Connectivity Indexes (Transportation Network Design)

In a Nutshell

Connectivity Indexes address a community's transportation network connectivity, most commonly streets and sidewalks. A connectivity index is simply a unit of measurement - a metric. The purpose of the evaluation is to assess a specific piece (connectivity) of a larger complete streets design. There are multiple methods to measure street connectivity but the most commonly accepted model is the "Links & Nodes" calculation. This analysis ultimately addresses traffic congestion and travel patterns in a community.

From a more pro-active stance, this urban design approach can be promoted by city or county legislation and development codes. One such approach is establishing maximum block lengths in zoning and subdivision codes and ordinances.

The “How To”

An Introduction to Transportation/Roadway Network Connectivity

The idea of transportation connectivity is simple. Citizens want to go from Point A to Point B, but their travel is bound by transportation networks (and mode options) and private property. Cities and counties play a critical role in the design and lay-out of their communities. Increasingly, researchers and transportation professionals are identifying that suburban traffic congestion is likely tied to the separation of uses (i.e. single-use zoning districts) as well as the subdivision and cul de sac road lay-out of many of these communities. The effect is auto traffic funnels into the same roadways, often forcing motorists to take indirect routes to get to their destination, as demonstrated in an illustration from the Kentucky Department of Transportation.

The economic reality of this transportation network design is the same number of lane miles, organized in a suburban pattern, offers the same infrastructure but less capacity than traditional grid street systems. The Atlanta Regional Commission offers a short but comprehensive review of connectivity that features a graphic that demonstrates this effect.

Cities and counties interested in street connectivity will want to organize an implementation strategy that addresses:

1. A connectivity index assessment of your current, existing community
2. Legislative reform to ensure local codes promote better connectivity in the future
3. Pursuing capital infrastructure investment projects that improve connectivity in the existing community

Community Benefits yielded from Network Connectivity

There are many benefits to your community that are created by street networks with higher connectivity, such as:

- Decreased traffic congestion on arterials and thoroughfares
- Shorter travel times
- Reduced Vehicle Miles Traveled (VMTs)
- Continuous and more direct routes for pedestrians, bicyclists, and transit users
- Improved 911 and public safety response times
- Multiple route options and increased individual choice
- More effective utility right-of-way management
- More cost-efficient street maintenance programs
- Reduced speeding
- Increased pedestrian and bicyclist safety
- Reduced auto accidents
- Better and more cost-effective public services that use routing, such as:
    - Snow plowing
    - School buses
    - Buses and other mass transit
    - Police patrols
    - Garbage, recycling, and yard waste collection

Planning & Zoning

The "How To" tab explains three approaches to improving connectivity - (1) index assessments, (2) local government codes and ordinances, and (3) capital investment projects to improve the existing community. All three are explained in technical detail on this "Planning & Zoning" tab, however, it will be beneficial to have reviewed the "How To" tab prior to reviewing the material below.

ONE: Calculating a Connectivity Index

An index is a straightforward quantitative calculation that provides a "connectivity bottom-line" that can be easily compared across neighborhoods, cities, or regions. The most commonly used index is a ratio of links to nodes. Those two inputs are:

- **Links:** street segments
- **Nodes:** intersections and/or cul de sac point

The calculation is as simple as counting all of the links and nodes, and then dividing the links by the nodes. For example a neighborhood with nine (9) links and eight (8) nodes would yield a score of 1.13. The larger the number produced by the index indicates the greater the street connectivity in the study area. Commonly used benchmarks are an index score of 1.7 for a traditional grid-street system and a score of 1.2 for a typical, modern suburban design. An absolutely perfect, 100% connected grid maxes out at a 2.5 score. The Transportation Research Board produced a report that analyzes multiple ways to calculate connectivity, with "Links & Nodes" demonstrated on the fourth (4) page of the document (in pdf).

The metric promotes intersections rather than long dead-end streets. Under this approach, a well-connected road network will:

- Feature lots of short road lengths (links)
- Feature numerous intersections (nodes)
- Minimize the use of dead-end streets

- Strategically use but minimize cul de sacs
- Offer pedestrian and bicycle connections
- Offer multiple options in route choice

TWO: How Can Local Governments be Pro-Active Going Forward?

Using the connectivity index is a good way to understand where you stand today. But many policy makers and local government leaders are going to want to know how they can improve tomorrow's decisions. The good news is working with the development community, cities and counties can take important action to promote better street and transportation system design in new construction. The most direct approach is acknowledging that private development ultimately becomes public infrastructure. The design and construction of residential subdivisions and commercial properties are traditionally defined by baseline regulations in local zoning, development, and land use codes and ordinances. Cities and counties can work with the development community to improve these codes to promote better connectivity and neighborhood design. More information on working with the development, real estate, and home builder communities is located on the "Discover More" tab.

Lancaster County, Pennsylvania has compiled best practices from a few cities across the United States and their approach to requiring better street connectivity in new developments - these range from Franklin, Tennessee's "mobility and circulation" ordinance to Austin, Texas's "street connectivity" ordinance. Also included is the American Planning Association's Policy Guide on Smart Growth.

How to Apply this to Your Plan Review Procedures

Cities and counties can apply this analysis to their standard plan review process. In the same way your city planners, zoning officials, engineers, fire marshal, and other plan reviewers examine a proposed development for the number of parking spaces, or stormwater management, or lane widths, your local government can also calculate the connectivity index as part of that review and approval. At a basic level the city or county can just note in their staff advisory how connectivity-positive the development is, or if your jurisdiction adopts such code language then it can be a requirement the same as these other conditions of approval.

Specific land use regulation standards and/or measurements that you can adopt include:

- Maximum block lengths
- Maximum block size
- Block Density
- Street & Intersection Density
- Connected Node Ratios
- Pedestrian Route Directness
- Effective Walking Area Index

The Transportation Research Board offers a report that describes each one of these approaches as well as showcases Portland, Oregon's analytical process that selected four of these tools and drafted ordinance language to improve their connectivity and pedestrian mobility. Also, the Victoria Transport Policy Institute offers a clearinghouse on connectivity, including Tables 5 and 6 that list such adopted standards in a variety of communities, ranging from Orlando, Florida to Raleigh, North Carolina to Fort Collins, Colorado. They also present a concept known as a "fused grid" which provides excellent connectivity while still offering residential cul de sacs and dead-end streets.

THREE: Capital Projects & Infrastructure Investment

By adding connectivity analysis to your city or county's existing infrastructure investment plan (often called a Capital Improvement Plan - CIP) local government leaders can start to have an immediate impact. Typically CIP projects are evaluated and scored based on a variety of factors and criteria - the simplest step is to add a factor that rates whether the project improves, hurts, or is connectivity-neutral. If projects are particularly beneficial to improving street system connectivity, give it extra points; if it negatively impacts connectivity, score it lower. A more direct approach is specifically identifying and designing infrastructure projects that will target areas needing enhanced connectivity. This should not only include new or modified streets but also other transportation options, such as bicycle and multi-purpose trails, sidewalks, pedestrian paths, and access to transit. Concept projects can be added to a city or county's comprehensive plan.

Two approaches to pro-active connectivity projects are "Bicycle & Pedestrian Plans" and the Safe Routes to School program. There are many resources available for both programs, including grant funding:

Bicycle & Pedestrian

- Federal Transportation Policy on Bicycle & Pedestrian Transit
- Missouri Department of Transportation (MODOT) - Bicycle & Pedestrian Programs
- Trailnet Annual Grant for Local Bicycle & Pedestrian Master Plans
- The Regional St. Louis Bicycling & Walking Transportation Plan
- The Gateway Bike Plan
- Illinois State Bicycle Plan
- Metro-East Parks & Recreation District Invests in Bicycle Trails and offers Grants

Safe Routes to Schools

- Trailnet offers information on Safe Routes to School programs
- Illinois Department of Transportation (IDOT) Safe Routes to School
- Missouri Department of Transportation (MODOT) Safe Routes to School
- National Partnership: Safe Routes to School - Illinois
- National Partnership: Safe Routes to School - Missouri
- National Partnership: Safe Routes to School - Resources for Local Governments

Also review the One STL tools for Bicycle & Pedestrian Facilities & Programs tool.

Dollars & Cents

When properly designed and implemented, there are a lot of cost benefits from increasing street connectivity. A holistic approach is the statewide policy adopted by the Commonwealth of Virginia, managed by their Department of Transportation (VDOT). From a technical standpoint they offer a best practices manual on accepting developer-built infrastructure into public maintenance and ownership. The Virginia policy outlines an example of the importance to governments spending tax dollars on maintenance and public services to serve these neighborhoods. Their policy document (in pdf) outlines the following economic benefits:

- Decreased traffic congestion
- Narrower street width produces less stormwater run-off
- Slower auto speeds through neighborhoods

- Improved quality of life in residential areas
- Increased traffic capacity
- Reduced city/county local service costs
- Improved police and fire response times

One specific example is included in their report that profiles a study conducted by the Charlotte Fire Department that found the cost-per-household for fire service was $206 per household in a neighborhood with a connectivity index of 1.3, whereas the cost was $740 per household in a neighborhood with a 1.09 connectivity index score. Simply, the exact same fire service was nearly *four-times as expensive* in a neighborhood with more cul de sacs and one that featured more connections.

The LeHigh Valley Pennsylvania Street Connectivity Guide provides step-by-step analysis of why it matters, how to do it, how to measure it, and the cost benefits.

Cost Impact on Local Government

If a city or county wants to conduct really sophisticated studies, or lack the internal staff to create connectivity indexes, then there may be a cost of thousands to work with a consultant. Considering the long-term cost savings with better street connectivity, it is likely worth the investment. However, if a unit of local government can perform most of the analysis in-house, generate project ideas themselves, and work with case studies and other cities and counties to draft their ordinances, then the only cost is manpower. A city or county can truly adopt many of these policies and conduct this type of calculation fairly cheaply - better, more robust efforts that incorporate steering committees and more public input will consume more staff time, but again, still be relatively inexpensive.

The long-term program cost is generally absorbed into your existing plan review, zoning, and administrative operations. Even capital expenses can come from existing budgets if planned CIP projects are geared towards improving street and neighborhood connectivity.

Measuring Success

A Big Picture Analysis

Evaluating the success of a street network that promotes multi-modal connectivity is complex. The Congress for the New Urbanism offers many resources on understanding transportation networks and what makes them more effective. They offer an introductory manual on sustainable street design. Using the same connectivity indexes outlined in this tool also works over time as well - simply tracking a neighborhood or the entire community's connectivity annually and identifying positive trends with that statistic will provide a high-level evaluation of your success. A complex version of analysis would be using a GIS system, such as ESRI's ArcMap10 and its Network Analyst feature, to perform this connectivity analysis, which is described in a research paper by Georgia Tech. The reality is the accuracy of an evaluation comes from the customization of these methods to a local area - each area is different; why and how people walk, drive, ride a bike, or use transit can be fairly specific to the local area, and that behavior will be influenced by the spatial urban design in different ways. Like any good success metric, the evaluation needs to be geared to your original goals.

A Simple Analysis

In a more case-by-case analysis a city or county can publish a report that highlights new construction projects

where connectivity was improved over the initial proposal, and/or government capital projects that were completed aimed at increasing connectivity. These efforts are singular and really easy to show local progress. Connectivity index calculations can be updated in the areas where new construction or infrastructure work was completed to demonstrate the improved connectivity. Tracking the city as a whole (i.e. Smith City has a connectivity index score of 1.31 and a Walk Score of 67, which are 23% and 17% increases in the last five years) can be effective, but also performing the same historical analysis using these metrics in targeted neighborhoods where projects are occurring can be useful too. For smaller towns and suburbs this approach will likely be the most realistic and the most useful to their local government leaders.

Discover More

Is the "Links & Nodes" Index the Only Way?

No, there are additional metrics you can use. Other approaches to calculating road network connectivity include:

- **Intersections per Road Mile:** this evaluation is very simple. Essentially a length of road is measured, the number of intersections on that stretch of road is tallied, and that ratio is converted to a per mile metric format. This allows for easy comparison across different road segments and different communities.
- **Straight-Line Distance Analysis:** this evaluation generates a ratio of real/actual travel distance as compared to that same trip on a 'straight-line' distance. The comparison indicates how indirect (and likely curvilinear and low-connectivity) the existing route is contrasted against a more direct street design. GIS systems can be helpful in calculating this difference, however, they can be fairly accurately derived from paper or internet maps as well.

Some transportation and civil engineering experts see these two metrics as insufficient and lacking the richness of the "Links & Nodes" approach. However, they can be useful in supplementing a connectivity index study to identify correlating measurements.

Are there Other Ways to Measure the Neighborhood than just Cars?

Yes, definitely. The Walk Score system has gained popularity in evaluating whether residential areas are walkable. They also offer Bike Score and Transit Score, available by the metropolitan area, city, or neighborhood down to the zip code. Their profile of the City of St. Louis is helpful in understanding how their tools work together. These tools have been featured on the television channel TLC and their program "How Stuff Works."

Local Residents & Developers will Not Like Gridiron Street Design

This is likely true in many of your communities in the St. Louis region. However, many of those same residents also do not like traffic congestion. There is an important public policy and transportation design conversation within this tension. It is important to recognize that it is not an either/or choice - communities do not need to be either all "lollipops" along one arterial, nor do they have to be perfect 90-degree angle grids typically found in 19th Century development. The purpose is to identify the most effective balance in street system design that achieves all of these important community goals.

Residents

For communicating with residents, a local government should be sure to promote all of the benefits from the

"How To" tab in this tool, but also enhanced/increased sidewalks in their neighborhoods, safe routes to school for their children, hiking and bicycle trail opportunities, better access to neighborhood businesses, and simple things like being able to get to work faster in the morning and walk to an ice cream stand with their kids at night. Better transportation network connectivity can achieve all of these things without impacting the quality of life many citizens want from their residential neighborhoods.

Developers & Home Builders

For working with developers, including them early in the process (perhaps an advisory committee engaged in the index study and policy development), and offering compromise solutions such as permitting narrower streets. One of the main concerns reported by home builders is the loss of profit-efficient cul de sac lots and the increase in large corner lots. Although many homeowners enjoy corner lots, developers have to be concerned with their bottom-line as well. Creating land use regulations that allow for flexibility and alternatives has proven effective - if a developer can demonstrate critical impacts to profitability in a subdivision design that promotes greater connectivity, the city or county can offer strategic variances, such as a decrease in minimum lot size. Again, all of the goals of the project and the community can be achieved through deliberative transportation design.

The Atlanta Regional Thoroughfare Plan addresses both of these topics in a flier on connectivity.