Roadway Connectivity

Creating More Connected Roadway and Pathway Networks

TDM Encyclopedia

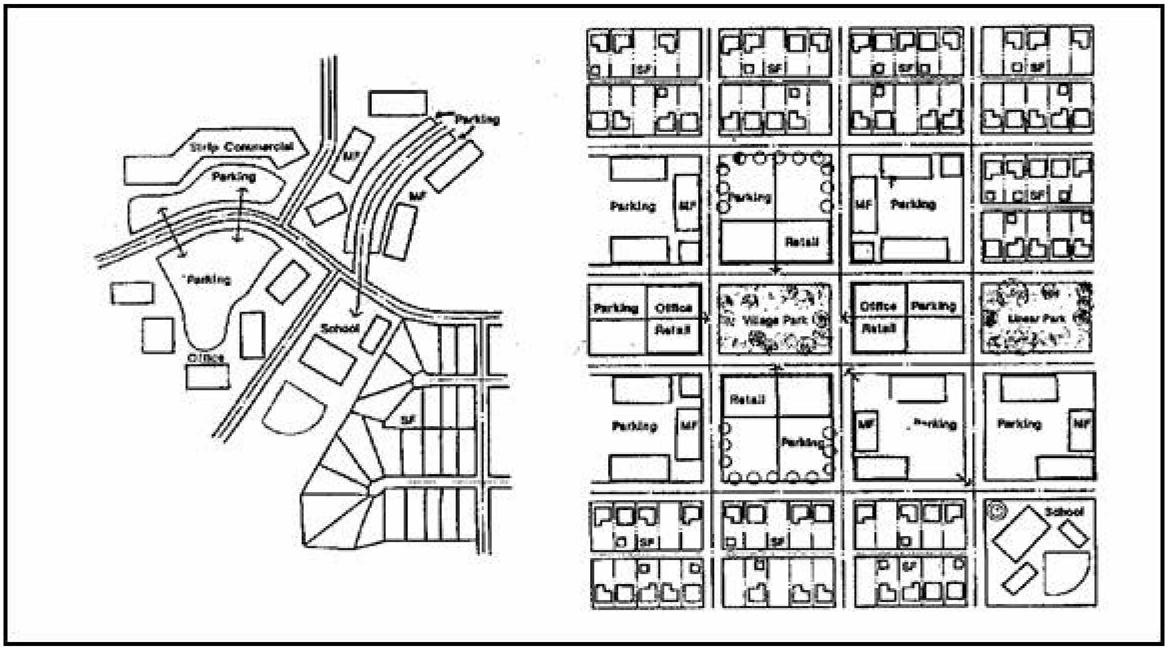
Victoria Transport Policy Institute

Updated 20 May 2010This chapter describes how improved roadway and pathway connectivity, which tends to improve accessibility and reduce vehicle travel distances.

Description

Connectivity (also called *permeability*) refers to the directness of links and the density of connections in path or road network. A well-connected road or path network has many short links, numerous 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 more Accessible and Resilient system.

Figure 1 Hierarchical and Connected Road Systems (Kulash, Anglin and Marks, 1990)

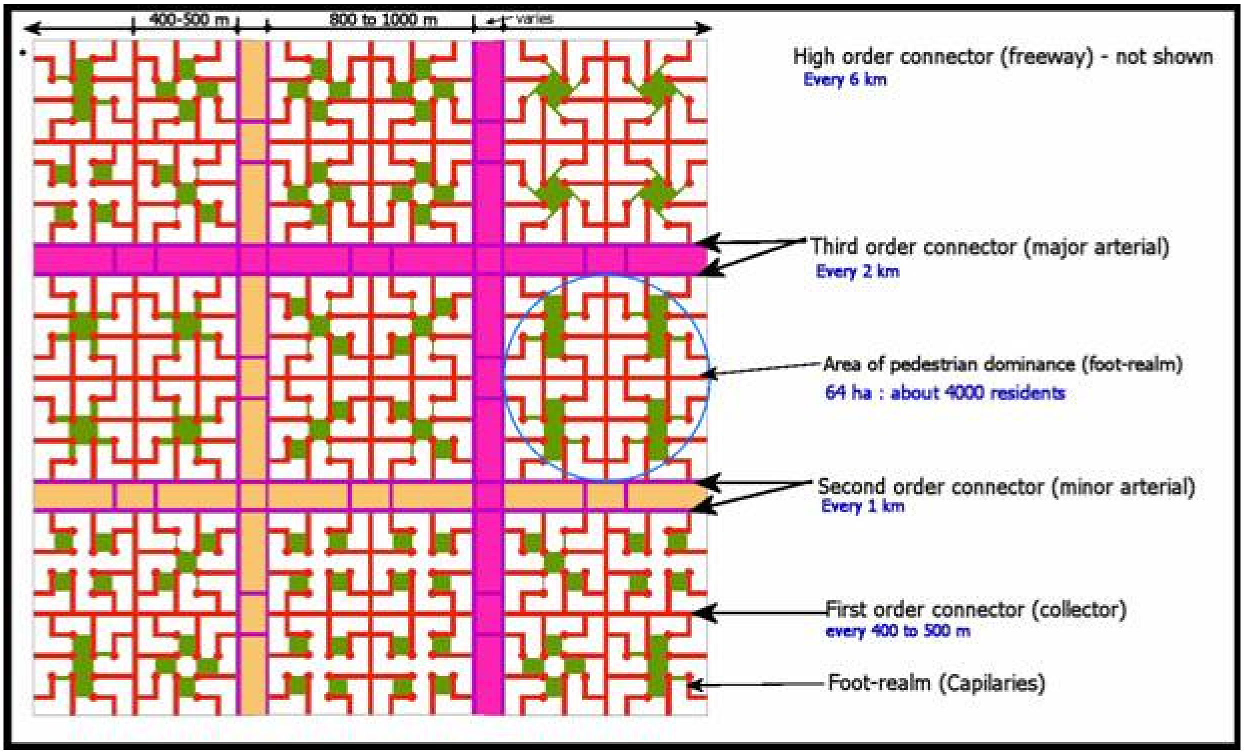


The hierarchical road system, illustrated on the left, has many dead-end streets and requires travel on arterials for most trips. A connected road system, illustrated on the right, allows more direct travel between destinations, offers more route options, and makes nonmotorized travel more feasible.

During the 1960s through the 1990s, roadway design practices favored a poorly-connected *hierarchical* network, with numerous cul-de-sacs that connect to a few major arterials. This increases the amount of travel required to reach destinations, concentrates traffic onto fewer roads, and creates barriers to nonmotorized travel. A connected road network emphasizes Accessibility by accommodating more direct travel with traffic dispersed over more roads, while a hierarchical road network emphasizes *mobility* by accommodating higher traffic volumes and speeds on fewer roads. New Urbanism and Smart Growth land use 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).

Sometimes, different levels of connectivity are intentionally applied to different modes, sometimes called *filtered permeability*. For example, some urban road networks have more direct connections for walking, cycling and public transit than for private automobile (Vehicle Restrictions). A Fused Grid street design (Figure 2), uses public squares at the end of cul-de-sac streets to provide pedestrian and cycling connections that are closed to vehicle traffic (CMHC, 2004). This helps improve Community Livability and encourage nonmotorized transportation.

Figure 2	Fused Grid (www.cmhc-schl.gc.ca/en/inpr/su/sucopl/fugr/index.cfm)



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

Natural barriers such as rivers, highways and major arterials sometimes create barriers to direct local travel, particularly for non-motorized travel, called the *barrier effect* or *severance* ("Barrier Effect," Litman, 2005). Various design strategies can help improve connectivity across such barriers, including special bridges, decking over major roadways, and creating Pedways, which are walking networks within major commercial centers that connect buildings and transportation terminals (Savvides,2005).

Efforts to increase roadway connectivity must overcome the common preference for residential cul-de-sac street. Cul-de-sacs are popular because they have limited traffic volumes and speeds, and help create a sense of community and 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 can be offset by reducing street widths.

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 nonmotorized travel, taking into account nonmotorized shortcuts, such as paths that connect cul-de-sacs, and barriers such highways and roads that lack sidewalks. Several different methods can be used.

- The number of roadway links divided by the number of roadway nodes (Ewing, 1996). Links are the segments between intersections, node 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. Deadend and cul-de-sac streets reduce the index value. This sort of connectivity is particularly important for nonmotorized accessibility. A score of 1.4 is the minimum needed for a walkable community.
- The ratio of intersections divided by intersections and dead-ends, expressed on scale from zero to 1.0 (USEPA, 2002). An index over 0.75 is desirable.
- The number of surface street intersections within a given area, such as a square mile. The more intersections, the greater the degree of connectivity.
- An 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 deadends and blocks are large, people much travel farther to reach destinations, resulting in a higher index. A WPDI 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.

The extreme of an unconnected road network is the gated community, a development or neighborhood surrounded by a fence, with access strictly restricted to residents and their guests. This tends to reduce roadway connectivity for residents and others, increasing motor vehicle travel and reducing nonmotorized accessibility (Blakely and Snyder, 1995; Burke and Sebaly, 2001).

How It Is Implemented

Connectivity can be increased during roadway and pathway planning, 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. New Urbanism development practices emphasize a high degree of street connectivity.

Typical street connectivity standards or goals include the features listed below. Of course, such standards must be flexible to accommodate specific conditions, such as geographic barriers.

- Encourage average intersection spacing for local streets 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 (that is, it creates mid-block paths and pedestrian shortcuts).
- Reduces street pavement widths to 24-36 feet.
- 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 or 400 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.
- Creates Pedways, which are walking networks within major commercial centers that connect buildings and transportation terminals.

Travel Impacts

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

The SMARTRAQ 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 (2005) finds that improved local street connectivity can reduce traffic volumes, and therefore traffic congestion, on major arterials. Traffic modeling by Kulash, Anglin and Marks (1990) 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 (Crane, 1999).

Frank and Hawkins (2007) estimate that in a typical urban neighborhood, a change from a pure small-block grid to a modified grid (a *Fused Grid*, in which pedestrian and cycling travel is allowed, but automobile traffic is blocked at a significant portion of intersections) that increases the relative connectivity for pedestrians by 10% would typically increase home-based walking trips by 11.3%, increase the odds a person will meet the recommended level of physical activity through walking in their local travel by 26%, and decrease vehicles miles of local travel by 23%.

A USEPA study (2004) 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 Smart Growth Index (USEPA, 2002) 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).

Table 1 Travel Impact Summary

Objective	Rating	Comments
Reduces total traffic.	2	Reduces travel distances and therefore VMT.
Reduces peak period traffic.	1	
Shifts peak to off-peak periods.	0	
Shifts automobile travel to alternative modes.	1	Tends to improve walking and cycling.
Improves access, reduces the need for travel.	3	
Increased ridesharing.	0	
Increased public transit.	0	
Increased cycling.	2	
Increased walking.	3	
Increased Telework.	0	
Reduced freight traffic.	1	

Rating from 3 (very beneficial) to –3 (very harmful). A 0 indicates no impact or mixed impacts.

Benefits and Costs

By improving Accessibility, increasing route options, improving walkability and reducing vehicle travel, improved roadway Connectivity can provide a variety of benefits. Improved Connectivity tends to increase transportation system Resilience by increasing route options, reducing problems when a particular link is closed. 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 roadway is blocked by a traffic accident or fallen tree. A more connected street system allows a fire station to serve about three times as much area as in an area with unconnected streets, increases the efficiency and safety of services such as garbage collection and street sweeping (crash rates and insurance costs for such vehicles tend to increase if they are frequently required to back up), and tends to reduce water quality problems that result from stagnant water in dead-end pipes at the end of cul-de-sacs (Handy, Paterson and Butler, 2004, p. 37 and p. 56). These can result in substantial government cost savings or service quality improvements.

Increased road and 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 shortcuts, or implementing Traffic Calming and Vehicle Restrictions to control vehicle traffic.

Costs include additional land and construction requires for additional facilities, increased design requirements, and increased conflicts with adjacent land uses (for example, when a new link is added through an existing property). Increased Connectivity may require lower traffic speeds, since there are shorter links and more intersections. Residential properties tend to have lower values on connected streets than on cul-de-sacs, but this may be offset by incorporating appropriate traffic control and security features into connected streets, as reflected in New Urbanist design practices.

Table 2 **Benefit Summary**

Objective	Rating	Comments
Congestion Reduction	1	
Road & Parking Savings	1	
Consumer Savings	2	Reduces travel distances and improves walking and cycling options.
Transport Choice	2	
Road Safety	1	
Environmental Protection	1	
Efficient Land Use	3	
Community Livability	2	

Rating from 3 (very beneficial) to –3 (very harmful). A 0 indicates no impact or mixed impacts.

Equity Impacts

Improved connectivity tends to help achieve equity impacts to the degree that it improves accessibility and travel options for people who are transportation disadvantaged. In some situations, adding new links to an existing roadway network may cause conflicts and seem unfair to nearby residents.

Table 3 **Equity Summary**

Criteria	Rating	Comments
Treats everybody equally.	0	
Individuals bear the costs they impose.	0	
Progressive with respect to income.	2	
Benefits transportation disadvantaged.	3	
Improves basic mobility.	3	

Rating from 3 (very beneficial) to –3 (very harmful). A 0 indicates no impact or mixed impacts.

Applications

Connectivity improvements can be applied in many situations, and are particularly appropriate for local planners and developers.

Table 4 Application Summary

Geographic	Rating	Organization	Rating
Large urban region.	2	Federal government.	1
High-density, urban.	3	State/provincial government.	2
Medium-density, urban/suburban.	3	Regional government.	2
Town.	3	Municipal/local government.	3
Low-density, rural.	1	Business Associations/TMA.	3
Commercial center.	3	Individual business.	2
Residential neighborhood.	3	Developer.	3
Resort/recreation area.	2	Neighborhood association.	3
College/university communities.	3	Campus.	2

Ratings range from 0 (not appropriate) to 3 (very appropriate).

Category

Land Use Management Strategy.

Relationships With Other TDM Strategies

Roadway Connectivity is an important component of New Urbanism, Smart Growth, and Location-Efficient Development. It supports and is supported by Clustering, Context Sensitive Design, Traffic Calming, Pedestrian and Bicycle Improvements, Road Space Reallocation, and Community Livability.

Stakeholders

Primary stakeholders include local planners, developers, and local residents impacted by changes in roadway and pathway design.

Barriers To Implementation

Increased Connectivity requires roadway and pathway system changes which can be costly and slow to implement, and often involve conflicts with nearby residents who fear increased traffic.

Best Practices

Handy, Paterson and Butler (2004) provide recommendations for improving roadway and pathway connectivity.

- Minimize dead-end streets, and where they exist limit their length to about 200 feet.
- Where dead-end streets exist, try to create paths that provide shortcuts for walking and cycling.

- A modified-grid street network with a high degree of connectivity should generally be used in urban areas.

- As much as possible, new developments and urban redevelopments should have a high degree of roadway and pathway connectivity.

- Use short street and small blocks as much as possible. An ideal for urban development is a 300 to 500 foot grid for pedestrians and bicycles networks and a 500 to 1,000 foot grid for motor vehicle streets.

- Planners should watch for opportunities to increase connectivity, particularly for nonmotorized paths.

- Traffic Calming should generally be used instead of street closures to control excessive vehicle traffic on urban streets.

Examples and Case Studies

Charlotte (NC) Sacks Cul De Sac

Charlotte Observer, October 18, 2003

"The reign of the cul-de-sac ended Wednesday, with a unanimous vote of the Charlotte City Council." Under a change in the subdivision ordinance, the dead-end circles so common in suburbia can be constructed only when geographic barriers prevent street connections. Though existing cul-de-sacs won't be affected, the idea, city planners and politicians say, is to alleviate traffic by better linking future communities.

"Charlotte went cul-de-sac happy in the 1970s and 1980s," said Mayor Pat McCrory. "We failed to develop a grid system of roads and now we have gridlock." The case against cul-de-sacs is the way they limit access to and from neighborhoods. Frequently, subdivisions of cul-de-sacs have only one or two connections to an adjacent road. When cul-de-sac communities are lined up along that road, it clogs with drivers who have no alternative route. Planners note that traffic flows better in and around neighborhoods such as Myers Park, built in the early 20th century on a grid system that gives drivers more choices."

Reconnecting Arterials (Savvides,2005)

Savvides (2005) describes how urban path and street connectivity can be improved by using decking of trenched urban arterials, which allows real estate development and connect areas previously separated by the arterial's right-of-way.

Street Connectivity Standards

Tables 5 and 6 summarize street connectivity standards and requirements in various U.S. cities. See original report for notes and additional information.

Table 5 Street Connectivity Standards (Handy, Paterson and Butler, 2004)

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 6 Street Connectivity Requirements (Handy, Paterson and Butler, 2004)

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

City of Salem (www.cityofsalem.net)

The City of Salem Design Standards requires that “Local streets should form a well- connected network that provides for safe, direct, and convenient access by automobile, bicycle, and pedestrian.”

Portland Regional Connectivity Policies (www.metro-region.org/library_docs/trans/streetconnect.pdf)

The Portland Regional Transportation Plan includes specific policies to increase roadway connectivity in new developments, as well as various strategies to improve the connectivity of nonmotorized networks in existing urbanized areas.

Bremen, Germany (Glotz-Richter, 2003)

In the early 1960s, the city of Bremen was divided into four sectors, or “traffic cells.” Automobiles are allowed to travel within each cell, but to travel between these cells they must use a circumferential ring road. Pedestrian, bicycle and transit vehicles can travel directly between these cells. As a result, vehicle traffic volumes are significantly reduced and travel by other modes is significantly improved.

Gothenburg, Sweden (Vuchic, 1999)

The city of Gothenburg is Sweden’s second largest city, with almost half a million residents. In the late 1960s, the city’s historic center was divided into five traffic cells. As in Bermen, automobiles can travel within each cell but not directly between cells, they must use a ring road. Pedestrian, bicycle and transit vehicles can travel directly between cells. The result has been a 48% reduction in vehicle traffic despite increased vehicle ownership by residents, improved pedestrian and cycling conditions (and a 45% reduction in pedestrian accidents), and improved transit service.

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