arterials that border the development are not counted as nodes, thus decreasing the number of nodes relative to links and increasing the connectivity index for the same development relative to the index under the Cary rules. Whichever rules are used, they must be clearly spelled out in the code so that the connectivity requirement is consistently applied within that community. Although San Antonio, Concord, and Hillsborough County all use the same rules, they have established different standards: 1.2, 1.4, and 2.0, respectively.

One disadvantage of the connectivity index is that it is not as intuitive as the block length requirement, which can complicate planners' attempts



Figures 3.3A, 3.3B, and 3.3C. (Left) Cary rules: Include nodes with arterials but no external links. (Center) Orlando rules: Include nodes with arterials and one link beyond the last node. (Right) San Antonio, Concord, and Hillsborough rules: Do not include nodes on arterials.



A. Parmar

Figures 3.4 and 3.5. (Left) The Hyde Park neighborhood in Austin, Texas, has a connectivity index value of 1.45. (Right) The neighborhoods in Austin's Dessau Road area have connectivity index values closer to 1.34.

One disadvantage of the connectivity index is that it is not as intuitive as the block length requirement, which can complicate planners' attempts to educate local officials, citizens, and developers about the importance of connectivity.

to educate local officials, citizens, and developers about the importance of connectivity. A street network with a connectivity index value of 1.4, for example, is not readily visualized, while a block length requirement of 300 feet has a direct physical implication. In addition, the rules established for counting nodes and links can significantly influence the evaluation of connectivity in different networks. For example, the Hyde Park neighborhood in Austin, Texas (Figure 3.4), has a connectivity index value of 1.45 as calculated according to Cary's rules, which excludes links on perimeter streets. In contrast, the neighborhoods in Austin's Dessau Road area (Figure 3.5), developed since the 1980s, have connectivity index values closer to 1.34. Including external links to intersections on perimeter streets, as is allowed in Orlando, increases the values to 1.76 for Hyde Park and to 1.38 for the Dessau Road area. The difference in connectivity between the two networks is thus considerably greater under Orlando's system than under Cary's system. The measurement of connectivity in traditional gridded networks appears to be particularly sensitive to whether nodes and links on perimeter streets are included in the calculation.

Connectivity to Arterials

These case-study communities vary substantially in their application of connectivity requirements to arterials. The Portland area cities specify the spacing of connections to arterials, as does Fort Collins, while the other cities do not apply their connectivity requirements to arterials. Metro's connectivity study in Portland, which projected traffic benefits from connectivity, also specified connectivity as a number of intersections per mile of arterial streets. In Cornelius, where arterials are under the control of the state DOT, connections to arterials are not included in the requirements. Whether connectivity applies to arterials may have a significant bearing on how effectively the requirements accomplish transportation goals such as reducing local trips on arterials or increasing the attractiveness of alternative modes.

Stubs

Several cities incorporate requirements for street stubs and the mapping of future streets into their connectivity requirements as a way of ensuring connectivity with future streets. Metro and the cities in its jurisdiction are required to create maps with potential future street connections required to meet connectivity requirements. Eugene and Fort Collins have similar processes. While these maps do not define the exact layouts and locations of future connections, they do provide a comprehensive view of future connectivity by guiding the approximate location of future connecting streets. Connectivity indexes can also be used to provide an incentive for including stubs. If stubs are counted as a link but not as a node (in contrast to cul-de-sacs, which count as one link and one node), developers have an incentive to include street stubs as a way of increasing their connectivity index (White 2003b).

Narrower street width standards, in addition to calming traffic, have reduced costs to developers, making the connectivity proposals more palatable. They also reduce or eliminate environmental impacts due to run-off from impervious cover.

Street Widths

Most cities have instituted narrower streets and traffic calming techniques to address the potential for cut-through traffic, but few systematically require traffic calming in new, connected subdivisions. Those that do have calming requirements (Beaverton, when necessary, and Orlando) have fairly broad, loosely defined requirements. Another technique used to discourage cut-through traffic is encouraging developers to design street systems that, while connected, do not provide "straight shot" routes through neighborhoods. T intersections and curving roads are the most frequently used tools. Narrower street standards have also been key to minimizing or avoiding increased pavement in most of the communities. These standards, in addition to calming traffic, have reduced costs to developers, making the connectivity proposals more palatable. They also reduce environmental impacts due to run-off from impervious cover.

Cul-de-sacs

The communities are about equally split between those that allow cul-de-sacs and those that do not. Cities that use block length requirements are more likely to prohibit cul-de-sacs while those that use a connectivity index allow cul-de-sacs as long as the development meets the specified connectivity value. In cities that prohibit cul-de-sacs, exceptions are generally granted when the topography or environmental considerations justify the design. All but one city specify a maximum length for cul-de-sacs, ranging from 200 feet to 900 feet.

Gated Communities and Private Streets

Orlando alone allows gated streets for single-family housing developments, and only where the street system will not be extended; most cities prohibit their use entirely. Similarly, most of the communities significantly limit the use of private streets.

Bicycle and Pedestrian Connectivity

Many of the communities have established requirements for the frequency of bicycle and pedestrian connections as well. In some cases, as in Cary, these requirements are offered as alternatives in situations where full street connections are impractical. In other cases, as in Portland and Eugene, these requirements are more stringent than those for full street connections. In these latter cases, streets can serve as bicycle and pedestrian connections, but if streets are more widely spaced than codes allow for these connections, developers must provide additional connections for bicycles and pedestrians. Both Portland and Eugene also establish design standards that require actual routes from any origin to specific local destinations to be no more than 1.5 to two times the straight-line distance. This requirement ensures that streets not only connect to each other but to where residents need to go.

Variances and Exceptions

In implementing their codes, several cities have allowed variances or used incentives rather than requirements. Eugene and Fort Collins allow developers to present alternative means of accomplishing the established goals for their connectivity requirements. Orlando has not established mandatory requirements and instead uses an incentive approach by providing developers with discounts on development fees if they meet the city's connectivity index. Cary is considering a similar approach to encourage developers to exceed a minimal, required level of connectivity.

In implementing their codes, several cities have allowed variances or used incentives rather than requirements.

All of these communities generally allow exceptions to their connection requirements in particular instances where topography, built features, or lot lines make connections infeasible. Cornelius often grants exceptions, but, on the whole, these measures are relatively infrequent. In general, staff judges the validity of a developer's claim that a particular connection is infeasible or that certain blocks must be longer than specified in the code. The staff's decision is either accepted or modified when the planning commission considers the entire development plan. Thus, most of the cities do not have rigorous variance procedures in order to provide exceptions. Cary, however, requires pedestrian connections for all of the cul-de-sacs in a subdivision for which its connectivity index is waived. Beaverton has already mapped many of its planned connections, so it requires a more rigorous procedure (a variance) to change that map significantly.

Adoption and Implementation

All of the cities surveyed had instituted their connectivity requirements as part of broader planning efforts and code rewrites. Some communities, such as Huntersville and Cornelius, included connectivity requirements in a complete overhaul of their land development codes, while others considered connectivity as a part of larger transportation planning efforts. Eugene's connectivity requirements, for example, were tied to comprehensive street plans that addressed issues such as classifications, widths, and transit accessibility in addition to connectivity. A planner in Eugene also recommended that establishing connectivity standards is best done in conjunction with other code changes, such as narrowing streets (Lowe 1999).

For all the communities in this study, it has been easier to implement the connectivity standards in new subdivision projects rather than in infill projects. City officials say that most new subdivisions in their community are being built using their connectivity standards. They have had limited success in applying these standards in infill projects due to either site constraints or resistance from neighborhood groups. All of the areas in this study are experiencing high growth, and so far none have observed an adverse effect on the values of houses built on connected streets versus those built in conventional subdivisions. None of the cities found implementation to be difficult, and all are anticipating significant benefits from a connected street pattern, which provides more direct routes for all modes, more dispersed traffic, faster emergency responses, and more efficient utility distribution. Of course, this sample includes only cities that have succeeded in adopting and implementing standards; other communities may face greater implementation challenges and more vocal opposition.

One critical lesson that emerges from these early efforts to increase street connectivity is the importance of education, not only of city staff and council members but also of emergency service providers, developers, and the public. Emergency service providers frequently expressed concern over the impact of narrower streets on the maneuverability of emergency vehicles. Developers in most communities expressed concern at least initially about the possibility of a decline in the number of lots in their projects and of an increase in costs because of increased street lengths. In those communities with stub requirements intended to ensure connectivity with future developments, residents living on stubs expressed concern over future increases in through traffic. Efforts on the part of these cities to explain the purpose of the ordinance using specific facts and figures, and to provide illustrations of communities with high connectivity and narrower streets seemed to go a long way toward alleviating local concerns. Of course, education works the other way, too, and efforts on the part of the city to listen to and understand the concerns of emergency service providers, developers, and the public also contributed to the successful adoption of connectivity requirements in these communities. The cases of Raleigh and Austin, presented in the next chapter, help to illuminate these issues and highlight the importance of sound analysis of the costs and benefits of increased connectivity in the adoption process.

One critical lesson that emerges from these early efforts to increase street connectivity is the importance of education, not only of city staff and council members but also of emergency service providers, developers, and the public.

CHAPTER 4

Context-Sensitive Street Connectivity: A Tale of Two Cities

The previous two chapters point to a number of challenges and opportunities that confront communities considering street connectivity standards. Each community must decide what approach best fits its needs (e.g., a maximum block length versus a connectivity index; prohibiting gated subdivisions versus prohibiting cul-de-sacs; flexible standards versus tight variance provisions) in light of expected public and private benefits and costs. Although often framed as an economic decision, choosing an approach is in reality a political calculus since local policy makers must ultimately assign their own values in deciding what benefits and costs are most important. So as to help municipal planners establish these values and work through the politics of connectivity adoption, this chapter describes in detail the research, negotiations, and dialogue that occurred in two intensively debated local street connectivity efforts in Raleigh, North Carolina, and Austin, Texas.

The Raleigh case points to the value of developing contextually relevant research and policy information to educate the public and policy makers so they can make informed choices about street connectivity trade-offs. The Austin case points to the difficulties that can develop when planners do not provide enough locally relevant information to help stakeholders make those informed choices. Both case studies, however, illustrate the importance of maintaining an open dialogue among planners, developers, policy makers, and other interested groups to craft street connectivity standards that are sensitive to the local political context as well as to local development trends and physiographic conditions.

RALEIGH, NORTH CAROLINA

In 1991 and 1992, the transportation and planning staff of Raleigh set out to create street connectivity standards in response to rising concern among city council members over the increase in subdivisions dominated by cul-de-sacs and the proliferation of private streets, each of which tended to isolate residential areas rather than integrate them with surrounding neighborhood street systems (Raleigh 1992). In 1992, the city council adopted a strategic plan that included the goal of finding incentives "to encourage street patterns that will be better connected" (Howe 2003a). This marked the start of an extensive public discussion and research program spanning several years. The ensuing efforts encompassed a review of historic interconnected street patterns in Raleigh and across the United States, as well as discussions on the multiple potential benefits and costs of increased connectivity for the community. The benefits to the development community of less street connectivity were clear enough: marketing lots within enclave subdivisions and on dead-end streets with little traffic can be easier than on through streets, and exclusivity through private roads and gates is also a marketing plus. But the impact of connectivity on the public sector took considerably more staff time to develop and explain.

Most of the Raleigh's analytic efforts focused on public benefits and costs in four areas: (1) travel efficiency and mode choice, (2) fire response and services costs, (3) water and residential trash collection costs, and (4) environmental costs.

Most of the city's analytic efforts focused on public benefits and costs in four areas: (1) travel efficiency and mode choice, (2) fire response and services costs, (3) water and residential trash collection costs, and (4) environmental costs. The following sections describe each of these analyses.

Travel Efficiency and Mode Choice

Raleigh's decision to improve street connectivity was motivated by the limited vehicular and pedestrian travel choice between subdivisions and to schools, transit stops, parks, and neighborhood shopping provided in most of the city's new residential developments (Raleigh 1992). Moreover, this disconnected street system was placing too much dependence on collector and arterial streets as the sole means of continuous movement for cars and pedestrians between neighborhoods. In 1991 and 1992, the Raleigh Transportation Department studied the issue in more detail using a travel demand forecasting model to simulate alternative travel scenarios that varied street densities, connections, and block lengths (Raleigh 1992). Because reasonable traffic flow demands some sort of east-west and north-south connectivity, the simulation study sought to answer the question, How dense does the grid need to be?

The transportation planning staff sought a connectivity standard that would more evenly distribute traffic through a local street system without requiring excessive new-street construction. Staff primarily used traffic volume on each residential street to measure the distribution of traffic and attempted to set a standard that would reduce volumes on residential streets below a "pain threshold" that reflected appropriate volumes for collector streets, something less than 3,000 trips per day on any one street. In their analysis, staff also evaluated vehicle miles traveled, vehicle hours traveled, aggregate travel costs, and access link volumes. After running six alternative scenarios, staff recommended a maximum block length standard of 1,500 feet by 1,500 feet that would still allow multiple cul-de-sacs served by residential through streets, but that would also substantially increase alternatives for vehicles and pedestrians by eliminating long stretches of through streets intersected only by cul-de-sacs. According to the regulations developed from these recommendations a block cannot be defined by a dead-end street. Gated streets are discouraged, but in situations where they are allowed, they must incorporate vehicle turnarounds with a 90-foot right-of-way diameter and 70-foot curb face-to-curb face diameter. The city allows but restricts the use of cul-de-sacs; the maximum length of a cul-de-sac is 800 feet in residential areas and 400 feet in commercial areas. These final regulatory requirements were discussed at length with Raleigh area landscape architects, engineers, and developers to build consensus on the proposed standards. In the planning staff's opinion, the key to gaining support of these standards was the reduction of street widths.

In the simulation study conducted by planning staff, the new block-length and cul-de-sac standards were estimated to add only about $150 net per dwelling unit within one sample neighborhood where it was tested with reduced lot widths (Raleigh 1992). Total vehicle miles traveled (VMT) on internal neighborhood streets in compliance with the standards were estimated to be 16 percent fewer than the VMT on a street system that relied more heavily on cul-de-sacs. The standards also reduced the average residential block to sizes comparable to that of a sample of older, high connectivity neighborhoods in Raleigh (Raleigh 1992). In short, the simulation study provided evidence that the new connectivity standards would create a street pattern that was more efficient in dispersing traffic, provided more mode and route choices, would not be overly expensive to the development community, and would create street patterns comparable to those found in older well-known and established neighborhoods. These rules were adopted into the city's zoning and subdivision codes in 1993 with support from public safety departments for the enhanced response times made possible.

The simulation study provided evidence that the new connectivity standards would create a street pattern that was more efficient . . . and would create street patterns comparable to those found in older well-known and established neighborhoods.

Nevertheless, the politics of implementation remains troublesome, so studies continue to be done to assess probable costs and benefits. These studies are generally done on a case-by-case basis as specific connectivity issues arise, and decisions generally hinge on whether a public safety or emergency response issue is raised. When the issue is an incremental added inefficiency, or even an incremental increase in traffic on adjacent through streets, the council finds it difficult to approve connections where there is organized opposition to them. This is because the constituency for efficient government, and even the constituency whose ox is being gored by putting more traffic onto their streets is generally invisible relative to those rising up to "protect" the neighborhood from connected streets (Howe 2003a).

Residential Trash Collection Service and Water Services Costs

Like many municipal refuse collection systems, Raleigh's trash collection workers use set routes. A crew's day ends whenever the crew completes its route. According to planning staff, smart workers always vie for routes in Raleigh's older, grid-based neighborhoods since a grid pattern eliminates dead-heading. Dead-heading occurs when a truck picks up trash at each residence as it works down a dead-end street but then "dead-heads" the return length of the street (Raleigh 1992). Although municipal trash and recycling route maps can be used to calculate linear feet of redundant vehicle trips, from which wasted public services costs can then be calculated (i.e., excess gas, worker salaries, and vehicle depreciation per foot or quarter-mile), city planners did not perform this analysis and instead relied on accepted industry knowledge and anecdotal evidence from solid waste crews. No one contested this approach. Staff did note, however, that municipal liability for collection vehicle accidents and property damage could be reduced through greater connectivity since the necessity for backing maneuvers—often used on dead-end streets—would decrease (Raleigh 1992).

Raleigh planners also noted that water service advantages would follow from a more interconnected street system since potable water lines typically follow street patterns. The city noted that the dead-end lines in residential cul-de-sacs typically suffer from a chronic lack of water pressure (Raleigh 2002b). Water systems work far more effectively when the pipes can be looped and interconnected, allowing even pressure to be distributed throughout the network. Rather than using data specific to Raleigh on chlorinating problems, low pressure zone costs, or the public costs of booster pumps and other equipment to fix such problems, the city referenced the decision by its nearest municipal neighbor, Cary, to solve its water system delivery problems through enhanced connectivity (Raleigh 1992).

A fire station in the most interconnected neighborhood could provide service to more than three times as many commercial and residential units as the least connected neighborhood.

Fire and Emergency Services Costs

In November 2000, the Raleigh Transportation and Planning departments undertook a research project to see what the comparative fire and EMS service efficiencies would be in neighborhoods with varying levels of street connectivity (Howe 2003). The study calculated the total acreage and dwelling and commercial units that could be serviced within 1.5 miles of a fire station—chosen because the city's fire response level of service standard is an access reach of 1.5 miles—for three different neighborhood types: (1) older neighborhoods with a dense urban grid and few dead-end streets, (2) an area built during the 1970s and 1980s with somewhat less street connectivity and more dead-end streets, and (3) neighborhoods from the late 1980s and early 1990s with many dead-end streets where street connectivity is quite limited. In order to simulate build-out conditions, the study applied weighting factors to increase the total dwelling and commercial units in fire response zones that still had vacant parcels.

In all cases, the analysis showed far greater service efficiencies for those older neighborhoods with greater street connectivity. Even when discounting the density of development in these areas, the raw acreage covered in each case confirmed the greater efficiency in fire response coverage for areas with better street connectivity (Raleigh 2002b). In sum, a fire station in the most interconnected neighborhood could provide service to more than three times as many commercial and residential units as the least connected neighborhood. This finding also translated into more than twice the total acreage that could be served per station.

While comparative service efficiency numbers like these are important, they become even more valuable—and convincing—to policy makers and the public when they are translated into real budget terms. According to city estimates, building, furnishing, and staffing a fire station for a year can cost over $1.7 million (see Table 4.1). By improving street connectivity and thereby expanding service areas, Raleigh will be able to minimize its public service expenditures on new fire stations. Because police and fire services tend to consume the largest portions of most municipal operating budgets, increased connectivity standards can help any city to minimize the number of new police and fire stations built and to ensure that those stations have maximum service coverage.

TABLE 4.1. CITY OF RALEIGH FIRE STATION COST ESTIMATES

Capital Costs	
Construction of Station	$873,745
Furnishings for Station	$30,000
Fire Apparatus (Engine)	$257,910
Subtotal	**$1,161,655**
Operating Costs	
Utilities/Year	$6,550
Operating Costs/Year	$13,970
Salary, Fringe/Year	$581,850
Subtotal	**$602,370**
Grand Total—Fire Station Costs	**$1,764,025**

Public Safety and Environmental Costs

In order to be fair, a public dialogue about street connectivity must consider all important and plausible benefits and costs. In addition to benefits, Raleigh planning staff also analyzed the likely downsides to street connectivity in terms of public safety and water quality costs. Because data on the link between crime and street connectivity continues to be limited and inconclusive, much of the information staff has provided to the public and policy makers since the initial efforts to increase connectivity has been anecdotal and conveyed the lack of clear consensus on the issue. In the early 1990s, the public and policy makers were informed about crime prevention through environmental design theories such as "defensible space," where the grid is broken and street connectivity is intentionally reduced to make it easier for neighbors to define their territory and monitor outsiders. The city also noted, however, that emergency response efforts can be slowed by lower connectivity and that criminals may be able to make a clean escape in less connected street systems as well (Raleigh 2002b).

A more certain drawback that staff considered was water-quality impacts. Increased street connectivity often means more stream crossings, which adversely affects riparian habitat corridors and creates biological dead zones wherever culverts are used to make crossings. Culverts eliminate light and natural streambeds, disrupt stream vegetative buffer zones, and interrupt migration patterns along the riparian zone. North Carolina has very strict state-water quality rules that include protection of a 50-foot buffer on both sides of environmentally sensitive creeks and streams (Johnson 2002). When the connectivity rules were first introduced, developers were concerned about the potentially prohibitive expense of stream crossings, the extended review processing time, and the uncertainty of permitting by the state due to water-quality issues. It was not clear how to create acceptable crossings over environmentally sensitive stream corridors. Although bridges are the preferred alternative to stream crossings from a biological standpoint, they cost about three times as much as a standard culvert (Raleigh 2002b). Given that North Carolina's Division of Water Quality has the authority to deny a developer a permit to fill buffer zones, the city may have to examine alternatives for sharing the costs of stream crossings to ensure that the connectivity standards do not result in excessive costs for developers. The city was exploring the possible use

When the connectivity rules were first introduced, developers were concerned about the potentially prohibitive expense of stream crossings, the extended review processing time, and the uncertainty of permitting by the state due to water-quality issues.

of impact fees, cost-sharing, or joint provision of bridges where environmental constraints were most problematic but connectivity was important.

Results

In short, most city staff feel that Raleigh's success in implementing connectivity standards is due to the consistency of the city council's leadership in promoting connectivity and the staff's efforts in backing up arguments with researched facts (Johnson 2002). The standards have been in place for nearly 10 years, and the lessons learned during implementation are carrying over into other areas of the land development code. For example, street connectivity requirements for group housing were strengthened in July 1998 to require through-street connections for large complexes of 20 acres or more or complexes of 200 dwelling units or more.

The city has had some success in achieving interconnectivity in new subdivisions as well as in those infill projects where opportunities are available for increasing connectivity, although some implementation problems have occurred (Howe 2003a). Not surprisingly the city council finds it difficult to approve connections where there is organized opposition to these kinds of connections. For example, in 1995, the city council allowed developers to reduce six external street connections to two, effectively isolating the 158-acre Smith Estate infill development project after surrounding neighborhoods complained quite vocally about traffic impacts; the only direct access left for the project was via a single thoroughfare. Another example worth mention is the Exeter Way project that borders Raleigh and Durham, and is bisected by a creek. In this case, the city council voted to not require the developer to connect to two stubbed streets largely because connectivity issues had become a difficult election topic for the mayor. After this decision was made, however, a brush fire occurred on the Durham side of the creek but within the Raleigh city limits. Raleigh firefighters tried to access the fire from the Raleigh side but were unable to because the street didn't extend across the creek, thus forcing them around a large superblock, which increased the response time substantially (Howe 2003b).

In closing, it is important to note that the vast majority of street connections happen without political upheaval, and the program in general results in substantially more connective streets now. The city council is often most willing to face that heat whenever the public safety departments indicate that response times will be negatively affected by removing a connection or failing to make a connection (Howe 2003b).

AUSTIN, TEXAS

Austin's connectivity efforts were initiated in 1998 by the Comprehensive Plan Subcommittee of the Austin Planning Commission. That subcommittee had become highly dissatisfied and frustrated with having to approve sprawling, car-dependent suburban subdivisions through plat reviews. Gated communities and suburban style subdivisions were the dominant development pattern on Austin's urban-rural fringe, and many planning commissioners thought that those subdivisions were rapidly transforming Austin into another Dallas or Houston. Moreover, planning commissioners associated those low levels of street connectivity with increasing traffic volumes on the adjacent arterials and growing pressure to expand major arterials from two- to four- and six-lane thoroughfares. Planning commissioners viewed these high speed, multilane arterials as antagonistic to community livability and travel mode choice. Enhanced street connectivity was needed, the commissioners believed, to disperse vehicle traffic throughout the street system and thus to make better use of available street capacity and obviate the need for additional widening of arterials.

Rachael Rawlins, David Sullivan, and Gwynn Webb anchored the planning commission's connectivity efforts in a number of ways. They sought information on what other communities had accomplished to date and reviewed reports and training materials on street connectivity provided by professional design organizations. They met with development review staff and city service providers such as the fire department and EMS to work through concerns linked to enhanced street connectivity. Rawlins, a land- use attorney, drafted a proposed ordinance that eliminated much of the loose variance language from Austin's existing subdivision code, one of the main factors that motivated the commissioners to seek code revisions. The commissioners likewise felt that variances to the code's weak connectivity provisions were granted far too often. The commissioners' ordinance significantly strengthened those provisions but also made them as basic and straightforward as possible in order to ease their adoption, implementation, and application by staff.

The initial response from the city council was one of cautious interest. Several important questions were raised about potential costs and benefits and about how other cities had approached the issue. These concerns led the council to authorize a national study on street connectivity activity conducted by the Graduate Program in Community and Regional Planning at the University of Texas at Austin (UT-Austin) in March 1999 (Handy, Paterson, de Garmo, and Stanland 1999). However, it was also around this time that the Austin development community began expressing concerns about the proposed street connectivity ordinance, arguing that it would significantly increase their development costs. Consequently, several meetings were held among city planning commissioners, city staff, and representatives of local developers to work through those concerns.

Because the cost issue figured so prominently for the development community, a half-day workshop was conducted in June 1999 to explore what the connectivity requirements would mean for developers (this was not an inconsequential concern as Austin was experiencing an affordable housing problem by virtue of its rapid economic and population growth in the late 1990s). Representatives of the development community, the planning commission, local architects and planners, and city staff worked together to redesign two previously approved subdivisions using the proposed street connectivity standards. The workshop results suggested:

1. lot yields were higher in both redesigned subdivisions;
2. impervious cover remained constant in one subdivision while it increased by an estimated 21 percent in the second; and
3. costs were estimated to increase by approximately $335 per lot for one subdivision and an estimated $1,310 per lot in the second (Librach 2001).

The planning staff placed a major caveat on these findings, noting that they had been generated in a very short period of time and that no staff time had been devoted to verifying the unit-cost figures presented by the developers. Nevertheless, the development community and the city's Neighborhood Housing and Community Development Office staff stated that these figures presented unacceptable land development cost increases, especially in light of Austin's affordable housing problems (Hilgers 2000). Yet both parties agreed that greater street connectivity was an important public goal.

Planning commission members continued to meet with representatives for local developers through 2000 in an effort to find an appropriate middle ground. In addition, the UT-Austin Street Connectivity Study (Handy, Paterson, deGarmo and Stanland 1999) had been reviewed by the City of Austin Planning Staff and the Austin Planning Commissioners who shared the report and their own versions of an executive summary with the Austin City Council (Librach 2001). That report encompassed much of the material presented in Chapter 3 of this PAS Report, with the exception of data on practice-based experience since, by 1999, most localities had only recently adopted their ordinance. By early 2001, with the U.S. economy starting to enter its recessionary tailspin, discussion on the other important public benefits that might accrue from enhanced street connectivity had largely been eclipsed by the development community's housing affordability arguments. While the planning commission remained unified in its support of new connectivity measures, developers pushed the housing affordability issue in an attempt to turn city council opinion against these measures.

Members of the planning commission and the UT-Austin planning faculty collaborated to refine a proposed street connectivity ordinance that sought an economically neutral impact by including narrower street widths and new side street classifications.

Members of the planning commission and the UT-Austin planning faculty collaborated to refine a proposed street connectivity ordinance that sought an economically neutral impact by including narrower street widths and new side street classifications. When the draft ordinance finally came up for its first public hearing in February 2001, it consisted of the following requirements:

- require streets in new subdivisions to connect with existing streets;
- limit dead-end streets to only those cases where there are findings of fact that justify the use based on topography, environmental constraints, or similar circumstances;
- limit block lengths to 600 feet unless justified for topographical, environmental, or similar reasons;
- require pedestrian connections at mid-block where dead-end streets or longer blocks must be used;
- reduce residential street widths to slow traffic in residential areas; and
- prohibit gated subdivisions.

The city planning staff, however, offered the city council an alternative, incentive-based, street connectivity ordinance that was supported by the city manager, development community, and city's neighborhood housing officials. Under the incentive ordinance, which is largely voluntary, developers would gain a number of cost-saving benefits if the plat submissions met the shorter block lengths, limited dead ends, and improved pedestrian connection provisions found in the planning commission's proposed ordinance. The proposed benefits to the developers included:

- reduced residential street widths;
- reduced minimum lot sizes for some residential single-family zones;
- reduced front setbacks (from 25 feet to 15 feet);
- impervious cover allowances for increased street connections; and
- fee waivers and expedited subdivision and building review permits.

A guaranteed minimum level of connectivity would be achieved by requiring all new subdivisions to connect to existing streets and by prohibiting gated subdivisions.

At the urging of the planning commission's representatives, the city council did not vote on either ordinance in order to allow further negotiations with the development community, planning commissioners, and city staff (Rawlins 2003). The alternative incentive-based ordinance suffered from several flaws, according to the planning commission and UT-Austin planning faculty: (1) no effort was made to tighten loopholes in the city's existing subdivision variance language, which made street connectivity variances commonplace, and (2) an "optional" incentive ordinance had a strong possibility of not being embraced by the development community and therefore not being effective. The commission and faculty perceived this "optional connectivity" as especially pernicious: by making its requirements optional, they argued, the incentive ordinance undermined the fundamental notion of connectivity, which works best only when applied to a street system as a whole but which fails when interruptions—caused by a developer who refuses the incentives—are introduced.

As a result, negotiations continued for several more months among the planning commissioners, UT-Austin planning faculty, developers, and city planning and development review staff. These negotiations led to a substantially modified street connectivity ordinance that was both a "composite compromise" and a better reflection of the political and physical development constraints found in Austin. Probably the most important changes were (1) making the ordinance mandatory and (2) shifting from a single maximum block length to a sliding scale of maximum block lengths, based on lot size, to better reflect the variations in connectivity demands created by different housing densities and the vehicle trips they generate. The new proposed standards required a maximum block length of 600 feet in subdivisions with average lot sizes of 10,000 square feet or less; 800 feet in subdivisions with average lot sizes more than 10,000 square feet and less than 20,000 square feet; and 1,200 feet in subdivisions with average lot sizes of 20,000 square feet or more. In addition, a number of livable neighborhood street design criteria were added to the city's Transportation Criteria Manual to calm street traffic and make streets more pedestrian friendly (Austin 1994).

New provisions were also added to offset possible land development cost increases, including reduced paving widths for local streets, side streets, collector streets, and alleys; smaller minimum lot sizes; reduced front yard setbacks; and increases in maximum building and impervious cover. Yet even these changes needed further massaging to gain local political support. For example, the new minimum lot size provisions (reduced from 5,750 to 5,000 square feet) offered greater opportunity for increased lot yield in areas zoned for four dwelling units per acre or less. But this change raised the hackles of residents of inner-city neighborhoods who wanted no more density than they already had on remaining vacant lots. Thus, the proposed ordinance was changed so that the new connectivity and minimum lot standards would apply only to subdivisions of five acres or more.

Finally, UT-Austin planning faculty revisited the cost issue by reevaluating and redesigning the worst-case subdivision from the June 1999 workshop. The revised subdivision design revealed that the additional development costs per lot would actually be negligible. In fact, these costs were comparable with estimates made by Raleigh for its connectivity standards (see sidebar, Table 4.2, and Figures 4.1 and 4.2 for the side-by-side comparisons).

Despite these compromise measures and extensive new analysis, the city council failed to carry the proposed ordinance forward. Negotiations had begun to drag into the 2002 election cycle, and none of the council members seemed willing to take a stand on the issue prior to the encroaching electoral debates.

CONVENTIONAL PRACTICE VERSUS ENHANCED CONNECTIVITY STANDARDS
AUSTIN, TEXAS

The proposed enhanced street connectivity standards for Austin included several changes to the common practice of platting subdivisions with few connections to exterior streets and with very long interior block lengths. Increased connectivity would be achieved in the proposed standards through shorter spacing between points of ingress and egress as well as through shorter block and cul-de-sac lengths. At the same time, the impact on development costs would be mitigated with narrower minimum street and right-of-way widths and smaller minimum lot sizes.

In 2001, faculty in the Graduate Program in Community and Regional Planning at the University of Texas at Austin prepared a demonstration case study, shown in Figures 4.1 and 4.2 and documented in Table 4.2, in order to evaluate the impacts of the proposed standards. The Canterbury Trails subdivision, a recently platted development in suburban south Austin, was chosen as a worst-case example that would show significant improvements to connectivity under the proposed new standards. Importantly, this case study was expected to be an important test of the possible negative effects on land use (reduced lot yield) and monetary costs (increased lot cost) of the proposed standards.

City of Austin, Texas

Original Plan: Existing Conditions, Existing Rules

The Canterbury Trails subdivision contains 357 lots on 67.1 residential acres, with a net density of 5.3 lots per acre. Standard lot sizes range from 4,600 to 6,000 square feet, which is typical of close-in suburban developments in the Austin metropolitan area. Canterbury Trails has only two points of entry from an arterial roadway and no other connections to adjoining exterior collector streets, resulting in an average external street connectivity of 4,150 feet between points of ingress and egress. Five cul-de-sacs exist on a total of only seven residential blocks. With 25 nodes and 22 links, the network has a connectivity index value of 1.14, calculated via the method used in Cary, North Carolina (see Chapter 3 of this PAS Report). The average number of lots per block is 51, and the average block length is 1,560 feet.

Figure 4.1. Preliminary layout plan.

S. Vanka

Alternative Plan: Proposed Enhanced Connectivity Standards

The alternative plan for the subdivision, redesigned to meet the proposed enhanced connectivity standards, differs from the original in two primary ways.

First, the improvements in connectivity were dramatic, both externally and internally. Pedestrian connectivity increased with the introduction of 11 new pedestrian paths that must bisect longer-length blocks. External street connectivity improved from two points of access in the original plan to seven in the alternative plan, and the average spacing between external points of ingress/egress was reduced from 4,150 feet to 1,190 feet, a 71 percent decline. The redesign resulted in 42 links and 32 nodes, which bumped the connectivity index up 15 percent, from 1.14 to 1.31. The average block length was reduced by 56 percent, to 685 feet, and the lots-per-block average dipped 61 percent, to 20.

Figure 4.2. Alternative scenario with enhanced connectivity.

CONVENTIONAL PRACTICE VERSUS ENHANCED CONNECTIVITY STANDARDS AUSTIN, TEXAS *(continued)*

Second, the impacts on the cost of development were either modest or nominal, although some contention about the economic calculations still persists among the various interested parties. Costs were affected by changes in the lot yield and in the length and width of streets. In the alternative plan, the lot yield increased by 11 percent to 5.9 lots per acre, even with a 26 percent increase in total street length under the proposed standards, from 10,905 to 13,710 linear feet. This increased yield was attributable to the narrowing of street rights-of-way and reduced minimum lot size under the new standards. A financial model developed by the largest developer and home-builder in Austin, KB Homes, was used to calculate the resulting impacts on development costs. Total street construction costs increased from $1,436,000 in the original plan to $1,624,000 in the alternative plan, a rise of 13 percent. Importantly, though, the cost per lot for street construction under the alternative plan increased by only $80 or less than 2 percent, and the effect on total developed lot cost (considering land costs and other utility costs) increased by less than 0.4 percent—a statistically insignificant impact.

TABLE 4-2
CANTERBURY TRAILS SUBDIVISION: ORIGINAL PLAN VERSUS ALTERNATIVE PLAN

	Original Plan	Alternative Plan
Gross area (acres)	104.9	104.9
Commercial/multifamily use (acres)	11.36	11.36
Floodplain/open space (acres)	26.4	26.4
Net area of residential use (acres)	67.1	67.1
Number of residential lots	357	396
Typical lot size (square feet)	5,400	5,000
Minimum lot size (square feet)	4,600	4,500
Residential density (units/acre)	5.3	5.9
Range in street widths (feet)	30/36/40	20/26/36
Total street length (feet)	10,905	13,710
Total pedestrian path length (feet)	0	2,000
Total street surface area (square feet)	378,365	392,000
Number of access points into subdivision	2	7
Total number of blocks	7	20
Average number of lots per block	51	20
Total cost for street network	1,435,805	1,624,221
Total cost for streets, per block	4,022	4,102
Street network density (miles, square miles)[1]	19.7	24.7
Number of nodes	25	42
Number of links	22	32
Street connectivity ratio[2]	1.14	1.31
Average spacing between ingress/egress	4,150	1,190
Average block length (feet)	1,560	685
Average block length (number of lots)	51	20

1. Street network density: linear miles of street divided by square miles in development.
2. Street connectivity ratio: (number of links)/(number of nodes).

As of 2003, street connectivity issues continue to simmer and limited interest has been shown among some city council members to address the issue once again. Support among the planning commissioners, past and present, remains strong, but unlike the Raleigh case, Austin's city council leadership has not been strong.

COMPARING THE CASES

What lessons can cities learn from these cases? First, it seems clear that devoting staff time and energy to developing cost-benefit data is important to inform the public and policy makers about street connectivity trade-offs. Moreover, it seems clear that these cost-benefit data should be presented in terms that are locally relevant. In the Austin case, most cost-benefit information was conveyed in terms of data gleaned from other cities' experiences (as summarized in Handy et al. 1999), rather than Austin-specific examples. The primary locally generated data used in the discussions addressed the housing affordability issue, a very important issue for the city at that time. But these data cast almost all attention on the possible downside to the proposed connectivity standards rather than its possible benefits.

It seems clear that devoting staff time and energy to developing cost-benefit data is important to inform the public and policy makers about street connectivity trade-offs.

Second, sustained political and staff leadership is important as well. Raleigh's ordinance was clearly a city council initiative with strong staff support. City Council Member Charles Meeker, who later became mayor, was credited with showing the courage to suggest street connectivity code changes that were good for the city, even when unpopular with some of the neighborhoods (Howe 2003a). In Austin, the planning commission was the primary driving force, which was accompanied by modest city council support. The city planning staff found itself in an awkward middle ground with the mayor and other council members supporting an optional incentive-based approach to street connectivity, while the planning commission and some other city council members pushed for a stronger mandatory approach. The lack of city council direction led to difficulties within the city staff on where to concentrate their efforts. There was also a sense of urgency in the Austin case, as planning commissioners' recognized that a short "window of opportunity" where they could maintain their supporters and bring a negotiated solution to the city council before elections. Negotiations dragged on for too long, however, and the issue now awaits a second round of efforts.

Finally, these case studies demonstrate the importance of a continuous dialogue among the affected stakeholders. In Raleigh, numerous meetings were held with local design professionals to listen to their concerns and to explain the city's objectives. These meetings enabled the city to develop standards that improved street connectivity without creating undue hardship on the development community while at the same time realizing larger public benefits (Raleigh 1992; Howe 2003a). Likewise, all street connectivity information generated during the study and approval process was reviewed in public hearings and posted to the Internet for public review, and it is still posted today. The data were valuable in building support for the new street connectivity standards, and they continue to be a valuable information source whenever neighborhoods question the reasons for maintaining these standards (Howe 2003a). In Austin, an open dialogue and extensive negotiations did lead to a more refined and contextually sensitive street connectivity ordinance. But the final proposed ordinance may have also suffered from these negotiations: it became a much more complex ordinance that was less easy to sell to the city council and other stakeholders. Moreover, the failure to use the Internet to broaden the public discussion of the ordinance may have allowed narrow interest groups to dominate the discussion. Finally, it is also worth noting that the proposed Austin ordinance would have required a much higher level of connectivity than was required in the Raleigh case, which may also explain some of the development community resistance.

AFTERWORD

More to Think About

Although the effectiveness of street connectivity ordinances remains to be proved, cities are finding success in developing and adopting such ordinances, and planners believe they are beginning to make a difference. Only time—and concerted policy evaluation efforts—will tell if these ordinances succeed in meeting the goals of the communities that adopt them: decreased traffic on arterials, enhanced transit and nonmotorized travel, improved emergency services access and disaster evacuation, and more efficient utilities and other services. In the meantime, other communities hoping to improve street connectivity can draw on the initial experiences of the communities studied in this report. As connectivity efforts increase across the United States, several important issues merit further consideration. The questions in this chapter and the answers we offer focus on those issues.

What is the most appropriate way to measure connectivity? The block length requirement used by most communities so far has been easy to understand and simple to implement since it generally requires only a change to existing block length requirements in the city code. Alternately, the connectivity index allows greater flexibility in the design of street networks and serves as a performance standard in the development approval process. But these are not the only possible approaches and not necessarily the best. The fundamental goals of connectivity requirements are to increase the numbers of connections and the directness of routes. More direct measures of these goals include the number of intersections per mile of road (the converse of block length) and, even better, the ratio between network and straight-line distances. Researchers have frequently used these measures as a way of characterizing the structure of a street network (e.g., Hess 1997; Handy and Clifton 2001; Southworth and Ben Joseph 1997); but with the exception of Portland Metro, these measures have not yet been used in connectivity ordinances.

How much connectivity is the right amount? Although concern today is focused on the disconnected street networks found in conventional residential subdivisions, these networks evolved out of concerns over through traffic on residential streets in traditional grids. In countless grid neighborhoods built before World War II, barriers and diverters have been installed to discourage through traffic and force it onto arterials designed for higher levels of traffic; more recently, a number of communities have installed similar devices to deter crime. The differentiation of streets based on movement versus access functions is, arguably, essential for both accommodating and taming the car. But it is possible that this differentiation has gone far beyond what is necessary to achieve its purpose. The key for communities is to find an appropriate balance between minimizing traffic on residential streets and dispersing traffic throughout the network.

A traditional rectilinear grid may not be the only the way to achieve a community's objectives. . . . Experimentation with alternative, hybrid designs for street networks might produce a radically new approach to meeting connectivity objectives.

What is the best network design for achieving the desired level of connectivity? Although connectivity requirements have often been adopted as a part of an effort to promote traditional-style development, a traditional rectilinear grid may not be the only the way to achieve a community's objectives. As one planner noted, connectivity "does not have to be a uniform grid" (Mullen 1999). Most of the communities studied allow curves and nearly all allow cul-de-sacs in certain situations. Those using a connectivity index requirement offer the greatest degree of flexibility in the design of the street network since they focus on a network's performance rather than its shape. An examination of traditional neighborhoods built before World War II often reveals greater discontinuities than one might expect (e.g., Handy, Clifton, and Fisher 1998), and the street networks in most new developments labeled New Urbanist do not follow a perfect grid. Experimentation with alternative, hybrid designs for street networks might produce a radically new approach to meeting connectivity objectives. Peter Calthorpe has called for "a new paradigm of growth on undeveloped sites . . . [that] would match a new circulation system with the new forms of land use now emerging through the New Urbanism and Smart Growth movements" (Calthorpe 2002, 11). He argues for an alternative transportation network that is "diverse and complex" that "reinforces access to walkable neighborhoods and urban town centers" and that incorporates transit "in a way that is affordable, appropriately placed, and integral to the system" (pp. 12–13). Connectivity measures can help in this effort to create a new type of network if they shift the focus from the means to the end, from the structure of the network to its performance.

What does street connectivity mean for nonautomobile modes? Although several communities have included requirements for bicycle and pedestrian connectivity, the focus has clearly been on connectivity for cars. In general, improved connectivity for cars should lead to improved connectivity for bicycles and pedestrians, unless streets are designed in such a way as to be unfriendly to both. If separate facilities are provided, bicycle and pedestrian connectivity can be even greater than car connectivity. Mark Childs has promoted the concept of "live-end streets" (in contrast to dead-end streets) that link cul-de-sacs with pedestrian paths (Childs 1996). Transit connectivity can also benefit from improved connectivity in all modes, although the amount of improvement depends on the design of transit routes. By influencing the travel distances for each mode, connectivity requirements can have an important impact on mode choice. One could argue that if the goal is to reduce car use, connectivity should be maximized for bicycles, pedestrians, and transit but not for cars. The differences in connectivity, however, would have to be substantial to encourage a significant shift in mode choice. A model for such a strategy may exist: Davis, California, well-known as a bicycling community, encourages high levels of pedestrian and bicycle connectivity through a system of greenbelts but allows wide use of cul-de-sacs that tend to lower automobile connectivity (Figure A.1).

In general, improved connectivity for cars should lead to improved connectivity for bicycles and pedestrians, unless streets are designed in such a way as to be unfriendly to both.

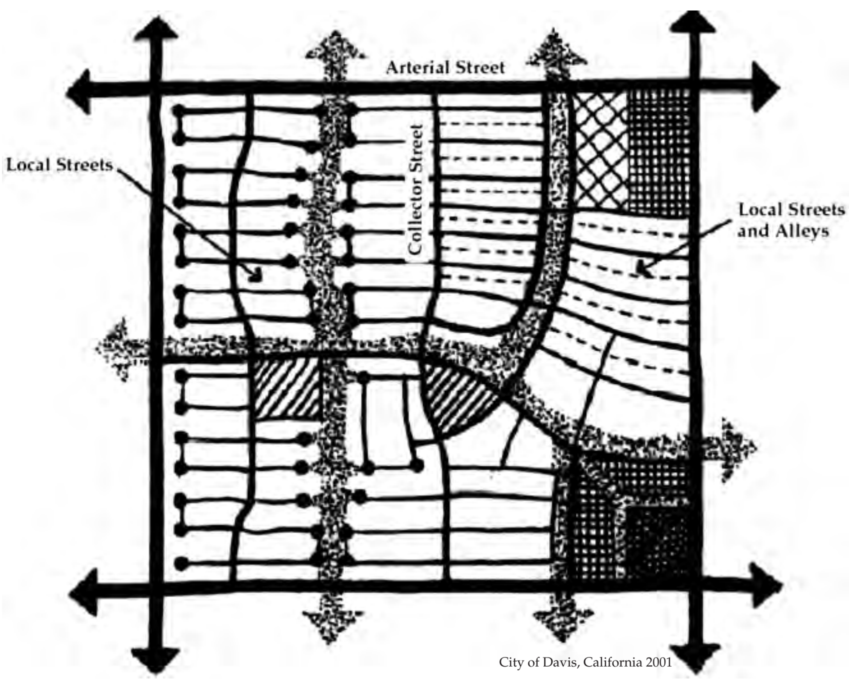


Figure A.1. Davis, California, encourages bicycling and walking through its greenbelt system and uses cul-de-sacs to discourage car use. This diagram shows a typical half-mile square.

How can connectivity in commercial areas be improved? Today's commercial areas are made up of a hodge-podge of disconnected strip malls and big-box stores. Shoppers cannot drive from one site to the next without using an arterial. Rarely are paths provided that would enable shoppers to walk between even neighboring paths. Office workers often have no choice but to drive to lunch or the bank, even when such services are located close by. In response to the traffic congestion that this form of development generates, some communities have made efforts to ensure connectivity between commercial sites. In San Antonio, Texas, for example, the city negotiates shared driveway arrangements with developers, a practice that helps keep the

Finding a way to retrofit existing developments may be the thorniest issue of all.

number of driveways along frontage roads within the limits set by the Texas Department of Transportation (Lewis et al. 1999). In Palm Beach County, Florida, the Board of County Commissioners may consider an ordinance that would require the linking of retail projects, a proposal that has been less controversial than an early proposal to require connectivity between residential developments (Gopaul 2002). Such efforts begin to address the problems engendered by prevailing design practices for commercial areas; they merit a study of their own.

What can be done about existing street networks? Finding a way to retrofit existing developments may be the thorniest issue of all. Infill developments and redevelopment projects can be used to increase local connectivity, but their overall effect is usually insignificant or at best marginal. Efforts to add bicycle and pedestrian paths to existing residential developments can generate considerable resistance from nearby residents. In the absence of the kind of power that Haussmann wielded in remaking the street network of mid-nineteenth-century Paris, cities will mostly have to make due with the street networks they have. But the permanence of such networks may provide the strongest case of all for increasing connectivity in the street network as it grows.

APPENDIX A

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APPENDIX B

Street Connectivity Codes

METRO REGIONAL GOVERNMENT FOR PORTLAND, OREGON, AREA

Code of the Metropolitan Service District

Urban Growth Management Functional Plan

Chapter 3.07

Title 6: Regional Accessibility

3.07.630 Design Standards for Street Connectivity

The design of local street systems, including "local" and "collector" functional classifications, is generally beyond the scope of the Regional Transportation Plan (RTP). However, the aggregate effect of local street design impacts the effectiveness of the regional system when local travel is restricted by a lack of connecting routes, and local trips are forced onto the regional network. Therefore, streets should be designed to keep through trips on arterial streets and provide local trips with alternative routes. The following design and performance options are intended to improve local circulation in a manner that protects the integrity of the regional system. Cities and counties within the Metro region are hereby required to amend their comprehensive plans and implementing ordinances, if necessary, to comply with or exceed one of the following options in the development review process:

A. Design Option. Cities and counties shall ensure that their comprehensive plans, implementing ordinances and administrative codes require demonstration of compliance with the following, consistent with regional street design policies:

1. For new residential and mixed-use development, all contiguous areas of vacant and primarily undeveloped land of five acres or more shall be identified by cities and counties and the following will be prepared, consistent with regional street design policies:

   A map that identifies possible local street connections to adjacent developing areas. The map shall include:

   a. Full street connections at intervals of no more than 530 feet, except where prevented by topography, barriers such as railroads or freeways, or environmental constraints such as major streams and rivers. Street connections at intervals of no more than 330 feet are recommended in areas planned for the highest density mixed-use development.

   b. Accessways for pedestrians, bicycles or emergency vehicles on public easements or right-of-way where full street connections are not possible, with spacing between full street or accessway connections of no more than 330 feet, except where prevented by topography, barriers such as railroads or freeways, or environmental constraints such as major streams and rivers.

2. New residential and mixed-use developments shall include local street plans that:

   a. Encourage pedestrian and bicycle travel by providing short, direct public right-of-way routes to connect residential uses with nearby existing and planned commercial services, schools, parks and other neighborhood facilities; and

   b. Include no cul-de-sac streets longer than 200 feet, and no more than 25 dwelling units on a closed-end street system except where topography, barriers such as railroads or freeways, or environmental constraints such as major streams and rivers, prevent street extension; and

   c. Provide bike and pedestrian connections on public easements or right-of-way when full street connections are not possible, with spacing between connections of no more than 330 feet except where prevented by topography, barriers such as railroads or freeways, or environmental constraints such as major streams and rivers; and

d. Consider opportunities to incrementally extend and connect local streets in primarily developed areas; and

e. Serve a mix of land uses on contiguous local streets; and

f. Support posted speed limits; and

g. Consider narrow street design alternatives that feature total right-of-way of no more than 46 feet, including pavement widths of no more than 28 feet, curb-face to curb-face, sidewalk widths of at least five feet and landscaped pedestrian buffer strips that include street trees; and

h. Limit the use of cul-de-sac designs and closed street systems to situations where topography, preexisting development or environmental constraints prevent full street extensions.

3. For redevelopment of existing land uses, cities and counties shall develop local approaches for dealing with connectivity.

B. Performance Option . For residential and mixed-use areas, cities and counties shall amend their comprehensive plans, implementing ordinances and administrative codes, if necessary, to require demonstration of compliance with performance criteria in the following manner. Cities and counties shall develop local street design standards in text or maps or both with street intersection spacing to occur at intervals of no more than 530 feet except where prevented by topography, barriers such as railroads or freeways, or environmental constraints such as major streams and rivers. Street connections at intervals of no more than 330 feet are recommended in areas planned for the highest-density mixed-use development. Local street designs for new developments shall satisfy the following additional criteria:

1. Performance Criterion: minimize local traffic on the regional motor vehicle system by demonstrating that local vehicle trips on a given regional facility do not exceed the 1995 arithmetic median of regional trips for facilities of the same motor vehicle system classification by more than 25 percent.

2. Performance Criterion: everyday local travel needs are served by direct, connected local street systems where:

   (1) the shortest motor vehicle trip over public streets from a local origin to a collector or greater facility is no more than twice the straight-line distance; and

   (2) the shortest pedestrian trip on public right-of-way is no more than one and one-half the straight-line distance.

PORTLAND, OREGON

Code of the City of Portland, Oregon
Title 33 Planning Code
Chapter 33.654
Rights-of-Way

33.654.010 Purpose

Rights-of-way provide for movement and access to, within, and through a land division site by pedestrians, bicycles, and motor vehicles. These regulations ensure that the right-of-way system will serve each lot in the land division. Where possible, the system will extend through the land division to reach adjacent sites. Constraints, such as steep slopes or environmental zones on or near the site, may influence the location or preclude connected rights-of-way. These regulations protect the public health and safety by ensuring safe movement and access for emergency and service vehicles.

33.654.110 Connectivity and Location of Rights-of-Way

A. Purpose. The regulations of this section ensure provision of efficient access to as many lots as possible, and enhance direct movement by pedestrians, bicycles, and motor vehicles between destinations. Direct routes for bicycles and pedestrians from residential areas to neighborhood facilities, such as schools and parks, are particularly important to increase the convenience of travelling by foot or bicycle. The specific location of rights-of-way is influenced by a variety of conditions, including existing development, streets and lot patterns, and environmental features.

B. **Where these regulations apply.** The following approval criteria apply to all local streets, alleys, and pedestrian connections within the land division site.

C. **Approval criteria.**

1. Through streets and pedestrian connections in OS, R, C, and E Zones. In OS, R, C, and E zones, through streets and pedestrian connections are required where appropriate and practicable, taking the following into consideration:
   a. Through streets should generally be provided no more than 530 feet apart, and pedestrian connections should generally be provided no more than 330 feet apart. Through street and pedestrian connections should generally be at least 200 feet apart;
   b. Where the street pattern in the area immediately surrounding the site meets the spacing of subparagraph a., above, the existing street pattern should be extended onto the site;
   c. Characteristics of the site, adjacent sites, and vicinity, such as:
      (1) Terrain;
      (2) Whether adjacent sites may be further divided;
      (3) The location of existing streets and pedestrian connections;
      (4) Whether narrow frontages will constrain creation of a through street or pedestrian connection;
      (5) Whether environmental overlay zones interrupt the expected path of a through street or pedestrian connection; and
      (6) Whether existing dwelling units on- or off-site obstruct the expected path of a through street or pedestrian connection. Alternative locations or designs of rights-of-way should be considered that avoid existing dwelling units. However, provision of through streets or pedestrian connections should take precedence over protection of existing dwelling units where the surrounding transportation system will be significantly affected if a new through street or pedestrian connection is not created;
   d. Master street plans for the area identified in Goal 11B of the Comprehensive Plan;
   e. Pedestrian connections should take the most direct route practicable. Users should be able to see the ending of the connection from the entrance point, if possible.
2. Dead-end streets in OS, R, C, and E zones. In OS, R, C, and E zones, dead-end streets may be provided where through streets are not required. Dead-end streets should generally not exceed 200 feet in length, and should generally not serve more than 18 dwelling units. Public dead-end streets should generally be at least 200 feet apart.
3. Pedestrian connections in I Zones. In I zones, pedestrian connections to all Regional Transitways, Major Transit Priority Streets, Transit Access Streets, Community Transit Streets, Off-Street Paths, and recreational trails within 1,300 feet of the site are required where appropriate and practicable. The connections should take the most direct route practicable. Users should be able to see the ending of the connection from the entrance point, if possible. Only the portion of the pedestrian connection that is on the land division site is required.
4. Alleys in all zones. Alleys may be provided where appropriate.

33.654.120 Design of Rights-of-Way

A. Purpose. The purpose of these standards and approval criteria is to ensure that the vehicle, bicycle, and pedestrian circulation system is designed to be safe, efficient, and convenient.

B. Non-local street standard. For streets other than local service streets, the Office of Transportation has approved the right-of-way width and all elements within the street right-of-way.

C. Local street approval criteria and standards. The following approval criteria and standards apply to all local service streets except for common greens:

1. Approval criterion for width of the right-of-way. The width of the local street right-of-way must be sufficient to accommodate expected users, taking into consideration the characteristics of the site and vicinity, such as the existing street and pedestrian system improvements, existing structures, and natural features.

2. Standard for configuration of elements within the right-of-way. For public streets, the Office of Transportation has approved the configuration of elements within the street right-of-way. For private streets, the Bureau of Development Services (BDS) has approved the configuration of elements within the street right-of-way.

3. Standards for turnarounds.

   a. When a turnaround is required. A turnaround is required on a dead-end street in the following situations:

      (1) The street will serve four or more lots;

      (2) The street is at least 300 feet long; or

      (3) When required by the City Engineer, the Fire Bureau, or BDS.

   b. Temporary turnaround. Where a street is temporarily terminating within the land division site, the City Engineer, BDS, or Fire Bureau may require a temporary turnaround.

   c. The following approval criteria and standard applies to permanent and temporary turnarounds:

      (1) Approval criteria. The turnaround must:

      - Be of a size to accommodate expected users, taking into consideration the characteristics of the site such as existing structures, natural features, the length of the street, and the number of housing units served by the street;
      - Minimize paved area;
      - Provide adequate area for safe vehicular movement; and
      - Provide adequate area for safe and convenient movement by bicyclists and pedestrians traveling on the street or traveling from the street to a pedestrian connection.

      (2) Standard. For public streets, the Office of Transportation has approved the configuration of elements within the turnaround right-of-way. For private streets, the Bureau of Development Services has approved the configuration of elements within the turnaround right-of-way.

D. Common green approval criteria and standards. The following approval criteria and standards apply to common greens:

1. Right-of-way.

   a. Approval criterion for width of the right-of-way. The width of the common green right-of-way must be sufficient to accommodate expected users and uses. The width must take into consideration the characteristics of the site and vicinity, such as the existing pedestrian system, whether a through pedestrian connection will be provided, structures, natural features, and the community activities that may occur within the street.

   b. Standards for configuration of elements within the right-of-way.

      (1) For public streets, the Office of Transportation has approved the configuration of elements within the street right-of-way. For private streets, the Bureau of

Development Services has approved the configuration of elements within the street right-of-way.

(2) Common greens must be dead-end streets. Through common greens are prohibited.

c. Standards for turnarounds. Turnarounds are not required for a common green.

2. Standards for land divisions with common greens. Land divisions that include a common green must meet the following standards:

a. The Fire Bureau has approved the land division for emergency access; and

b. Lots that have a front lot line on a common green must meet Section 33.266.110, Minimum Required Parking Spaces.

E. Pedestrian connections. The following approval criteria and standards apply to pedestrian connections:

1. Approval criterion for width of the right-of-way. The width of the pedestrian connection right-of-way must be sufficient to accommodate expected users and provide a safe environment, taking into consideration the characteristics of the site and vicinity, such as the existing street and pedestrian system improvements, existing structures, natural features, and total length of the pedestrian connection. As much as is possible, the users should be able to stand at one end of the connection and see the other end.
2. Standard for configuration of elements within the right-of-way. For public pedestrian connections, the Office of Transportation has approved the configuration of elements within the pedestrian connection right-of-way. For private pedestrian connections, the Bureau of Development Services has approved the configuration of elements within the pedestrian connection right-of-way.

F. Alleys. The following approval criteria and standards apply to alleys:

1. Approval criterion for width of the right-of-way. The width of the alley right-of-way must be sufficient to accommodate expected users, taking into consideration the characteristics of the site and vicinity such as existing street and pedestrian system improvements, existing structures, and natural features.
2. Standard for configuration of elements within the right-of-way. For public alleys, the Office of Transportation has approved the configuration of elements within the alley right-of-way. For private alleys, the Bureau of Development Services has approved the configuration of elements within the alley right-of-way.
3. Standard for turnarounds. The City Engineer, Bureau of Development Services, or Fire Bureau may require a turnaround on a dead-end alley.

BEAVERTON, OREGON

Development Code

Chapter 60 Special Requirements
60.55. Transportation Facilities

60.55.35. Street Connectivity Standards.

1. The Comprehensive Plan Functional Classification plan and Local Connectivity maps in the Transportation System Plan shall be used to identify potential street and accessway connections. The City may require additional connections to adjacent areas identified through the development review processes. Development shall include street plans, consistent with the requirements of this code, that provide for the following:

A. In new residential, commercial, and mixed-use development, local street connections shall be spaced at intervals of no more than 530 feet as measured from the near side right-of-way line, except where impractical due to physical or topographic constraints such as the spacing of existing adjoining streets, freeways, railroads, slopes in excess of City standards for maximum slopes, wetlands, or other bodies of water. Local street connections at intervals of no more than 330 feet shall be considered in areas planned for the highest density mixed-use development.

60.55.35.1.

B. Accessways shall be provided as required by this code for pedestrians, bicycles, and/or emergency vehicles on public easements or rights-of-way where full street connections are not possible, with spacing between full street or accessway connections of no more than 330 feet, except where impractical due to physical or topographic constraints such as freeways, railroads, slopes in excess of City standards for maximum slopes, wetlands, or other bodies of water.

2. For redevelopment of existing land uses, streets and accessways shall be provided as identified in the Comprehensive Plan and as required by this Code through the development review process.

60.55.40. Access Standards.

1. All lots shall abut a public street for a distance of at least 20 feet.
2. The number of access points on arterial and collector streets from any development shall be minimized whenever possible through the use of driveways common to more than one development and interior circulation design which furthers this requirement.
3. No new driveways for detached dwellings shall be permitted to have direct access onto an arterial or collector street except in unusual circumstances where access to a local residential street is not practicable. The decision-making authority, after considering a recommendation of the Facilities Review Committee, may approve detached dwelling access to an arterial or collector.
4. Neighborhood routes and local streets shall primarily provide driveway access in residential areas. Driveway access onto collector streets shall only be allowed for existing development and is discouraged in residential areas. On neighborhood routes and local streets that intersect with a collector or arterial, driveway access to the neighborhood route or local street shall not be allowed within 50 feet of the intersection with the arterial or collector street as measured from the near side right-of-way line of the intersecting collector or arterial to the near side edge of the driveway.
5. For development of land zoned R4, R3.5, R2, and R1, and the commercial, multiple-use, and industrial zones, access points shall minimize traffic congestion and minimize directing traffic onto local streets through areas zoned R10, R7, or R5. If a site can access a neighborhood route or a street of higher functional classification, one or more additional access points to residential local streets may be allowed. Direct connections to residential local streets may be allowed within 300 feet of an intersection of the local street and a collector or arterial roadway, or where a parcel abuts only residential local streets. If an access point is proposed more than 300 feet from an intersection with a collector or arterial roadway, an exception to this 300 foot standard may be approved by the City, based on an access and circulation report prepared by a registered professional engineer. Whenever feasible, access to the public street system shall serve more than one site, taking into account at a minimum, property ownership, surrounding land uses, and physical characteristics of the area. Reciprocal access easements between adjacent lots may be required.
6. Access street spacing shall be provided at the following standards:
   Access is measured from the near side right-of-way line.

. . .

60.55.70. Accessways.

1. Accessways shall be provided in accordance with City standards and shall be required for all development proposed after November 7, 1996, that meet the following:

A. In all zoning districts, any block which is longer than 750 feet or where indicated by the Comprehensive Plan, an accessway shall be provided through or near the middle of the block.

B. If any of the conditions described in Section 60.55.70.1.M result in block lengths longer than 1200 feet, then two or more accessways may be required.

C. In any zoning district where a street connection is not feasible pursuant to Section 60.55.70.1.M, a new accessway to an existing transit stop, a planned transit route, as identified by Tri-Met and the City, a school, shopping center, or neighborhood park shall be provided as a component of a development proposal if the addition of an accessway would reduce walking or bicycling distance by at least 50 percent over other available accessways and that the reduced walking or bicycling distance is greater than 400 feet.

D. In any zoning district, a new accessway to a school shall be provided as a component of a development proposal if the addition of an accessway would reduce walking or bicycling distance by at least 50 percent over other available accessways and that the reduced walking or bicycling distance is greater than 200 feet.

E. In any residential or industrial zoning district, a new accessway to an existing transit stop, a planned transit route, as identified by Tri-Met and the City, a shopping center, or neighborhood park shall be provided as a component of a development proposal if the addition of an accessway would reduce walking or bicycling distance by at least 50 percent over other available accessways and that the reduced walking or bicycling distance is greater than 400 feet.

F. In any commercial and multiple-use zoning district, a new accessway to an existing transit stop, a planned transit route, as identified, by Tri-Met and the City, a shopping center, or neighborhood park shall be provided as a component of a development proposal if the addition of an accessway would reduce walking or bicycling distance by at least 50 percent over other available accessways and that the reduced walking or bicycling distance is greater than 200 feet

G. For purposes of subsections A through F above, other available pedestrian connections include public sidewalks and walkways within shopping centers and planned developments. Connections may cross parking lots on adjoining properties if the connection is open to the public for pedestrian use, is a paved surface, and is unobstructed.

H. For retail, office, and institution development at or near a major transit stop, pedestrian connections shall be provided to connect building entrances with streets adjoining the site. Pedestrian connections to adjoining properties shall be provided except where such a connection is impracticable as provided for in this Code. Pedestrian connections shall connect the on-site circulation system to existing or proposed streets, walkways, and driveways that abut the property. Where abutting properties are undeveloped or have potential for redevelopment, streets, accessways, or both on site shall be stubbed to the property line to allow a future extension on to the adjoining property.

I. The City may require an accessway to connect from one cul-de-sac to an adjacent cul-de-sac or street.

J. Accessway connections shall be as short as possible and, wherever practical, straight enough to allow one end of the path to be visible from the other. Accessways shall be located to provide a reasonably direct connection between likely pedestrian destinations.

K. Accessways through parking lots shall be physically separated from adjacent vehicle parking and parallel vehicle traffic by curbs or similar devices, including landscaping, trees and lighting, if not otherwise provided in the parking lot design.

L. Accessways shall be lighted either by street lights on adjacent streets or pedestrian-scale lighting to a minimum level of 0.5 foot-candle along the connection. Lighting shall have cut-off fixtures so that no glare is emitted beyond the pedestrian connection and onto adjacent properties.

M. Accessways shall be provided consistent with the requirements of Section 60.55.30 (Street Design Standards) and the Engineering Design Manual and Standard Drawings, unless infeasible for any of the following reasons:

1. Physical or topographic conditions make an accessway connection impracticable. Such conditions include but are not limited to freeways, railroads, slopes in excess of City standards for maximum slopes, wetlands, or other bodies of water where a connection could not reasonably be provided;
2. Existing buildings or other development on adjacent lands physically preclude a connection now or in the future considering the potential for redevelopment; or
3. Where accessways would violate provisions of leases, easements, covenants, or restrictions written and recorded as of May 1, 1995.
4. An accessway will be not be required where the impacts from development, redevelopment, or both are low and do not provide reasonable justification for the estimated costs of such accessway.

2. Internal circulation systems

A. All development in commercial and multiple-use zoning districts and other development for which a conditional use approval is required, shall provide a system of pedestrian facilities that encourage safe and convenient pedestrian movement within the site. Pedestrian facilities shall also link the site with the public street sidewalk system. Walkways are required between parts of a site where the public is invited to walk. Walkways are not required between buildings or portions of a site which are not intended or likely to be used by pedestrians, such as truck loading docks and warehouses. Walkways are required as part of office/warehouse and retail/warehouse combinations.

B. Location: A walkway into the site shall be provided for every 300 feet of street frontage or for every eight aisles of vehicle parking if parking is located between the building and the street. A walkway shall also be provided to any accessway abutting the site.

C. Connections: Walkways shall connect building entrances to one another and from building entrances to adjacent public streets and existing or planned transit stops. On-site walkways shall connect with walkways, sidewalks, bicycle facilities, alleyways, and other bicycle or pedestrian connections on adjacent properties used or planned for commercial, multifamily, institution, or park use. The City may require connections to be constructed and extended to the property line at the time of development.

D. Routing: Walkways shall be reasonably direct. Driveway crossings shall be minimized. Internal parking lot circulation and design shall provide reasonably direct access for pedestrians from streets and transit stops.

FORT COLLINS, COLORADO

Land-Use Code

Article 3 General Development Standards

Division 3.6 Transportation and Circulation

3.6.3 Street Pattern and Connectivity Standards

(A) **Purpose**. This Section is intended to ensure that the local street system is well designed with regard to safety, efficiency, and convenience for automobile, bicycle, pedestrian and transit modes of travel. For the purposes of this Division, “local street system” shall mean the interconnected system of collector and local streets providing access to development from an arterial street.

(B) **General Standard.** The local street system of any proposed development shall be designed to be safe, efficient, convenient and attractive, considering use by all modes of transportation that will use the system (including, without limitation, cars, trucks, buses, bicycles, pedestrians, and emergency vehicles). The local street system shall provide multiple direct connections to and between local destinations such as parks, schools, and shopping. Local streets must provide for both intra- and inter-neighborhood connections to knit developments together, rather than forming barriers between them. The street configuration within each parcel must contribute to the street system of the neighborhood.

(C) **Spacing of Full Movement Collector and Local Street Intersections With Arterial Streets.** Potentially signalized, full-movement intersections of collector or local streets with arterial streets shall be provided at least every 1,320 feet or one-quarter (+) mile along arterial streets, unless rendered infeasible due to unusual topographic features, existing development, or a natural area or feature.

(D) **Spacing of Limited Movement Collector or Local Street Intersections With Arterial Streets.** Additional nonsignalized, potentially limited movement, collector or local street intersections with arterial streets shall be spaced at intervals not to exceed 660 feet between full movement collector or local street intersections, unless rendered infeasible due to unusual topographic features, existing development, or a natural area or feature.

The City Engineer may require any limited movement collector or local street intersections to include an access control median or other acceptable access control device. The City Engineer may also allow limited movement intersection to be initially constructed to allow full movement access.

(E) **Distribution of Local Traffic to Multiple Arterial Streets.** All development plans shall contribute to developing a local street system that will allow access to and from the proposed development, as well as access to all existing and future development within the same section mile as the proposed development, from at least three arterial streets upon development of remaining parcels within the section mile, unless rendered infeasible by unusual topographic features, existing development, or a natural area or feature.

The local street system shall allow multi-modal access and multiple routes from each development to existing or planned neighborhood centers, parks and schools, without requiring the use of arterial streets, unless rendered infeasible by unusual topographic features, existing development, or a natural area or feature.

(F) **Utilization and Provision of Sub-Arterial Street Connections to and from Adjacent Developments and Developable Parcels.** All development plans shall incorporate and continue all sub-arterial streets stubbed to the boundary of the development plan by previously approved development plans or existing development. All development plans shall provide for future public street connections to adjacent developable parcels by providing a local street connection spaced at intervals not to exceed 660 feet along each development plan boundary that abuts potentially developable or redevelopable land.

(G) **Gated Developments.** Gated street entryways into residential developments shall be prohibited.

(H) **Alternative Compliance.** Upon request by an applicant, the decision maker may approve an alternative development plan that may be substituted in whole or in part for a plan meeting the standards of this Section.

(1) Procedure. Alternative compliance development plans shall be prepared and submitted in accordance with submittal requirements for plans as set forth in this Section. The plan and design shall clearly identify and discuss the modifications and alternatives proposed and the ways in which the plan will better accomplish the purpose of this Section than would a plan which complies with the standards of this Section.

(2) Review Criteria. To approve an alternative plan, the decision maker must first find that the proposed alternative plan accomplishes the purposes of this Division equally well or better than would a plan and design which complies with the standards of this Division, and that any reduction in access and circulation for vehicles maintains facilities for bicycle, pedestrian, and transit, to the maximum extent feasible.

In reviewing the proposed alternative plan, the decision maker shall take into account whether the alternative design minimizes the impacts on natural areas and features, fosters nonvehicular access, provides for distribution of the development's traffic without exceeding level-of-service standards, enhances neighborhood continuity and connectivity, and provides direct, sub-arterial street access to any parks, schools, neighborhood centers, commercial uses, employment uses, and Neighborhood Commercial Districts within or adjacent to the development from existing or future adjacent development within the same section mile.

CARY, NORTH CAROLINA

Land Development Ordinance
Public Hearing Draft
7.10 Connectivity

7.10.1 Purpose and Scope
The purpose of this section is to support the creation of a highly connected transportation system within the Town in order to provide choices for drivers, bicyclists, and pedestrians; promote walking and bicycling; connect neighborhoods to each other and to local destinations such as schools, parks, and shopping centers; reduce vehicle miles of travel and travel times; improve air quality; reduce emergency response times; increase effectiveness of municipal service delivery; and free up arterial capacity to better serve regional long-distance travel needs.

7.10.2 Consistency With Other Documents

The design and evaluation of vehicular, bicycle, and pedestrian circulation systems built in conjunction with new residential and non-residential development shall adhere to the Town's Design Guidelines Manual, Downtown Design Guidelines, Cary Comprehensive Transportation Plan, and Standard Specifications and Details Manual, in addition to the meeting the requirements of this section.

7.10.3 Standards for Streets/On-Site Vehicular Circulation

The following standards shall be met in all new residential development in order to increase connectivity:

(A) Street Connectivity
Any residential development shall be required to achieve a connectivity index of 1.2 or greater unless the Planning Director determines that this requirement is impractical due to topography and/or natural features. In the event that this requirement is waived, a six-foot pedestrian trail shall be provided to link any cul-de-sacs within a residential development in which the required connectivity index has been waived. A connectivity index is a ratio of the number of street links (road sections between intersections and cul-de-sacs) divided by the number of street nodes (intersections and cul-de-sac heads).
The illustration [Figure 3.2 in this PAS Report] provides an example of how to calculate the index. Street links on existing adjacent streets that are not part of the proposed subdivision are not included in the connectivity index calculation. NOTE: The measure of connectivity is the number of street links divided by the number of nodes. Nodes exist at street intersections as well as cul-de-sac heads. Links are the stretches of road that connect nodes. Stub outs shall also be considered as links. In [Figure 3.2 of this PAS Report] there are 11 links (circles) and nine nodes (stars); therefore, the connectivity index is 1.22

(B) Street Arrangement

(1) The proposed public or private street system shall be designed to provide vehicular interconnections to all similar or compatible adjacent uses (existing and future) when such interconnections would facilitate internal and external traffic movements in the area. Such connections shall be provided approximately every 1,250 to 1,500 linear feet for each direction (north, south, east, west) in which the subject property abuts

similar or compatible uses. If the common property boundary in any direction is less than 1,250 linear feet, the subject property will be required to provide an interconnection if it is determined by the Planning Director that the interconnection in that direction can best be accomplished through the subject property. When the Planning Director deems a vehicular connection impractical, he/she can increase the length requirement and/or require pedestrian connections. The intent of this standard is to improve access/egress for Town neighborhoods, provide faster response time for emergency vehicles, and improve the connections between neighborhoods.

(2) Where new development is adjacent to vacant land likely to be divided in the future, all streets, bicycle paths, and access ways in the development's proposed street system shall continue through to the boundary lines of the area under the same ownership as the subdivision, as determined by the Planning Director or the Town Engineer, to provide for the orderly subdivision of such adjacent land or the transportation and access needs of the community. In addition, all redevelopment and street improvement projects shall take advantage of opportunities for retrofitting existing streets to provide increased vehicular and pedestrian connectivity.

(3) In general, permanent cul-de-sacs and dead-end streets are discouraged in the design of street systems and should only be used when topography, the presence of natural features, and/or vehicular safety factors make a vehicular connection impractical. Where cul-de-sacs or dead-end streets are unavoidable, development plans shall incorporate provisions for future vehicular connections to adjacent, undeveloped properties, and to existing adjacent development where existing connections are poor.

(4) Permanent dead-end streets or cul-de-sacs shall comply with the length limits and design standards set forth in the Town's Standard Specifications and Details Manual, and shall be provided with a turnaround at the closed street end.

(C) Cross Access

All non-residential development shall be designed to allow for cross-access to adjacent properties to encourage shared parking and shared access points on public or private streets. A minimum distance of 100 feet shall be required between a cross-access way and an intersection or driveway entrance. When cross-access is deemed impractical by the Planning Director on the basis of topography, the presence of natural features, or vehicular safety factors, this requirement may be waived provided that appropriate bicycle and pedestrian connections are provided between adjacent developments or land uses.

7.10.4 Standards for Pedestrian Facilities

(A) Sidewalks

. . .

(5) Where residential developments have cul-de-sacs or dead-end streets, such streets shall be connected to the closest local or collector street or to cul-de-sacs in adjoining subdivisions via a sidewalk or multi-use path, except where deemed impractical by the Planning Director.

HUNTERSVILLE, NORTH CAROLINA

Subdivision Ordinance

7.000 Subdivision Development Requirements

7.100 Design Standards for Streets

7.150 Cul-de-Sac

Cul-de-sacs (streets designed to be permanently closed at one end), may not be longer than 350 feet and must be terminated by a vehicular turnaround design as accepted by the Mecklenburg County Engineering Department; provided, however, that this requirement may be waived where topographical or other unusual conditions exist.

Zoning Ordinance

Article 5: Streets

Summary

Streets should be designed to suit their functions. Many streets, especially local ones, have purposes other than vehicular traffic. As an alternative to current N.C. Department of Transportation road standards, the following street designs are provided for non-state maintained streets within the municipal limits of Huntersville and for streets within the Extraterritorial Zoning Jurisdiction which will be maintained by the town upon annexation. Streets built to the standards of this section are eligible for town maintenance. Streets in Huntersville are to be inviting public space and integral components of community design. A hierarchical street network should have a rich variety of types, including bicycle, pedestrian, and transit routes. All streets should connect to help create a comprehensive network of public areas to allow free movement of automobiles, bicyclists, and pedestrians. In order for this street network to be safe for motorists and pedestrians, all design elements must consistently be applied to calm automobile traffic.

In summary, streets shall:

1. Interconnect within a development and with adjoining development. Culs-de-sac shall be allowed only where topographical and/or lot line configurations offer no practical alternatives for connections or through traffic. Street stubs shall be provided within development adjacent to open land to provide for future connections. The Land Development Map should be reviewed to locate potential connections in new neighborhoods.
2. Be designed as the most prevalent public space of the town and, thus, scaled to the pedestrian.
3. Be bordered by sidewalks on both sides, with the exception of rural roads, lanes, alleys, and the undeveloped edge of neighborhood parkways. Sidewalks on one side of the road may be permitted in the Rural zone as an incentive to protect water quality.
4. Be lined with street trees on both sides, with the exception of rural roads, lanes, alleys, and the undeveloped edge of neighborhood parkways. Private drives are permitted only as described in the Rural and Transitional zone.
5. Be public. Private streets are not permitted within any new development. Alleys will be classified as public or private depending on function, according to the street acceptance policy.
6. Be the focus of buildings. Generally, all buildings will front on public streets.

Intersections

Segments of straight streets should be interrupted by intersections designed to

a. disperse traffic flow and reduce speeds, thereby eliminating the creation of de facto collector streets with high-speed, high-volume traffic; and

b. terminate vistas with a significant natural feature, a building, a small park, or other public space.

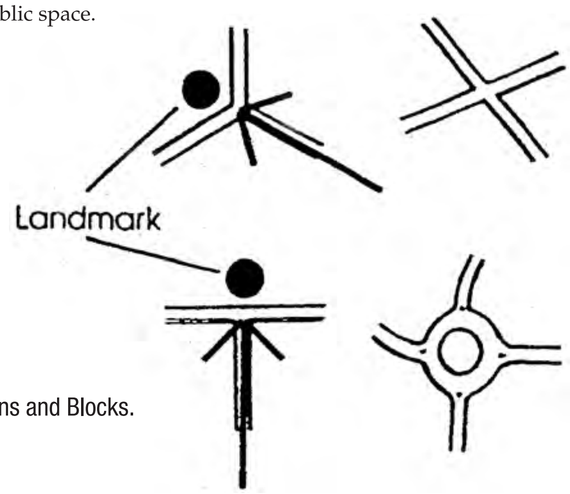


Figure B.1. Intersections and Blocks.

Other traffic calming measures such as neckdowns, chicanes, mid-block diverters, intersection diverters, curb bulbs, serial hill crests, and related devices will be considered on a case-by-case basis, based on safety and appropriateness in the proposed location.

Blocks

Street blocks defined by public streets are the fundamental design elements of traditional neighborhoods. In urban conditions, any dimension of a block may range from 250 to 500 linear feet between cross streets. In major subdivisions the dimension of blocks may not exceed 800 linear feet between cross streets. Within large-lot subdivisions the blocks may be up to 1,500 feet. The block pattern should continue to establish the development pattern at the project edge. Where a longer block will reduce the number of railroad grade crossings, major stream crossings, or where longer blocks will result in an arrangement of street connections, lots and public space more consistent with this Article and Article 7 of these regulations, the Town Board may authorize greater block lengths at the time of subdivision sketch plan review and approval.

Street Plan Types

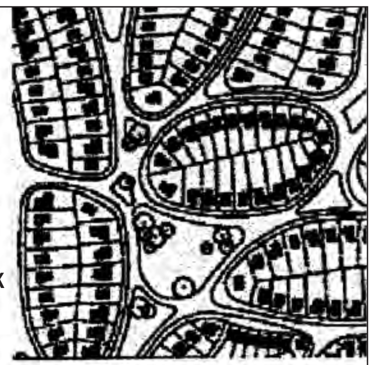
The layout of streets should provide structure to the neighborhoods. The formality of the street plan will vary depending upon site conditions and topography. Unique site conditions should be used to create special neighborhood qualities. The following are examples of street plan types, noting advantages and disadvantages.

Figure B-2. Street Plan Types.

ORGANIC NETWORK
NANTUCKET

Advantages
- Street hierarchy with main routes for through traffic
- Even dispersal of local traffic throughout network
- Responsive to terrain
- Responsive to environmental conditions
- Small scale suited to pedestrians

Disadvantages
- Variety of blocks and lots that do not conform to any overall plan.



CURVILINEAR NETWORK
RIVERSIDE, IL

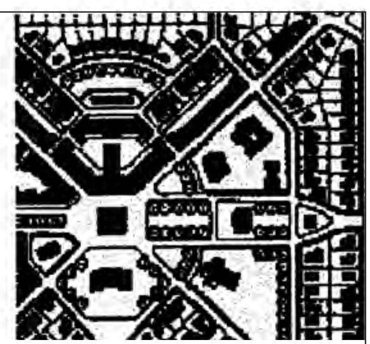
Advantages
- Avoids monotony by deflecting views
- Highly responsive to terrain
- Even dispersal of traffic through the network

Disadvantages
- Little directional orientation
- Uncontrollable variety of lots
- No natural hierarchy of street
- Lack of spatial definition

ORTHOGONAL GRID
SAVANNAH, GA

Advantages
- Excellent directional orientation
- Clear spatial definition
- Lot variety controlability
- Street hierarchy with en blocks for through traffic
- Even dispersal of traffic through grid
- Alleys for efficient double loading of service and for utilities

Disadvantages
- Monotonous unless periodicall interrupted
- Does not accommodate environmental interruptions
- Unresponsive to steep or special terrain



DIAGONAL NETWORK
MARIEMONT, OH

Advantages
- Street hierarchy with diagonals for through traffic
- Diagonals can respond to terrain
- Creates focal points at intersections
- Clear spatial definition

Disadvantages
- Some awkward block shapes at intersections of diagonals and regular grid

CORNELIUS, NORTH CAROLINA

Land Development Code

Section 7.1 General Street Design Principles

The Land Development Code encourages the development of a network of interconnecting streets that work to disperse traffic while connecting and integrating neighborhoods with the existing urban fabric of the Town. Equally as important, the Land Development Code encourages the development of a network of sidewalks and bicycle lanes that provide an attractive and safe mode of travel for cyclists and pedestrians. In addition to dispersing traffic, interconnecting street networks encourage alternate modes of transportation to the automobile, enhance transit service opportunities, improve traffic safety through promoting slower speeds, and potentially reduce vehicle miles traveled within the street network. The overall network function, and the comfort and safety of multi-modal or "shared" streets to slow and disperse traffic are primary to vehicular efficiency. It is the intent of this ordinance to build streets that are integral components of community design. Streets shall be detailed to complement neighborhoods and commercial centers and shall be pedestrian in scale. Street materials shall conform to the provisions of the Town of Cornelius Transportation Plan and Charlotte-Mecklenburg Land Development Standards Manual. Exceptions may be made for pedestrian crosswalks. Sidewalk material may vary according to the overall design and character of the development. Streets are encouraged to be designed with on-street parking. All streets shall be landscaped. In an effort to protect this investment, the Town views streets as the most important public space and therefore has developed a set of principles which permit this space to be used by both cars and people.

- Streets shall interconnect within a development and with adjoining development. Cul-de-sacs are permitted only where topographic conditions and/or exterior lot line configurations offer no practical alternatives for connection or through traffic. Street stubs should be provided with development adjacent to open land to provide for future connections. Streets shall be planned with due regard to the designated corridors shown on the Land Development Plan.
- Streets shall be designed as the main public space of the Town and shall be scaled to the pedestrian.
- Streets are designed to be only as wide as necessary to accommodate the vehicular mix serving adjacent land uses, while providing adequate access.
- Streets shall be bordered by sidewalks on both sides. The Board of Commissioners may grant exceptions upon recommendation by the Planning Board if it is shown that local pedestrian traffic on Minor Streets and other non-pedestrian-oriented streets warrant their location on one side only.
- Streets shall be designed with street trees planted in a manner appropriate to their function. Commercial streets shall have trees which complement the face of the buildings and which shade the sidewalk. Residential streets shall provide for an appropriate canopy, which shades both the street and sidewalk, and serves as a visual buffer between the street and the home.
- Wherever possible, street locations should account for difficult topographical conditions, paralleling excessive contours to avoid excessive cuts and fills and the destruction of significant trees and vegetation outside of street rights-of-way on adjacent lands.
- Whenever an irreconcilable conflict exists among vehicular and pedestrian usage, the conflict should be resolved in favor of the pedestrian unless in the best interest of public safety.
- All streets, whether publicly or privately maintained, shall be constructed in accordance with the design and construction standards in this code and shall be maintained for public access whether by easement or by public dedication.
- All street construction shall be in accordance with the Town of Cornelius Street Acceptance Policy.

- Street acceptance for public maintenance is at the discretion of the Town Board of Commissioners following submission of a petition for acceptance.
- Closed or gated streets are strictly prohibited.
- All on-street parking provided shall be parallel.
- Angle parking is permitted upon approval of the Board of Commissioners.
- The use of traffic calming devices such as raised intersections, lateral shifts, and traffic circles are encouraged as alternatives to conventional traffic control measures. Minor variations and exceptions to street engineering and design specified by the Town Board of Commissioners may be permitted. Such exceptions include variations to the pavement width, tree planting areas, street grade, sight distances, and centerline radii in accordance with principles above. Right-of-way widths should be preserved for continuity. All new streets shall be classified in accordance with the street hierarchy detailed in this Chapter. Farmhouse cluster subdivisions as privately maintained streets are exempt from these provisions.

Section 7.2. Street Engineering and Design Specifications

Where practical, a close should be used in place of a cul-de-sac. Cul-de-sacs, if permitted, shall not exceed 250 feet in length from the nearest intersection with a street providing through access (not a cul-de-sac). Cul-de-sacs shall be offset from the street centerline and shall form a square.

19. Connectivity

All or most proposed streets within the network shall form an interconnected pattern and shall connect with the adjacent street pattern. Connectivity shall be assessed by the ability to permit multiple routes, diffuse traffic, and shorten pedestrian walking distances. Alleys may be used to provide site access. Category 3 streets are generally found within the core area and near the perimeter of proposed development. A properly designed street network, unless prohibited by the existing street layout or topography should provide at least two routes of access to a given location. This affords a high level of accessibility for emergency vehicles and appropriate service routing for school buses and transit vehicles.

RALEIGH, NORTH CAROLINA

Urban Design Guidelines

General Street Design Principles

It is the intent of these guidelines to build streets that are integral components of community design. Streets should be designed as the main public spaces of the City and should be scaled to the pedestrian.

The Guidelines encourage the development of a network of interconnecting streets that disperse traffic while connecting and integrating neighborhoods with the existing urban fabric of the City. Equally as important, the Guidelines encourage the development of a network of sidewalks and bicycle lanes within the right-of-way that provide an attractive and safe mode of travel for cyclists and pedestrians.

Pedestrian-Oriented Streets have an activated public realm with formal landscaping where the building frontages open out to the sidewalk.

These Guidelines are applicable to all streets up to and including major thoroughfares, particularly those that enter a Mixed-Use Center. Streets that are within a Mixed-Use Center should be designed and posted as low-speed (20-35 mph) connectors.

. . .

5. Wherever possible, street locations should account for difficult topographical conditions, by avoiding excessive cuts and fills and the destruction of significant trees and vegetation outside of street-rights-of way on adjacent lands.
6. Closed or gated streets are strongly discouraged.

Streets, Sidewalks, and Driveway Access Handbook

3.2 Roadway Construction Through and Adjoining Developments

Dead-End Streets

Dead-end streets should be limited in use, serving residential and non-residential land uses that are expected to generate low traffic volumes. Unless an equally safe and convenient form of turning space is provided, dead-end streets shall terminate in a circular cul-de-sac. Dead-end streets shall conform to the design cross-sections shown in Section 4.2.

The maximum dead-end street length serving residential dwelling units shall not exceed 800 linear feet. The maximum dead-end street length serving non-residential uses shall not exceed 400 linear feet. The dead-end street length is measured from the center line of the intersecting street to the center of the circular cul-de-sac right-of-way. In cases where there is no cul-de-sac, the length shall be measured to the farthest point along the dead-end street from the intersecting street.

The Transportation Director may approve extra-long dead-end streets of up to 10 percent above the 800-foot (residential) and 400-foot (nonresidential) standards if a finding is made that there is no practical through extension possible due to severe topography or other physical features, or due to existing surrounding development.

. . .

3.6 Roadway Layout

The roadway layout of any development should be in conformity with a plan for the most advantageous development of the entire community. Public streets shall be constructed to the boundary lines of the development submitted for approval when required to provide for efficient circulation of traffic within the community.

Each side of a commercial street located within a Community or Neighborhood Focus Area as designated by the Comprehensive Plan, or a collector, residential, or minor residential street shall be intersected by at least one connective street within every 1,500-foot length of the street. The 1,500-foot length shall be measured from the origination point, if established, of the collector, commercial, residential, or minor residential street. If an intersection is located to interrupt a dominant traffic flow along two or more streets, then both streets are included in the calculation of the 1,500-foot length.

A development may be approved which contains a street(s) which does not meet the above layout or creates a violation of this layout if:

1) Existing surrounding development prevents extending a street to any adjoining developments to meet this regulation; or,

2) The adjoining existing street pattern or a planned "stub" street provides for an appropriate intersecting street beyond the 1,500-foot point, that would provide equivalent benefits as an intersecting street within 1,500 feet; or,

3) Severe topography or other physical features warrant making a connection of an intersecting street at another location either inside or outside the development to provide equivalent benefits as an intersecting street within a distance of 1,500 feet, and this other alternate specific location is provided for at the time the development making the request for an alternate location is approved.

Where a proposed development embraces a thoroughfare system roadway, it should be planned so that lots fronting on the roadway gain their access from collector system roadways or local access system streets.

Existing adjoining public streets, public platted streets, and publicly planned streets shall be continued and extended as public streets as part of the development. Streets that are not to be extended shall be terminated in a cul-de-sac in conformance with Section 4.2 of this manual.

Wherever there exists a dedicated or platted half street adjacent to the tract to be developed, the other half shall be platted and constructed.

Where a proposed development will extend a public street that is already stubbed out to the property line, such extension shall be a public street.

Where a through street or a series of streets establishes a connection between two public streets and such connection is greater than 1,200 feet in length or such connection may encourage through traffic not generated by the development, such street shall be a public street, except in instances where the approving authority determines that requiring such connection to be a public street will serve no purpose due to the existing or proposed street pattern, traffic flow, or traffic volumes.

Where a proposed development utilizing private streets has an area of 20 or more acres, at least one public through street must be provided in a location determined by the City to assure continuity of the public street system, except in instances where the approving authority determines that such public through street will serve no purpose due to the existing or proposed street pattern, traffic flow or traffic volume. The City may also require additional public through streets for the provision of emergency services such as police and fire protection, or to provide alternate circulation at congested or critical intersections.

Generally, streets should not be allowed in any conservation buffer district or a protective yard. A street in a conservation management district or a protective yard will be permitted when it is determined by the approving authority that a street will not be injurious to the public welfare and a street is necessary for traffic circulation of the entire neighboring area, provided further, that the street is located to minimize the disruption or destruction of the conservation management district or a protective yard.

. . .

4.13 Guidelines for Mixed-Use Centers

Mixed Use Centers as described in the Urban Design Guidelines approved by City Council on April 16, 2002, as may be amended, shall comply with all the following guidelines and roadway design crosssections that are in addition to the other requirements in the Handbook. Where a conflict in requirements exists, the stricter shall control. These guidelines shall apply to all streets within and bounding a Mixed-Use Center.

Street Interconnection

Streets should interconnect within a development and with adjoining development. Cul-de-sacs or dead-end streets are generally discouraged except where topographic environmental conditions and/or adjoining development patterns offer no practical alternatives for connection or through traffic. Street stubs shall be provided with development adjacent to open land to provide for future connections.

Private or gated streets are strongly discouraged within Mixed-Use Centers.

Within a Mixed-Use Center, an interconnected pattern of public connective streets shall be established, such that no street block face shall exceed 660 feet in length.

Each side of a public collector, commercial, residential collector, residential or minor residential street within a Mixed-Use Center shall be intersected by at least one connective street within every 660-foot length of the street. The 660-foot length shall be measured from the centerline of the intersecting streets. If an intersection is located that interrupts a dominant traffic flow along two or more streets, then both streets are included in the calculation of the 660-foot length.

Streets shall be interconnected so that any area within the Mixed-Use Center completely enclosed by public streets does not exceed ten acres.

A development may be approved which contains a street(s) in excess of 660-foot length (without an intersection on each side with a connective street or enclosing more than ten acres) if:

1) The existing adjoining and surrounding development prevents extending a street, or severe topography or other physical features warrant a longer street length, and this alternative location, whether inside or outside the development, is provided for at the time the development making the request is approved; or,

2) The existing street pattern provides equivalent benefits as a 660-foot block length in terms of traffic dispersal, and pedestrian access to uses within and outside the mixed-use center.

Driveways and Cross-Access

Each property containing or designated for nonresidential, apartment house, or group housing uses should provide at least one vehicular access to each abutting property. This is most often accomplished by joining adjacent parking lots and sharing driveways. Development plans should provide a cross-access easement and complete the connection if an immediate benefit can be derived by completing the link. If no immediate benefit can be derived, development plans should provide cross access and construction easements and arrange the site design so when the adjoining property owner extends the connection to the property line, the link will be completed. If the link is to be completed in the future, the grade of the connection, parking, landscaping and other improvements must be set to allow for extension into the adjacent lot.

Whenever possible, internal access drives should be located to join together existing public streets and/or connect to adjacent private drives so that the internal circulation functions as an integral part of the surrounding transportation network.

Developments should minimize or eliminate curb cuts along adjacent streets. Where possible, vehicular access should be shared with the adjacent properties and/or alleys should be used for access.

Transit

To facilitate transit usage and circulation, Mixed-Use Centers should provide transit stops at key nodes with easy access to the surrounding thoroughfares. Transit routes through the Mixed-Use Center shall be designed to accommodate the technical requirements of bus operations. Transit easements through and within mixed use centers shall be provided as requested by the Transportation Director. A coherent and easily maneuverable path through the Mixed-Use Center should be designed to permit transit to move freely and efficiently throughout the mixed-use center.

ORLANDO, FLORIDA

Southeast Orlando Sector Plan

Development Guidelines and Standards

Circulation Guidelines and Standards

Connectivity Index

Accessibility and connectivity are complementary concepts. In accordance with GMP Future Land Use Policy 4.2.5, and consistent with the GMP Transportation Element, the City shall combine the mobility of the traditional interconnected street pattern with the safety, security, and topographic sensitivity of the conventional or contemporary network. Such a hybrid network features short, curved stretches that follow the lay of the land or contribute to good urban design, as well as short loops and cul-de-sacs, so long as the higher-order street network is left intact. "Higher-order" means arterials, collectors, and sub-collectors that carry through traffic. An acceptable individual project master plan may feature interrupted grids of short street ending at T or Y intersections, traffic circles or squares/parks. By design, local streets may carry some through-traffic, but the truncated nature of local streets means that traffic moves more slowly and the heaviest volumes are diverted to higher-order streets. A simple measure of connectivity is the number of street links divided by the number of nodes or link ends (including cul-de-sac heads). The more links relative to nodes, the more connectivity. A connectivity index of 1.4 to 1.8 represents an acceptable street network in the Southeast Plan area. The optimal connectivity index for a perfect grid network is 2.5. This is the procedure for calculating the connectivity index:

1. Count the number of nodes. Nodes are any point of intersection of two or more roads or any cul-de-sac ends. There are eight nodes in the example (counting only the black nodes). [For example, see Figure 3.3 in this PAS Report.]

2. Count the number of links. Links are the segments of road connecting nodes. To properly calculate the connectivity index, you must include the first link beyone the last nodes. There are 12 links in the example (ignoring the dashed lines).
3. Use the following formula to calculate the connectivity index: links/ nodes = connectivity index. The connectivity index of the example is 12/8 = 1.5.

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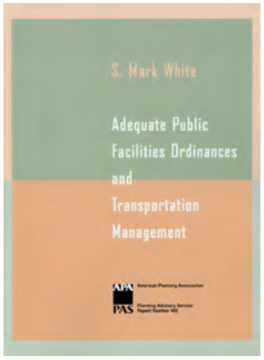
# of special interest

Transportation/Land-Use Connection

PAS 448/449. Terry Moore and Paul Thorsnes. 1994. 137 pp.

The land-use changes enabled by better roadways and encouraged by public policies rapidly increased travel demand. According to the authors of this report, the best answer to traffic congestion is integrating land use and transportation at the regional level. The report looks at ways to identify and measure interactions between land use and transportation, reviews current research in this area, and makes recommendations for change.



Adequate Public Facilities Ordinances and Transportation Management

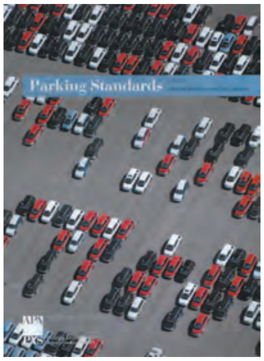
PAS 465. S. Mark White. 1996. 79 pp.

We need to look no further than our perennially congested roads to see that traditional transportation management strategies just aren't working. Traffic congestion plagues the residents of many U.S. communities more and more each year. This report will help all planners seeking practical solutions to this escalating problem. It shows how to use concurrency management or adequate public facilities ordinances (APFOs) to coordinate the traffic generated by new development with the availability of existing transportation facilities. It relies on regulatory tools already exercised by local governments—development permits and capital budgeting powers. The report also explains how to prepare an APFO that will stand up to legal tests.

Creating Transit-Supportive Land Use Regulations

PAS 468. Marya Morris. 1997. 72 pp.

Planners are challenged to balance the diverse—and sometimes competing—needs of drivers, walkers, bicyclists, and public transit riders. Here is a comprehensive collection of codes, standards, and designs that forward-thinking communities of all sizes have used to create more balanced transportation systems. Topics include transit- and pedestrian-friendly site design, parking, mixed-use development, and support densities and incentives.



Parking Standards

PAS 510/511. Michael Davidson and Fay Dolnick, eds. 2002. 181 pp.

This new report, an expanded and updated version of a previous best seller, contains not only an exhaustive set of parking standards, but also a section dealing with the complexities of creating practical parking standards in the present-day U.S. For instance, there is general agreement in recent planning literature that when the supply of parking greatly exceeds typical demand, the results are detrimental to a range of stakeholders. However, while benefits may accrue from minimizing the amount of off-street parking, downsizing parking requirements may be a tricky proposition because many communities fear detrimental impact on overall community development objectives. The commentary in this report addresses that quandary, as well as techniques like shared parking, maximum parking standards, downtown parking standards, and more.

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