MEMORANDUM

Date:	July 10, 2009	**TG:**	08164.00
To:	Terry Moore, ECONorthwest		
From:	Andrew Mortensen, Transpo Group		
cc:			
Subject:	Street and Non-Motorized Connectivity		

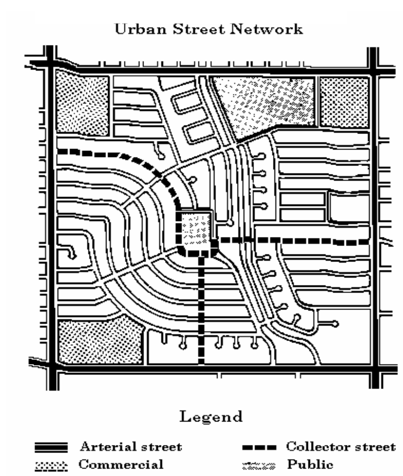
This memorandum provides context to the subject matter of street and non-motorized system connectivity. It was originally written as a broad summary for application in various transportation planning studies. It has been modified slightly for better summary of concepts critical to the transportation plan and policy subject matter considered in the Motorized and Non-Motorized Travel Reports as part of the Olympia Mobility Strategy project. The memorandum includes four major sections:

1. Introduction
2. Importance of Connectivity
3. Barriers to Connectivity
4. Travel Impacts Associated with Connectivity
5. Implementing Connectivity

Introduction

In the early 1960's a federally driven process was initiated to establish the first set of consistent, street functional classification plans for U.S. cities. These plans and policies were updated and revised in the 1970's as Metropolitan Planning Organizations (MPOs) were formed to assist in regional transportation planning. Most regional and many local roadway and street functional classification policies originated from the FHWA Functional Classification guidelines[1]. As noted in the FHWA guideline for urban streets and shown in **Figure 1**, collectors are mapped on an internal, 1-mile grid to essentially provide ½ or 1/3-mile connection between local streets and the perimeter arterials, which form the grid boundary. FHWA's original 'scheme" does not indicate nor did the underlying policy direction emphasize external continuity of collector and local street connectors beyond the arterial-bound grid.

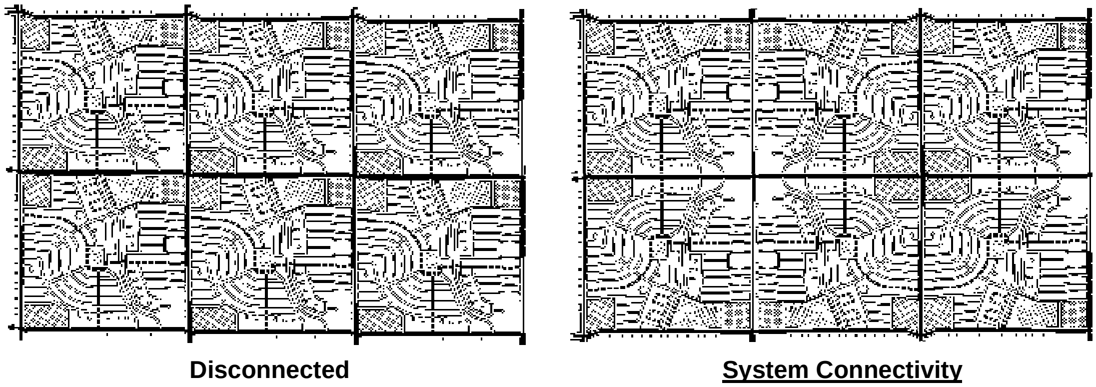
Figure 1: FHWA Scheme



Since the 1960s, and up until the 1990s, many cities have favored a land development pattern and street hierarchical network of poor connectivity, with numerous cul-de-sacs that connect to a few major arterials. This paradigm is compounded further by local connectivity issues: environmental constraints (topography, rivers, sensitive lands, etc), and lack of policy and planning regulations that require greater connectivity. As illustrated in **Figure 2**, the unintended outcome of the FHWA functional classification model, lax local standards, and environmental constraints can lead to serious street system discontinuity.

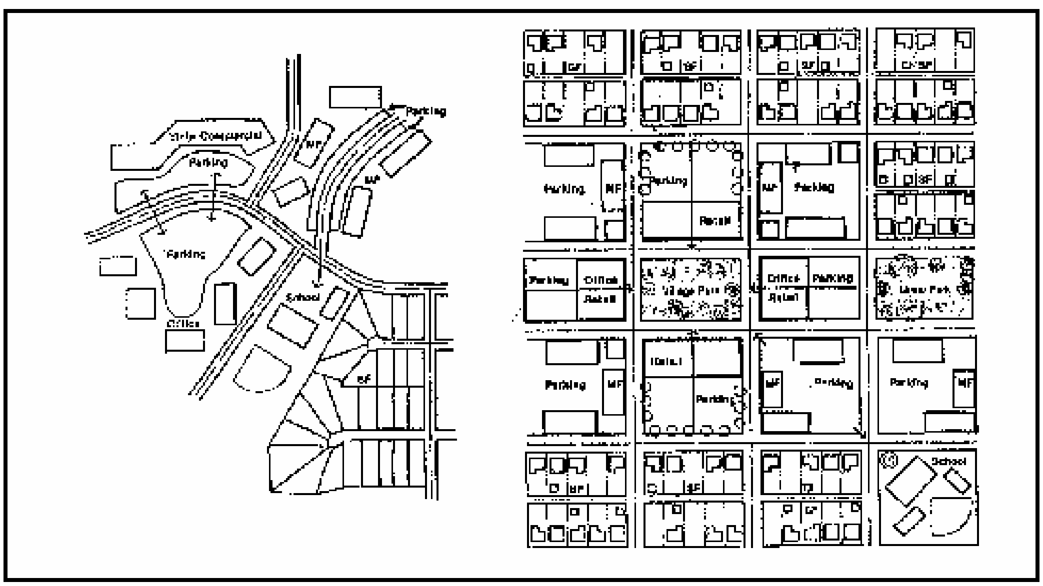
The consequence of this paradigm results in additional travel required (for all modes) to reach destinations, concentrates traffic onto fewer roads, and creates barriers to non-motorized travel.

Figure 2. Street System Paradigms



As shown in **Figure 3**, U.S. cities have seen two distinct street patterns emerge over time: hierarchical and connected networks. A connected street network, typical of pre-1960's and now Smart Growth system development emphasizes accessibility and accommodates more direct travel with traffic dispersed over more streets. The hierarchical street network emphasizes mobility by accommodating higher traffic volumes and speeds on streets. Smart Growth land use and transportation policies support improved connectivity as a way to increase land use accessibility. For a particular development or neighborhood, connectivity applies both internally (streets within that area) and externally (connections with arterials and other neighborhoods).

Figure 3. Hierarchical and Connected Road Systems[2]



The hierarchical road system, illustrated on the left, has many dead-end streets and requires travel on arterials for most trips. A connected road system, illustrated on the right, allows more direct travel between destinations, offers more route options, and makes non-motorized travel more feasible.

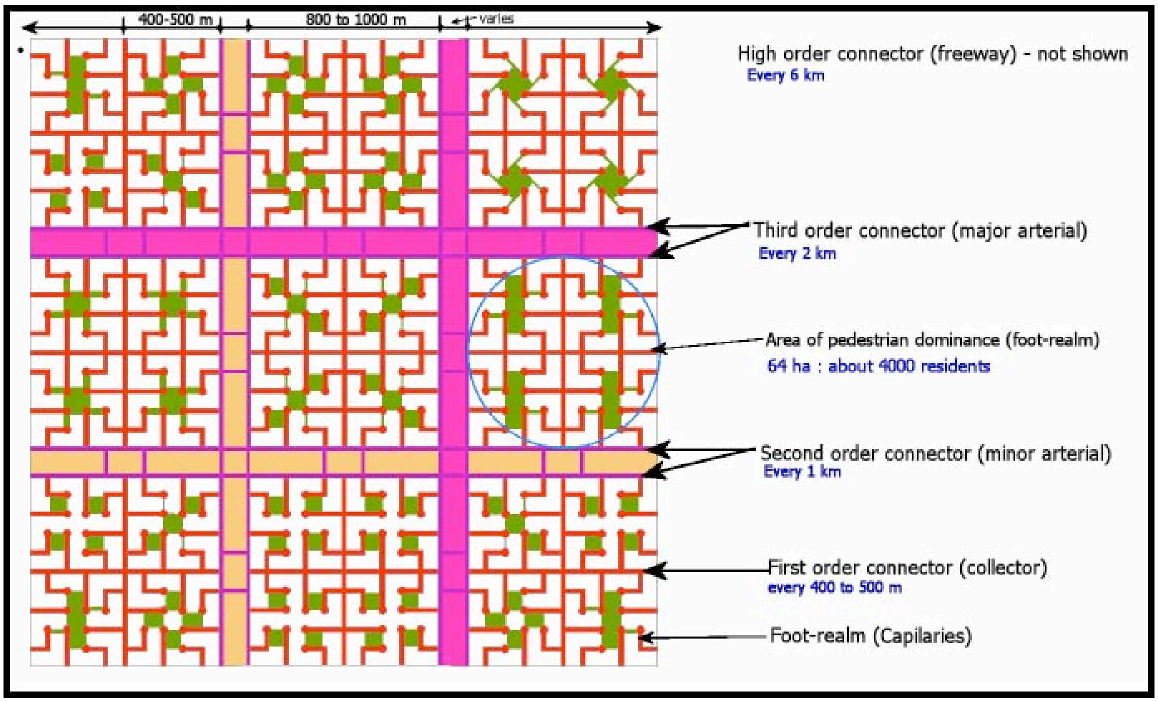
Many parts of this memorandum include original research summaries from three key professional experts: Phil Langdon[3] and Todd Littman[4] for street connectivity, and Jennifer Dill[5] for non-motorized connectivity.

Importance of Connectivity

The notion of connectivity refers to the directness of segments and the density of connections (intersections) in non-motorized paths or street networks. A well-connected street system or pathway network has many short links and intersections, and minimal dead-ends (cul-de-sacs). As connectivity increases, travel distances decrease and route options increase, allowing more direct travel between destinations, creating a transportation system that is more accessible, especially for pedestrians and bicyclists.

A Fused Grid[6] street design, as shown in **Figure 4**, uses public squares at the end of cul-de-sac streets to provide pedestrian and cycling connections that are closed to vehicle traffic. This helps improve community livability and encourage non-motorized transportation. Many cities are practicing these principles within the built environment as retrofit measures to develop important pedestrian and bicycle connections between neighborhoods that are essentially fenced from each other by the original street design and layout.

Figure 4. Fused Grid



A Fused Grid street network uses greenspace to connect cul-de-sac ends, improving connectivity for non-motorized travel (walking and cycling).

Improved street connectivity can provide a variety of benefits through measures to improving accessibility with increased route options, improving walkability and reducing vehicle travel. Improved connectivity tends to increase transportation system performance by increasing route options. It improves emergency response by allowing emergency vehicles more direct access, and reduces the risk that an area will become inaccessible if a particular part of the street network is blocked. A more connected street system allows a fire station to serve about three times as much area as in an area with unconnected streets.

Increased street and non-motorized path connectivity reduces per capita vehicle travel and improves overall accessibility, particularly for non-drivers. It can therefore help reduce traffic congestion, accidents and pollution emissions, and improve mobility for non-drivers. It tends to be particularly effective at achieving TDM objectives where the connectivity of alternative modes is improved more than that of private automobile travel, for example, by providing pedestrian and bicycle shortcuts, or implementing traffic calming measures to control vehicle traffic.

Barriers to Connectivity

There are several barriers that either prevent or discourage development of desirable and complete street networks. Some are more critical than others. Some barriers may simply not be overcome.

1. Street Service Life

Without regular maintenance, street pavement lasts 20-30 years before reconstruction is required. For some streets, originally constructed to auto-oriented design standards, it may take years to establish bicycle, transit and some pedestrian features as part of a major reconstruction project.

Further, right-of-way may be constrained by patterns of existing development which has a life cycle of its own. When individual developments are proposed, or local capital projects are developed, many designers look to adopted standards as the sole source for guidance. This works well if the street design standards are "complete," with emphasis on multi-modal access and mobility. This doesn't work well when street standards are auto-dominant. The result: projects often do not upgrade facilities with better sidewalks or bike lanes or transit features unless standards require them.

2. Limited Funding

Funding constraints come in several forms:

- Insufficient resources available at federal, state and local levels (this is almost universally true, as even the most comprehensive and solvent funding programs usually do not cover every Plan's list of needed improvements) - more funding would make multi-modal transportation services and choices more widely available.
- Most funding processes (MPO/STIP or local CIP) allocate by project rather than by network; once detailed planning begins, focus is on corridor, not network.
- Some funding eligibility is restricted to functional classification (federal); more so are restricted by mode (federal, state and local).
- In general, the Public does not understand the true cost of transportation.

3. The Land Use / Development and Transportation Decision Making Disconnect

- Transportation modal decision making is often also disconnected; network connections are especially essential for pedestrians, but not prioritized since pedestrians are not prioritized.
- Detailed (transportation) planning and problem solving is often on a single-issue, project basis; this tends to neglect or de-emphasize a network approach.
- Environmental analyses are performed by project rather than cumulatively over networks; positive network effects often overlooked.

4. The Value of Street Networks and Connectivity is Not Understood

- Predominant, negative perception of networks as fostering increased traffic and declining safety.
- Insufficient documentation to the benefits of extensive street networks.

5. Outdated codes and ordinances proliferate ineffective planning and implementation.

6. Existing development patterns

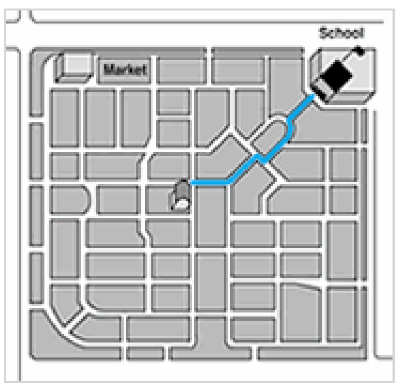
- It is difficult to require network connections between new developments and existing developments that are “closed”

7. Topographic and environmental barriers

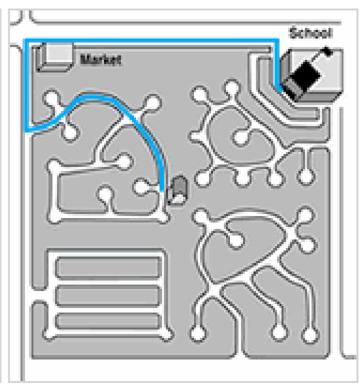
8. Superblock and large footprint developments

- Developers often argue for closing existing blocks of streets, subtracting from existing networks
- Large new developments often do not include network components.
- Incorrect perception that limiting network and access will control traffic problems.

Natural features such as rivers and manmade features like highways and freeways often serve as or create barriers to direct local travel, particularly for bicycle and pedestrian travel. Albeit expensive, there are design strategies that can help improve connectivity across such barriers, including special bridges or sometimes under crossings (freeways).

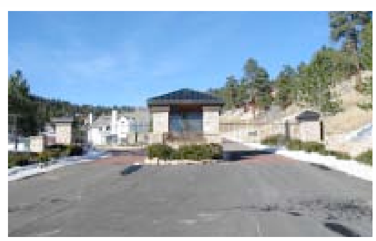


Street Connectivity - Many Options



Lack of Connectivity - Few Options

The larger, more system-wide opportunity to increase connectivity is at the land use subdivision and planning level – overcoming the common preference for residential cul-de-sac streets. Cul-de-sacs have been popularized because they have limited traffic volumes and speeds, and are perceived to create a sense of security. More connected residential streets can have these attributes if designed with short blocks, “T” intersections, narrower widths and other traffic calming features to control vehicle traffic speeds and volumes, and community design features to promote a sense of community and Security. Another objection to a connected street network is that it requires more road right-of-way land, but this is often offset by reducing street widths.



The extreme, unconnected street and pathway network is the gated community, a development or neighborhood surrounded by a fence, with access restricted to residents and their guests. Gated communities reduce street connectivity for residents and others, resulting in increased motor vehicle travel and reduced non-motorized accessibility[7] [8].

Even within some traditional residential neighborhoods some residents view connectivity as a potential threat to their safety.

Travel Impacts Associated With Connectivity

Connectivity and Travel Mode Share

Increased street connectivity can reduce vehicle travel by reducing travel distances between destinations and by supporting alternative modes. Increased connectivity tends to improve bicycling and walking conditions where paths provide shortcuts, so walking and cycling are relatively faster than driving. This also supports transit use.

The SMARTRAQ[9] Project analysis in Atlanta, Georgia found that doubling the current regional average intersection density, from 8.3 to 16.6 intersections per square kilometer reduces average vehicle mileage by about 1.6%, causing a reduction from about 32.6 to about 32.1 average weekday per capita (16+ years old) vehicle miles in the region, all else held constant. The LUTAQH (Land Use, Transportation, Air Quality and Health) research project sponsored by the Puget Sound Regional Council (www.psrc.org) also found that per household VMT declines with increased street connectivity, all else held constant. That study indicates that a 10% increase in intersections per square mile reduces VMT by about 0.5%.

Traffic modeling by Alba and Beimborn[10] finds that improved local street connectivity can reduce traffic volumes, and therefore traffic congestion, on major arterials. Traffic modeling by Kulash, Anglin and Marks[11] predicts that a connected road network reduces VMT within a neighborhood by 57% compared with conventional designs, although neighborhood travel only represents 5-10% of total vehicle travel, and shorter trip distances may be offset somewhat by increased trips.

A U.S. EPA study in 2004[12] found that increased street connectivity, a more pedestrian-friendly environment and shorter route options have a positive impact on performance, (per-capita vehicle travel, congestion delays, traffic accidents and pollution emissions). The U.S. EPA Smart Growth Index describes a methodology for calculating the effects of increased roadway connectivity on vehicle trips and vehicle travel. However, current models are not very accurate at predicting how a particular change in roadway connectivity will affect travel patterns. Where other factors are conducive (a neighborhood contains services such as schools and stores, walking conditions are adequate, and there are incentives to use alternative modes), increased roadway connectivity can probably reduce total per capita vehicle mileage by a few percent (Land Use Impacts on Transport).

Studies in the Puget Sound area by Lee and Moudon[13] concluded with four land use and transportation factors associated with walking, and reducing auto trips (measured as VMT per capita):

Density	residential units within 1 kilometer of household
Destinations	grocery stores, restaurant, retail, schools nearby
Distance	to key destinations
Route	smaller blocks, more prevalent sidewalks (measures may include % 4-legged intersections and % sidewalk completion along streets)

The combination of these factors can have as much as 35% reduction in person miles traveled, the majority of which is undertaken by the predominant mode: auto (either as drive-alone or shared-ride).

Several other research findings all support the notion that well-connected street/transportation networks in urban neighborhoods generate more walking and bicycling and fewer auto trips[14] [15].

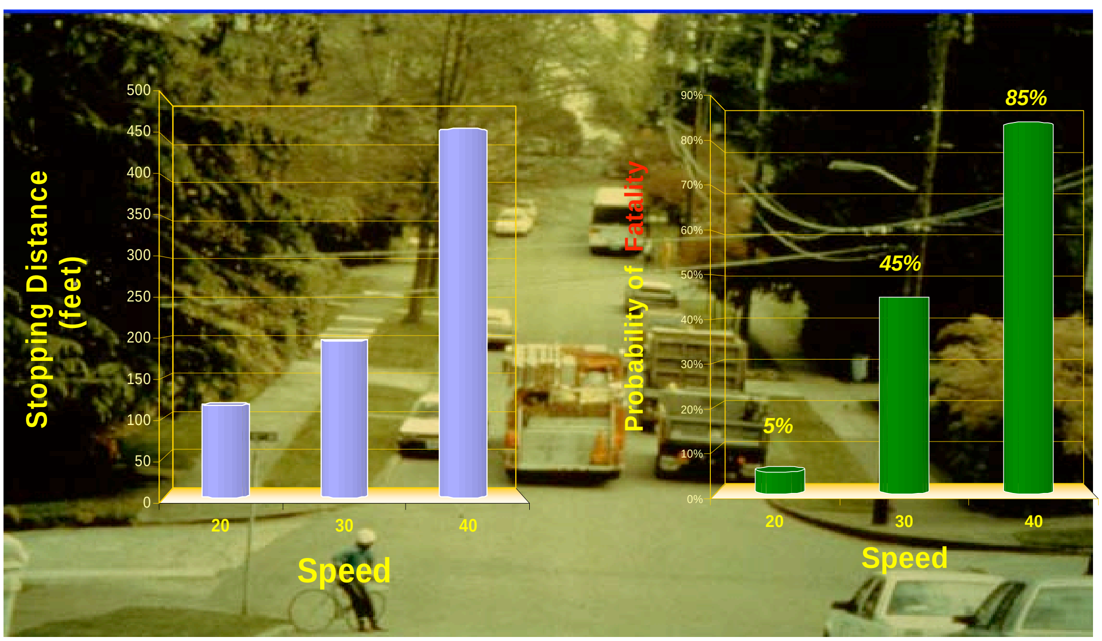
Connectivity and Safety

In 2008, transportation researchers Wesley Marshall and Norman Garrick[16] concluded part of their study of over 130,000 vehicular crashes within California cities, populations ranging from 30,000 to 150,000. Their conclusion was that the most unsafe streets in California, in terms of traffic fatalities, are the newest ones — those areas developed primarily since 1950. The cities with the fewest fatalities, by contrast, are those with significant portions built before 1950. The newer cities tended to have more "dendritic" networks — branching, with tree-like hierarchy that includes many cul-de-sacs, limiting the movement of traffic through residential areas. They also don't have as many intersections. The pre-1950 cities, on the other hand, tend to be more grid-like, giving motorists many more routes to choose from.

Contrary to historic and conventional thought among traffic specialists (the tree-like hierarchy of streets are thought to be superior as they are presumed to make residential neighborhoods quieter and safer), Marshall and Garrick cited other American Society of Civil Engineers (ASCE) research[17] which indicates that more-connected street networks ***tend to reduce travel speeds***; and while the overall incidents of vehicular accidents remain the same, the reduction in speed equates to a significant reduction in the severity of accidents.

Vehicular speeding also has serious consequences when a pedestrian is involved. As shown in **Figure 5**, a pedestrian hit at 40 mph has an 85 percent chance of being killed; at 30 mph the likelihood goes down to 45 percent, while at 20 mph the fatality rate is only 5 percent. Faster vehicle speeds increase the likelihood of a pedestrian being hit. At higher speeds, motorists are less likely to see a pedestrian, and are even less likely to be able to stop in time to avoid hitting one.

Figure 5. Traffic Speed and Safety[18]



The ASCE study also concluded that street networks containing many cul-de-sacs increased travel demand on arterial roads by 75 percent and on collector roads by 80 percent, compared to a "gridded" street design. That, too, may help explain the higher fatality rate associated with the street networks that became prevalent after 1950.

Two important findings are summarized in the study: (1) population (land use) density is an important safety factor, and (2) intersection density is the key transportation measure distinguishing safety characteristics. **Table 1** summarizes the study's key findings.

Table 1. California City Network Crash Data

	Safer Cities	Less Safe Cities
Fatalities / 100,000 Population		
Total	3.1	**10.1**
Not On Limited Access Highways	2.3	8.6
Fatal Crash History (1997-2005)		
Population Density (people / sq mi)	5,736	2,673
Intersection Density (average/sq mi)	106	62
Average Block Size (acres)	18.2	34.5

Population Density
The safer cities in the study had roughly twice the population density of the more dangerous cities — 5,736 people per square mile, versus 2,673 per square mile. In the period from 1997 through 2005, the safer cities experienced 3.1 fatal crashes per year per 100,000 population, while the more dangerous cities suffered 10.1 fatal crashes per 100,000 population — a death rate more than three times as high.

Intersection Density
Marshall and Garrick suggest that the focus on connectivity, from a transportation safety perspective of reducing deaths in traffic accidents, is how many intersections there are in a given land area. The more dangerous cities had 41 percent fewer intersections per square mile. Their study also considered the measure of connectivity. While a high ratio of links to nodes was observed to help explain lower fatalities and severe injuries, it was the intersection density, rather than the link-node ratio, that appeared to be a better measure of safety.

Implementing Connectivity

Transportation connectivity can be increased in a number of ways:

- during street and non-motorized pathway planning and project development,
- when subdivisions are designed,
- by adopting street connectivity standards or goals,
- by requiring alleyways and mid-block pedestrian shortcuts,
- by constructing new roads and paths connecting destinations,

- by using shorter streets and smaller blocks, and
- by applying traffic calming rather than closing off streets to control excessive vehicle traffic.

Typical street connectivity standards or goals include the following:

- Encourage average intersection spacing for local street to be 300-400 feet.
- Limits maximum intersection spacing for local streets to about 600 feet.
- Limits maximum intersection spacing for arterial streets to about 1,000 feet.
- Limits maximum spacing between pedestrian/bicycle connections to about 350 feet (to create mid-block paths and pedestrian shortcuts).
- Reduces local street pavement widths to 24-32 feet (varies with on-street parking restrictions).
- Limits maximum block size to 5-12 acres.
- Limits or discourages cul-de-sacs (for example, to 20% of streets).
- Limits the maximum length of cul-de-sacs to 200 feet.
- Limits or discourages gated communities and other restricted access roads.
- Requires multiple access connections between a development and arterial streets.
- Requires a minimum connectivity index, or rewards developments that have a high connectivity index with various incentives.
- Specifically favors pedestrian and cycling connections, and sometime connections for transit and emergency vehicles, where through traffic is closed to general automobile traffic.
- Creates a planning process to connect street "stubs," that is, streets that are initially cul-de-sacs but can be connected when adjacent parcels are developed in the future.

Connectivity Index

A connectivity index can be used to quantify how well a roadway network connects destinations. Indices can be measured separately for motorized and non-motorized travel, taking into account non-motorized shortcuts, such as path connectors that link cul-de-sacs or dead-end streets, and barriers such as freeways, highways and arterials that lack sidewalks. Several different methods can be used.

Link-Node Ratio

This measure was generally first described by Reid Ewing in 1996[19]. The measure is simply a ratio between the numbers of street links divided by the street nodes. Links are the segments between intersections, nodes the intersections themselves. Cul-de-sac heads count the same as any other link end point.

A higher index means that travelers have increased route choice, allowing more direct connections for access between any two locations. According to this index, a simple box is scored a 1.0. A four-square grid scores a 1.33 while a nine-square scores a 1.5. Dead-end and cul-de-sac streets reduce the index value. This sort of connectivity is particularly important for non-motorized accessibility. Ewing noted that a score of 1.4 is the minimum needed for a walkable community.

Intersection/Dead-end Ratio

The ratio of intersections divided by intersections and dead-ends, expressed on scale from zero to 1.0 (U.S. EPA, 2002[20]). An index over 0.75 is desirable.

Intersection Density
The number of surface street intersections within a given area, such as a square mile. The more intersections, the greater the degree of connectivity. (Note: some research is indicating use of 4-way intersection density as a better measure of connectivity)

Route Directness Index
A route directness (accessibility) index can be calculated by dividing direct travel distances by actual travel distances. For example, if streets are connected, relatively small, and have good sidewalks, people can travel nearly directly to destinations, resulting in a low index. If the street network has many unconnected dead-ends and blocks are large, people must travel farther to reach destinations, resulting in a higher index. A route directness index of 1.0 is the best possible rating, indicating that pedestrians can walk directly to a destination. An average value of 1.5 is considered acceptable.

These indices are affected by how each area is defined, such as whether parklands and industrial areas are included in analysis. It is therefore important to use professional judgment in addition to quantitative measurements when evaluating connectivity.

Comparing Connectivity Measures

A comparison of four different connectivity measures was conducted using two distinctive street systems. The two street systems, as shown in **Figure 6**, are located in the Boise, Idaho urban area, and were each developed on a one-mile, arterial-bound grid system, each having to account for natural water features (irrigation canals). The first was developed in the 1950's, based on the more traditional, local street grid system. The second was developed in the 1990's based on the hierarchical street network patter.

Four measures were tested: (1) link-to-node ratio, (2) intersection density, (3) route directness, and (4) percent four-way intersections. Within each of the 1-mile sections four locations were identified at the center of each ¼-mile section to calculate trip origins and destinations as part of the route directness index. Of note, it is possible to incorporate exclusive pedestrian and bicycle connections to augment the rough measures used in the example.

Summary statistics of the test are listed in **Table 2**. The **route directness index** revealed the two most significant findings relating to connectivity of the test areas:

1. The *grid* network was measured with almost double the ratio of actual street network distance to "crow flight" travel between trip origins/destinations, and most proximate to the ideal ratio of 1.0, indicating a much higher level of direct connectivity and significantly lower level of out-of-direction travel, and
2. The *hierarchical* network, based on the origin-destination pairs, requires a significantly greater distance of total origin-destination travel on the perimeter arterial network (2.68 miles) for internal trips (within the one-mile grid) than the *grid* network (.37 miles).

Since the number of intersections or nodes was roughly similar in the two areas, the following are noted:

- the *intersection density index*, naturally, did not reveal a remarkable contrast between the two street network patterns,
- the *link-to-node index* showed distinct levels of higher route choice in the *grid* network with a score of 1.79, exceeding the threshold of 1.4 for walkable communities – whereas the hierarchical network (1.10) did not, and (but more revealingly)
- the grid network has more than double the number of four-way intersections, hence the percent four-way intersection measure matches more directly the findings of the *route directness index* and may be the most efficient measure of the degree of connectivity.

It should be noted that the route directness index may be a difficult measure to administer on a city-wide bases. If the route-directness index is too difficult or timely to measure, the 4-way intersection measure is likely the most efficient and best substitute for area-wide planning purposes. **Figure 7** illustrates the Route Directness Index with a theoretical comparison of grid and hierarchical systems.

Figure 6. Comparing Hierarchical and Connected Street Systems

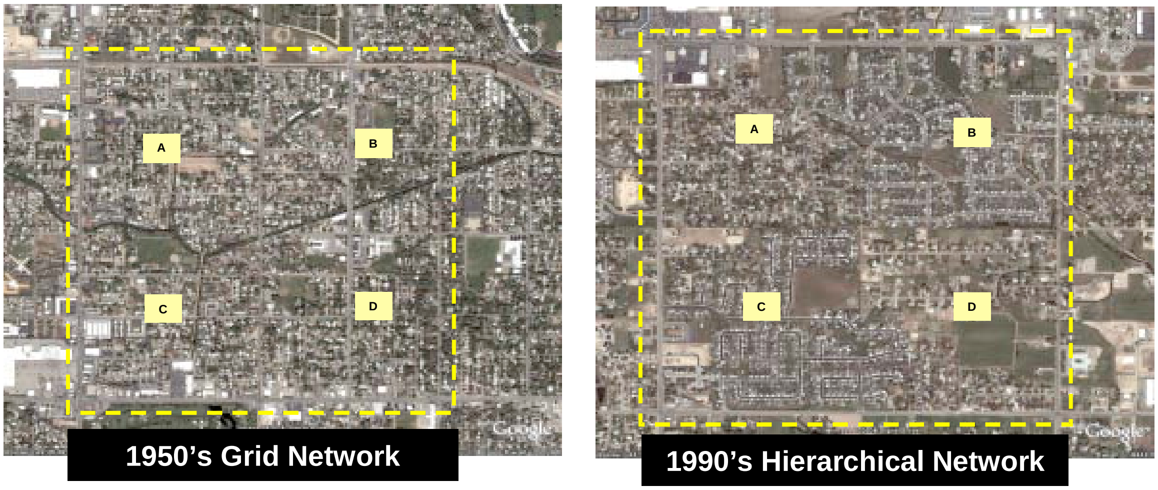


Table 2. Connectivity Index Comparison

	Link-to-Node Ratio			Intersection Density	Percent 4-Way Intersections		Route Directness					
							O-D Pairs		Measured Dist (mi)			Miles on Perimeter Arterial
	Link	Node	Ratio	Intersections / Sq Mi	4-Way Ints	% 4-Way	From	To	"Crow Flight"	Street Network	Ratio	
1950's Grid Network	261	146	**1.79**	107	43	**40.2%**	A	B	0.58	0.73	0.79	
							B	C	0.75	1.06	0.71	
							B	D	0.58	0.58	1	
							A	C	0.58	1.03	0.56	0.37
							C	D	0.54	0.54	1	
							A	D	0.71	1.1	0.65	
							Ave		0.62	0.84	0.74	**0.37**
1990's Hierarchical Network	158	143	**1.10**	93	19	**20.4%**	A	B	0.54	0.64	0.84	
							B	C	0.7	1.97	0.36	0.91
							B	D	0.48	0.88	0.55	0.30
							A	C	0.49	1.18	0.42	0.54
							C	D	0.51	1.59	0.32	0.63
							A	D	0.71	1.54	0.46	0.30
							Ave		0.57	1.30	0.44	**2.68**

Figure 7. **Route Directness Index: Comparing Grid and Hierarchy Networks**

Hierarchical

Grid

Street Connectivity Standards

Many U.S. cities have adopted street connectivity standards. **Tables 3** and **4** summarize street connectivity standards and requirements in various U.S. cities.

Table 3. Street Connectivity Standards

Location	Max. Local Street Intersection Spacing (feet)	Max. Arterial Intersection Spacing (feet)	Street Stubs Required?	Cul-De-Sacs Allowed	Max. Cul-De-Sac Length (feet)
Portland Metro	530	530	No	No (with exceptions)	200
City of Portland	530	530	Yes	No (with exceptions)	200
Beaverton, Or	530	1,000	Yes	No (with exceptions)	200
Eugene	600	none	Yes	No (with exceptions)	400
Fort Collins, CO	(Max. Block size 7-12 acres)	660-1,320	Yes	Limited	660
Boulder, Co	300-350 recommended	None	Yes	Yes, discouraged	600
Huntersville, NC	250-500	No data	Yes	No (with exceptions)	350
Cornelius, NC	200-1,320		Yes	No (with exceptions)	250
Conover, NC	400-1,200	No data	Yes	Yes	500
Raleigh, NC	1,500	No data	Yes	Yes	400-800
Cary, NC	Index = 1.2	1,250-1,500	Yes	Yes	900
Middletown, DE	Index = 1.7	None	Yes	Yes, discouraged	1,000
Orlando, FL	Index = 1.7	None	Yes	Yes	700 (30 units)

Table 4. Street Connectivity Requirements

Location	Max. Spacing Between Bike/Ped Connections (feet)	Local Street Width (feet)	Private Street Allowed?	Gated Streets Allowed?
Portland Metro	330	<28	Not Regulated	Not Regulated
City of Portland	330		Limited	No
Beaverton, Or	330	20-34	Limited	No
Eugene	Connections required at cul-de-sacs	20-34	Limited	Limited
Fort Collins, CO	700	24-36	Limited	No
Boulder, Co	300-350 recommended	24-36	No	No
Huntersville, NC	None	18-26	No	No
Cornelius, NC	None	18-26	Yes	No
Conover, NC	None	22	No	No
Raleigh, NC	None	26	Discouraged	Discouraged
Cary, NC	If index waived	27	yes	No
Middletown, DE	No data	24-32	No	No
Orlando, FL	None	24 min.	Yes	No

Policies for Implementing Improved Networks

Local policies and statutes are required to help ensure street and non-motorized connectivity measures are implemented. This section summarizes five areas of policy or program recommendations to implement improved networks: *Complete Streets* policy, mapping required connections, local street connectivity policies, revisions to development codes or statutes, and connectivity measurement tools for plan evaluation.

Adopt Complete Streets Policy

Complete Streets are designed and operated to enable safe access for all users. Pedestrians, bicyclists, motorists and transit riders of all ages and abilities must be able to safely move along and across a complete street. Creating *Complete Streets* means transportation agencies must change their orientation toward building primarily for cars. Instituting a *Complete Streets* policy ensures that transportation agencies routinely design and operate the entire right of way to enable safe access for all users. Places with *Complete Streets* policies are making sure that their streets and roads work for drivers, transit users, pedestrians, and bicyclists, as well as for older people, children, and people with disabilities.

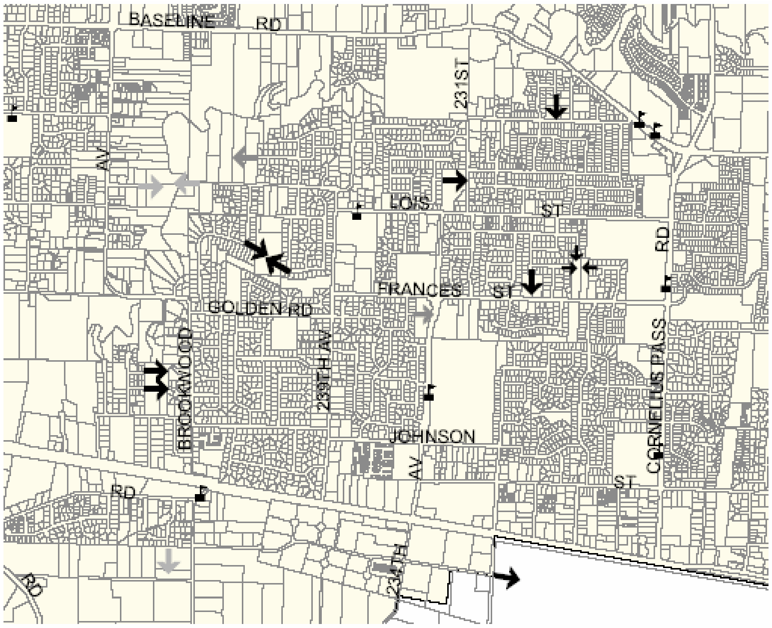
An example of a *Complete Streets* policy might take the form of:

> **Guiding Principle:** To design, operate and maintain City's streets to promote safe and convenient access and travel for all users; pedestrians, bicyclists, transit riders, and disabled users, as well as cars and trucks. This will be accomplished by -
>
> 1. Designing, operating and maintaining the transportation network to improve travel conditions for bicyclists, pedestrians, transit and freight, in a manner consistent with and supportive of the surrounding community;
>
> 2. Providing where practical an array of facilities and amenities that are recognized as contributing to *Complete Streets*, including: street and sidewalk lighting; pedestrian and bicycle safety improvements; access improvements for freight; access improvements in accordance with the Americans with Disabilities Act; public transit facilities accommodation, including but not limited to pedestrian access improvement to transit stops and stations; street trees and landscaping; and street amenities; and
>
> 3. Implementing policies and procedures with the construction, reconstruction or other changes of transportation facilities on arterial streets to support the creation of *Complete Streets* including capital improvements, rechannelization projects and major maintenance, recognizing that all streets are different and in each case user needs must be balanced.

Map Required *Local Street* Connections

Many cities map new (future) arterial and collector street connections as a guide for new development to complete important street connections. These maps are often adopted as part of a long-range transportation or comprehensive plan. For the same reason, mapping important *local* street connections in areas of future development helps ensure important connections are built between new development and the existing street and pathway networks. The purpose of the mapping is to identify contiguous areas of vacant and under-developed parcels (area size to be determined locally) of planned or zoned residential or mixed-use development, and prepare a conceptual local street plan that identifies the most important local street and exclusive non-motorized path connections that will improve local access and preserve the integrity of the street functional classification system and pedestrian and bicycle system plans. This local street plan, see **Figure 7** for example, is then to be used in the development review and permitting process to ensure the construction of those local street connections to adjacent areas that promote a logical, direct and connected local street system.

Figure 8. Example Local Street Connection Plan



This map or set of maps should be adopted as part of the Comprehensive Plan and relevant land development regulations. The arrows on the map represent potential connections and the general direction for the placement of the connection. In each case, the specific alignments and design will be determined at the development plan review stage. The criteria used to identify these connections are as follows:

- 330-foot grid for pedestrians and bicycles
- 500- or 530-foot grid for automobiles

To protect existing neighborhoods from potential traffic impacts of extending stub end streets, it may be appropriate to incorporate neighborhood traffic management into their design and construction of connector roadways. The goal is to continually improve city connectivity for all modes of transportation.

Adopt Local Street Connectivity Policies

Policies should be adopted to require a local street circulation pattern that provides access to property and connections to collector and arterial streets, neighborhood activity centers, and emergency access. Example policies include:

- Connectivity to the Street System and Neighborhood Activity Centers - Applicants submitting preliminary development plans shall provide for local street connections toward existing or planned streets and neighborhood activity centers located within one-half-mile of the development.
- Connectivity of New Developments to Adjoining Undeveloped Land - Applicants submitting preliminary development plans shall provide for extension of local streets to adjoining undeveloped properties and eventual connection with the existing street system. Street alignments should be sensitive to natural features, topography, and layout of adjacent development.
- Sidewalks - All development shall include sidewalk and walkway construction as required by Development Standards and Codes. All new street construction or reconstruction projects shall include sidewalks as specified in the City's standards and codes
- Block Standards - The City shall set a maximum block-length standard of 530 feet between street centerlines unless the City determines that adjacent layout or topographical conditions justify greater length.
- Public Accessways - The City shall require pedestrian and bicycle accessways to connect to cul-de-sac streets, to pass through long blocks, and to provide for networks of public paths creating non-motorized access to neighborhood activity centers.
- Street Width (minimize) - In order to facilitate pedestrian crossing, discourage through traffic, and reduce speeds, local streets shall not be excessive in width. However,

public local streets must have sufficient width to allow for emergency access and provide parking on at least one side.

- Discouraging Cut-through Traffic - Local streets shall be designed to minimize cut-through traffic. Limiting street length, width, and the installation of traffic calming measures may be used to discourage through traffic from using local streets.
- Purpose of Cul-de-sac Streets - The purpose of cul-de-sac streets shall be to increase density by accessing land not otherwise accessible through a connected street pattern due to topography or other constraints. Construction of cul-de-sac streets shall be prohibited otherwise.
- Cul-de-sac Street Length - Cul-de-sac streets shall not exceed 200 feet in length.

Revise Development Code

Local development codes for residential and mixed-use areas should require the following grid-based standards (with exceptions for certain barriers to providing connectivity):

Street grid	530 feet
Non-Motorized grid	330 feet

When full street connections are not possible the developer must provide bike and pedestrian accessways on public easements or rights of way in lieu of streets.

Developments must limit the use of closed-end streets (cul-de-sacs) to situation where barriers prevent a connected street network. When built, these streets must be no longer than 200 feet, with no more than 25 residential units.

Develop Connectivity Metric for Citywide Plan Evaluation, Development Site Plan Review and Evaluation, and Concurrency Program

Establish metrics to establish revised baselines (motorized and non-motorized plan elements) and monitor successful implementation of street and non-motorized path network improvements that meet established (and perhaps refined) criteria. Measuring intersection density (percent four-way intersections) as the primary connectivity index is recommended, as it has been identified as a consistent transportation metric that reflects variation in both (a) mode-share and (b) traffic safety.

Examples metrics might include:

- Percent completion of (a) local street, (b) pedestrian, and (c) bicycle networks meeting planning criteria (e.g., number of improvements, miles of improved local street network and non-motorized network)
- Improvement in connectivity index (e.g., yes/no, percent change in index for the project's area – could be a section or other sector)

Enhanced metrics for connectivity can help local plan and policy in a number of ways:

- registration and documentation of important/priority of exclusive, non-motorized connectors, which contribute to overall and improved connectivity,
- quantify the need for pedestrian crossings along major arterials, and
- in combination with measures of greater land use density and mix, establish quantification measures that demonstrate nexus to vehicle miles traveled per capita, helping address emerging greenhouse gas emissions policy.

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