Transit Village Monitoring Research

Connectivity Measures

Alan M. Voorhees Transportation Center (VTC)
Edward J. Bloustein School of Planning and Public Policy
Rutgers, The State University of New Jersey

Prepared By:

Stephan J. Schmidt and Jan S. Wells

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Alan M. Voorhees Transportation Center
Edward J. Bloustein School of Planning and Public Policy

TRANSIT VILLAGE INITIATIVE

Background

Recently, the field of planning has seen a rise in both academic and popular interest in New Urbanism and transit-oriented development (TOD). This has placed a renewed emphasis on higher densities, mixed land uses, pedestrian friendly development, and the coordination of land use and transportation, which, in turn, has created a need for methods to empirically quantify and measure urban form. Due to the increasing availability and accessibility of technology and data, a number of metrics have evolved to measure urban form. Some of these measures have been used to determine land use characteristics, such as: residential density, the 'strength' of the neighborhood center, or downtown[1], average lot size, and the mix of residential, commercial, and office uses.[2] However, other measures have focused on levels of "accessibility" between land use and the transportation network. These accessibility indicators are considered to be one of the primary tests of how well the two are coordinated.[3]

There are numerous measures of accessibility documented in the literature. In their study of new developments in the Portland, Oregon metropolitan area, Song and Knaap employ a number of different metrics to quantify street patterns in conventional subdivisions and new urbanist developments in the Portland, Oregon metropolitan area: internal connectivity[4], external connectivity[5], average block length, and average distances to the nearest commercial use, park, or transit station. Additional measures include the percentage of residential land use within walking distance of commercial uses (a measure of pedestrian access to retail) or transit (a measure of pedestrian access to transit).

However, connectivity, a measure of the interconnectedness of a transportation network or pattern, is one of the more important indicators.[6] A more highly connected transportation network indicates a greater number of available options in route planning. A practical index used to measure connectivity must be able to empirically quantify differences of complexity between street patterns. Such an index can therefore serve as a performance standard in the development approval process[7], or act as a comparative measure. The conventional method for measuring connectivity has been the number of links divided by the number of nodes (referred to as the 'Beta' index in Demers, 1997, Song and Knaap); the node referring to an end point (either an intersection or a cul-de-sac), and the links referring to the road segments connecting the nodes. The Beta index originated with graph theory,[8] but soon expanded to other fields in which measures of pattern connectivity were important, such as transportation[9] and landscape ecology.[10]

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[1] Ewing *et al*, 2002

[2] Song and Knaap

[3] Ewing *et al*, 2002

[4] Ratio of the number of street intersections versus the sum of the number of intersections and the number of cul-de-sacs. The argument here is that conventional subdivisions have more cul-de-sacs and less intersections than new urbanist neighborhoods (Criterion, 1999).

[5] Median distance between ingress/egress (access) points in feet (Criterion, 1999)

[6] Demers, 1997

[7] Handy *et al*, 2002

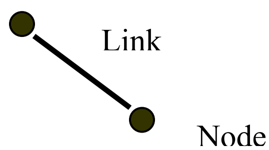
[8] See Lowe and Morydas, 1975 and Haggett, Cliff, and Frey, 1977

[9] Taffe and Gauthier, 1973

[10] Forman and Godron, 1986 and Forman , 1995

The Beta connectivity index has been used in a number of applications[11], and is simply equal to the "Number of Links" divided by the "Number of Nodes" or L/N, where a node is defined as an intersection, street crossing, or any other point where a link ends (Exhibit A).

Exhibit A



The basic premise is that the more links there are in relation to the number of nodes, the higher the level of connectivity; while a larger proportion of nodes to links indicates a lesser connectivity (this would explain low Beta scores in neighborhoods with a proportionally large number of cul-de-sacs: a node connected to only one link). The greater the connectivity, the greater the street networks 'pedestrian friendliness'. A Beta index of 0.8 indicates that, on average, there is .8 link for every nodes (values of greater than 1.0 suggest the presence of alternative routes between some pairs of nodes). This metric is unconstrained, but tends to fluctuate between 0 and 2.

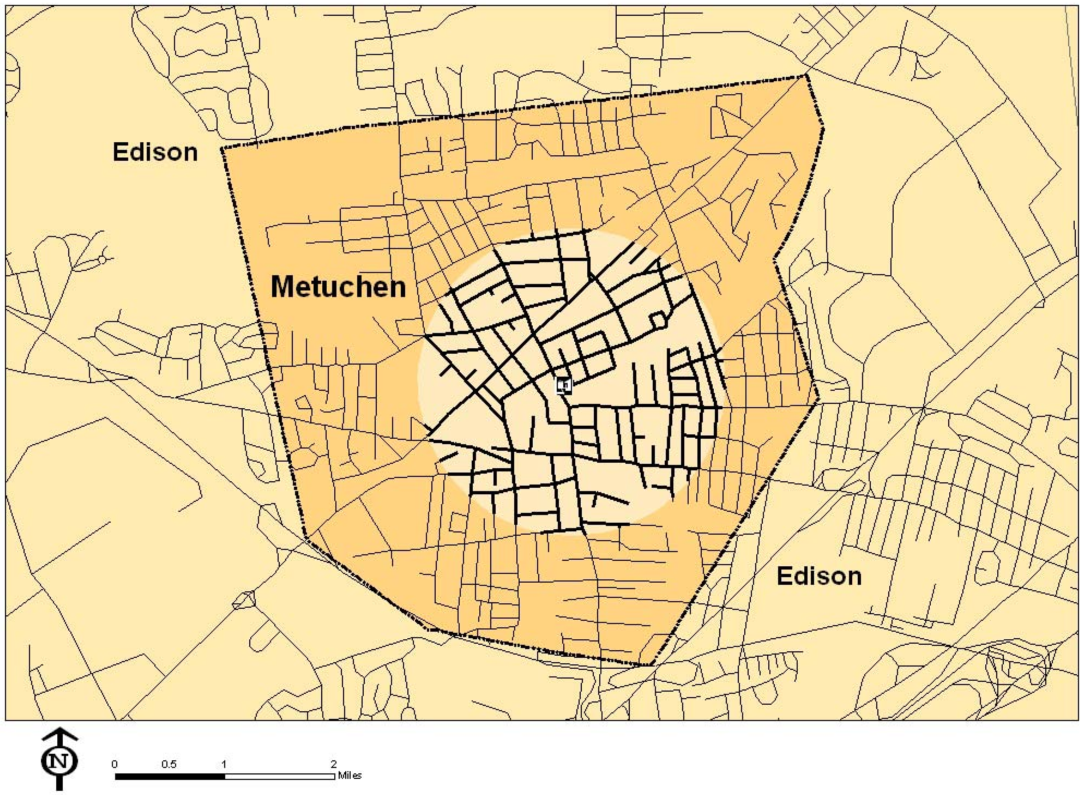
This paper will examine relative connectivity, using the New Jersey Transit Villages and a random selection of sample road networks, ranging from rural to urban throughout the state[12]. The purpose is to compare relative connectivity (and thus the 'walkability' or 'pedestrian friendliness') of the transit villages with other road networks.

Methodology

Using ArcGIS 9.0, half mile buffers were drawn around the 16 Transit Villages. In addition to this, 20 other sample sites were chosen. In order to insure a certain amount of randomness and to be as representative of New Jersey street patterns as possible, these additional sites were chosen at 10-mile intervals along five projecting transects with Newark, New Jersey as their origin. Thus, they do not correspond to train stations, as the Transit Village sites do. These sample sites were assigned numbers corresponding to their geography. All 36 buffered files were then clipped to TIGER street files (2003) in order to analyze the number of nodes and links within each study area. As ArcGIS clips the line files at the nearest node outside of the designated study area boundary, any node falling outside the boundary was not counted, while links which extended outside the boundary were counted as half links. This was done in order to achieve a more accurate count, as well as prevent any of the connectivity indices from being negative (which is what happens when there are more nodes than links). See Exhibit B below for an example.

[11] Song and Knaap; Ewing *et al*, 2002; Forman and Godron, 1986; Handy *et al*, 2002; Demers, 1997
[12] Internal and external connectivity are irrelevant in this situation as they are intended for well defined neighborhoods, not a half mile buffer line around a train station.

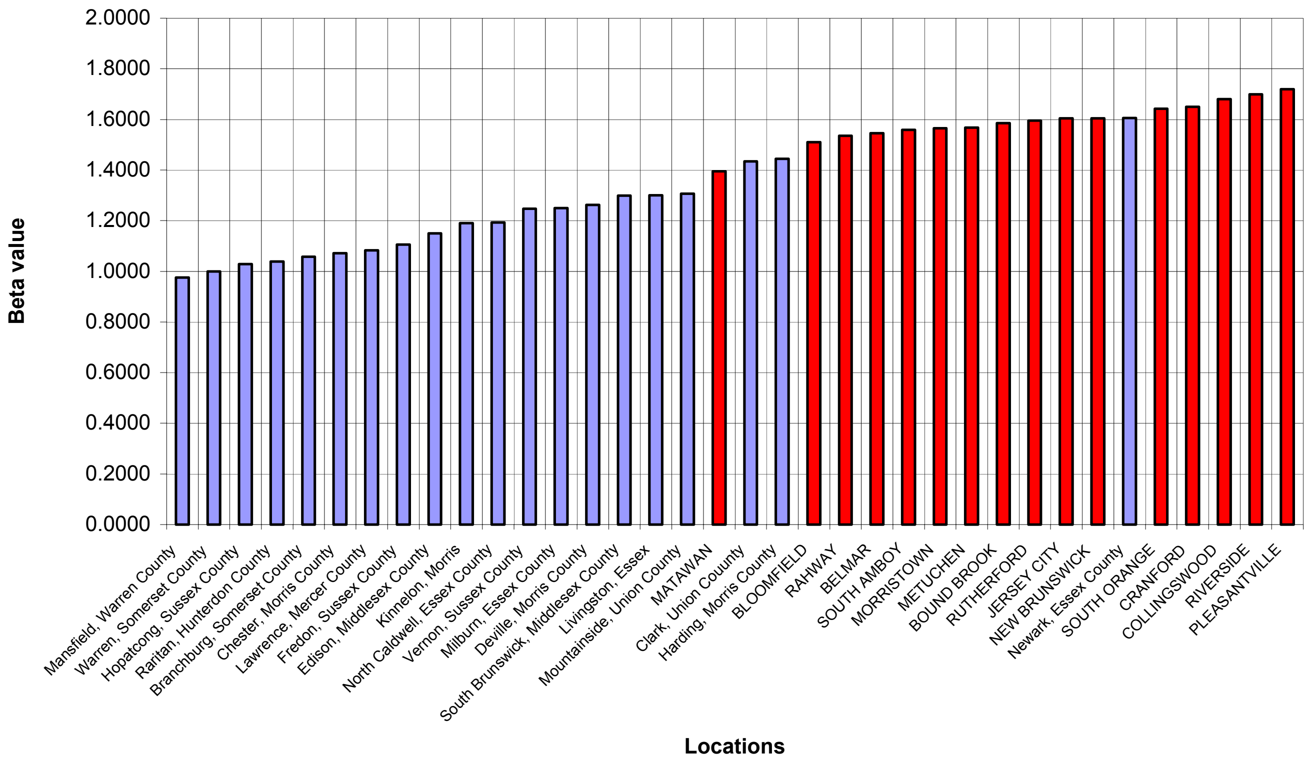
Exhibit B



As each node can potentially serve as multiple origins and destinations for links (acting as both a 'From' node as well as a 'To' node), the results were exported as Dbf files and brought into Microsoft Excel, where a query was run to search for unique values, so that nodes were not counted multiple times. The calculations were executed in Excel, and then plotted as a bar graph.

Conclusion
As the Figure A (below) depicts, the Transit Villages, indicated in red, tend to have higher connectivity indices. This is what should be expected. These are older communities, laid out in the 19th century, when the grid was the most common form of street pattern and residents walked to the transit station. Newer developments, particularly suburban and exurban communities tend to be auto-oriented, and consequently less connected. The higher connectivity of the Transit Villages is conducive to encouraging pedestrian-oriented development, fostering a sense of place, and increasing transit ridership.

Figure A: Beta Connectivity Indices



It is interesting to note that the most "connected" TVs are Pleasantville and Riverside. This may seem surprising as they are not densely built. However, connectivity does not necessarily correlate to dwelling units per acre.

Recommendations

It should be cautioned that with any attempt to quantify 'walkability' or 'pedestrian-friendliness', *quantitative* information can only say so much. A complete examination would also include *qualitative* measures. Therefore, it is recommended that:

- Pedestrian-streetscape audits should be conducted in all Transit Villages in order to complement the Beta index. The Voorhees Transportation Center's Pedestrian/Bicycle Resource Center has developed such an audit and can assist with implementation.
- Other quantitative measures mentioned previously — "average block length", "average distances to the nearest commercial use, park or transit stop", and "percentage of residential land use within walking distance of commercial uses or transit" — should also be developed.

Ultimately, a composite "walkability" profile can then be established for each Transit Village.

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