



Interconnectivity:

*A Review of the Current Status and Steps Necessary
To Increase the Level of Interconnectivity of Future
Development in Delaware*

by

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School of Urban Affairs
Institute for Public Administration
University of Delaware**

March 2006

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Acknowledgment of Sponsorship

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Acknowledgments

The Delaware Center for Transportation gratefully acknowledges the University of Delaware's Institute for Public Administration (IPA) for preparing this report in collaboration with the Delaware Department of Transportation (DelDOT). IPA links the research and resources of the University of Delaware with the management and information needs of local, state, and regional governments in the Delaware Valley. IPA provides assistance to agencies and local governments through direct staff assistance and research projects as well as training programs and policy forums. Jerome R. Lewis is IPA's director.

Special thanks to David Racca of the University of Delaware's Center for Applied Demographics & Survey Research for contributing a travel survey response database file used in a key portion of this report.

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Abstract

This study is an attempt to gauge the benefits of designing for interconnectivity, particularly as it relates to future development in Delaware. Since World War II, residential development has largely occurred through a process by which a private developer subdivides a large tract of land into many smaller lots upon which homes are subsequently built. The most common result is neighborhoods or communities that only access arterials roadways, and are not directly linked by a local road system. Over time, this reliance on the state network of roads results in longer trips and unnecessary congestion: an inefficient and inconvenient system. In the extreme, people may drive a mile or more to visit friends who live only hundreds of feet away.

The central question then is: can altering this recurring pattern of development reduce the dependence of residential vehicular traffic on external roadways; lessen traffic congestion; and shorten travel times and overall travel distances? To address this question, the following steps were taken: a review of the literature, a series of interviews with policymakers at relevant agencies, and an analysis of trip data from the Delaware Travel Monitoring System (DTMS), administered by the Center for Applied Demography and Survey Research (CADSR). Concurrently, the Delaware Department of Transportation (DelDOT) drafted a set of interconnectivity guidelines, suggesting standards for the location and design of residential streets. These guidelines are strongly supported by the literature and interviews. However, while the quantitative analysis generally tends to support the connectivity cause, its results cannot be viewed as entirely conclusive, particularly with regard to external trips. In fact, the entire methodology for measuring connectivity may need refinement. Therefore, the proposed implementation plan must be viewed as a point from which to continue study and refinement, not as an end unto itself.

I. Introduction

Connectivity implies a system of streets with multiple routes and connections serving the same origins and destinations. Connectivity not only relates to the number of intersections along a segment of street, but how an entire area is connected by the system. An area with high connectivity has multiple points of access around its perimeter as well as a dense system of parallel routes and cross-connections within the area, forming a grid-like hierarchy of arterials, collectors and local streets (Daisa, Kloster, Ledbetter, 1998: 2).

The local street network plays a very significant role in determining the character and form of a community. Residential local streets are instrumental in shaping the identity of a neighborhood, determining how people travel and how they feel about their neighborhood. Theoretically, a well-connected street network provides more travel choices, helps to disperse traffic, and encourages pedestrian and bicycle travel. Based on these thoughts, the study examines the connectivity of sixteen communities in New Castle County, Delaware. It then progresses to a more detailed examination of four primary study areas. Interviews with representatives of state and local transportation and land use agencies, as well as a literature review, contribute to a qualitative analysis.

The primary goal of this project is to determine if, in fact, there is a demonstrable connection between street connectivity and trip distance/duration. If possible, any relationships will be quantified.

Research Approach

Two basic approaches are utilized to address the issues of connectivity: interviews with representatives of state and local transportation and land use agencies and an analysis of the connectivity indexes of 16 initial communities. Taken together, the literature review and interviews suggest a series of best practices for encouraging connectivity in Delaware. The quantitative data analysis attempts to speak to the efficacy and desirability of planning for connectivity. From the initial 16, four primary study areas were selected to represent disparate examples of both acceptable and poor levels of connectivity. A traffic analysis focusing on trip length and duration was conducted in an attempt to ascertain discernible differences between automobile trips entirely within the study areas and those originating from, and leaving, the study areas. Ultimately, the analysis suggests an alternative method of measuring connectivity that may increase the utility of the connectivity index and allow for more concrete conclusions regarding trips not occurring entirely within a particular study area.

Fig 1 – How Connectivity is calculated

The formula is as follows:

Source: Ewing, Reid, “Best Development Practices,” 1996

$$\text{Connectivity Index} = \frac{\text{Link}}{\text{Node}}$$

Where L is the number of direct (actual) links between pairs of points, and N is the number of points.

Fig 2 – Links & Nodes



Connectivity Indexes

The initial level of connectivity of 16 test communities was calculated using the formula outlined in *Figure 1*. Each was chosen as it was believed to have either acceptable or poor levels of interconnectivity.

A connectivity index is defined simply as the ratio of links to nodes. This approach enables developers to measure, plan for, and adjust a proposed development's level of connectivity before ground is broken. It also may afford them greater flexibility, enabling the planner to account for constraining topographic features and design unique neighborhood layouts more readily than simply stamping established block lengths or road patterns into the landscape. The connectivity-index approach (with appropriate regulations) has the potential to provide an incentive to developers to reduce cul-de-sacs and include more four-way intersections while not formally dictating a specific road-network design.

The connectivity index describes the overall accessibility of a region in terms of the level of interconnectivity among nodes in the network (Smith, 1995). The measure of accessibility

with respect to transportation is based on the fact that travel generally follows established routes and these routes - links connecting origin and destination nodes - form a transportation network. In general, the higher the level of connectivity, the more convenient an area is to travel, particularly with regard to non-motorized modes. While it is possible to apply the connectivity formula to a geographic area of any size, it appears most useful when applied to a relatively contained area like a community subdivision or census block.

III. Literature Review

Butler, Kent, Susan Handy, and Robert G. Patterson. Planning for Street Connectivity: Getting from Here to There. APA Planning Advisory Service, 2003.

The concept of street connectivity has met with varied receptions in communities. Proponents point to:

- A decrease of traffic on arterial streets,
- More continuous and direct routes that encourage walking and bicycling,
- Greater access and quicker response times for emergency vehicles,
- More evacuation alternatives in the event of a disaster,
- Improvements in the quality of utility connections, facilitating maintenance and enabling more efficient trash and recycling collection and other transport-based community services.

Opponents - usually residents facing change in their familiar surroundings, or in an adjacent neighborhood - and developers argue that street connectivity can:

- Raise levels of through traffic on residential streets,
- Increase infrastructure costs and impervious cover,
- Require more land to develop the same number of housing units,
- Decrease the affordability of housing,
- Threaten the profitability of developments.

This report takes a close look at that debate and the evidence, offering research results and studies of the experience of 14 communities' efforts to incorporate greater connectivity, with Raleigh, N.C., and Austin, Tex, receiving in-depth studies. It concludes with the following questions.

1. What is the most appropriate way to measure connectivity?

The block-length requirement used by most communities so far has been easy to understand and simple to implement, since it generally requires only a change to existing block-length requirements in the city code. Alternately, the connectivity index allows greater flexibility in the design of street networks and serves as a performance standard in the development-approval process. But these are not the only possible approaches and not necessarily the best. The fundamental goals of connectivity requirements are to increase the numbers of connections and the directness of routes. More direct measures of these goals include the number of intersections per mile of road (maximum block length requirements), the ratio between street network and straight-line distances, and the traditional connectivity index (links divided by nodes).

2. How much connectivity is the right amount?

The differentiation of streets based on movement versus access functions is essential for both accommodating and controlling the car. But it is possible that this differentiation has gone far beyond what is necessary to achieve its purpose. The key for communities is to find an appropriate balance between minimizing traffic on residential streets and dispersing traffic throughout the network.

3. What is the best network design for achieving the desired level of connectivity?

Most of the communities studied allow curved street patterns. Nearly all allow cul-de-sacs in certain situations. Those using a connectivity-index requirement offer the greatest degree of flexibility in the design of the street network since they focus on a network's performance rather than its shape. An examination of traditional neighborhoods built before World War II often reveals greater discontinuities than one might expect, and the street networks in most new developments labeled New Urbanist do not follow a perfect grid. Connectivity measures can help

in this effort to create a new type of network if they shift the focus from the means to the end, from the structure of the network to its performance.

4. What does street connectivity mean for non-automobile modes?

In general, improved connectivity for cars should lead to improved connectivity for bicycles and pedestrians, unless streets are designed in such a way as to be unfriendly to both. If separate facilities are provided, bicycle and pedestrian connectivity can be even greater than car connectivity. Transit connectivity can also benefit from improved connectivity in all modes, although the amount of improvement depends on the design of transit routes. By influencing the travel distances for each mode, connectivity requirements can have an important impact on mode choice. Davis, Calif., well known as a bicycling community, encourages high levels of pedestrian and bicycle connectivity through a system of greenbelts but allows wide use of cul-de-sacs that tend to lower automobile connectivity.

5. How can connectivity in commercial areas be improved?

In response to the traffic congestion, some communities have made efforts to ensure connectivity among commercial sites. In San Antonio, Tex., the city negotiates shared-driveway arrangements with developers, a practice that helps keep the number of driveways along frontage roads within the limits set by the Texas Department of Transportation (Lewis et al. 1999). In Palm Beach County, Fla., the Board of County Commissioners may consider an ordinance that would require the linking of retail projects, a proposal that has been less controversial than an early proposal to require connectivity between residential developments (Gopaul 2002).

6. What can be done about existing street networks?

Finding a way to retrofit existing developments may be the thorniest issue of all. Infill developments and redevelopment projects can be used to increase local connectivity, but their

overall effect is usually insignificant or, at best, marginal. Efforts to add bicycle and pedestrian paths to existing residential developments can generate considerable resistance from nearby residents.

Kitamura, R. Mokhtarian, and P.L. Laidet. "A micro-analysis of land use and travel in five neighborhoods in the San Francisco Bay Area." Transportation 24 (1997): 125-158.

This study examined the effects of land use and attitudinal characteristics on travel behavior for five diverse San Francisco Bay Area neighborhoods. First, socio-economic and neighborhood characteristics were regressed against the number and proportion of trips by various modes. The best models for each measure of travel behavior confirmed that neighborhood characteristics add significant explanatory power when socioeconomic differences are controlled for. Specifically, measures of residential density, public transit accessibility, mixed land use, and the presence of sidewalks are significantly associated with trip generation by mode and modal split. Second, 39 attitude statements relating to urban life were factor-analyzed into eight factors: pre-environment, pro-transit, suburbanite, automotive mobility, time pressure, urban villager, transportation control measures (TCM), and workaholic.

It may be concluded that attitudes are certainly more strongly, and perhaps more directly, associated with travel than are land use characteristics. This suggests that land use policies promoting higher densities and mixtures may not alter travel demand.

Metropolitan Council. Creating Livable Streets: Street Design Guidelines for 2040. 2nd ed. Portland: Metropolitan Council, 2002.

This book provides the Portland, Ore., metropolitan area with regional street-design guidelines to support the goals of the Metro 2040 Growth Concept and the Regional Transportation Plan. By asking the question: The automobile is here; how can we create a pattern of mobility that uses it in the most effective and least harmful manner, it seeks “to promote community livability by balancing all modes of transportation.” This balance comes into further play in its design considerations:

- Provide travel mode choice.
- Support regional multi-modal travel.
- Support the economic vitality of the region.
- Create pedestrian and bicycle accessibility.
- Support public social contact.
- Provide orientation and identity to the region.
- Provide a safe environment.
- Provide for physical comfort.
- Provide spatial definition by orienting buildings to the street.
- Provide high quality of construction and design.
- Maintain the quality of the environment.

Community Planning Workshop. Connecting Transportation & Land Use Planning Street Connectivity. Eugene: U. of Oregon, 2003.

Barriers to Integrating Land Use and Transportation Planning:

- Political mistrust/disagreement.
- Lack of transportation financing for all modes of transportation.
- Public perception and lack of wanting to change.
- Regulations that do not allow the principles to take place on the ground.
- Built infrastructure that promotes more development.
- General bias towards automobiles.
- Lack of funding for long-range planning.
- Ordinances that do not allow smart-growth strategies.
- Difficulty educating citizens about benefits of smart growth.
- Developers not wanting to try new ways of developing.

Stone, J.R., M.D. Foster, and C.E. Johnson. “Neo-traditional neighborhoods: A solution to traffic congestion.” Site Impact Traffic Assessment: Problems and Solutions. Ed. Robert E. Paaswell, et al. Proc. Of a Conference in Chicago. 8-10 June 1992. New York: American Society of Civil Engineers, 1992.

This work presents an overview of current trends and their implications for non-motorized travel.

Seattle, Portland, San Diego, and Los Angeles move to develop effective transit systems.

- Voters in Los Angeles taxed themselves heavily to start rebuilding the once-famous transit system. Initial sections are open and operating.
- Trips into downtown Seattle have shifted heavily toward use of transit and bicycling, with improved facilities and strong support from political bodies. Increases in walking

trips from the nearby Capitol Hill District are also reported.

- San Diego, starting with \$60 million, gained high-volume ridership overnight when it introduced its 16-mile “Red Line” and the Tijuana Trolley.
- Portland is reclaiming views of mountain landmarks with successful introduction of an extensive system of buses and light rail.
- Many other cities, including Honolulu, Orlando, and Minneapolis are now increasing emphasis on transit and transit planning.

Traditional Neighborhood Design (TND) and Neo-Traditional Town Planning are hot trends on the planning scene.

Neo-traditional planning is a topic of debate and disagreement within the planning community. Advocates of traditional plans propose a nostalgic approach. They look to historic designs for small communities where traffic was light, people knew their neighbors, and land use encouraged walking and bicycling. A great deal of experimentation is taking place in the United States at this time. Florida alone has 15 neo-traditional communities on the drawing board. Projects to retrofit existing neighborhoods in conformance with traditionalist precepts have been proposed in Bellingham, Wash.; Stuart, Fla., as well as California, Texas, Alaska, Virginia, Maryland, North Carolina, and Georgia.

Traffic-calming strategies can reduce the speed of and emphasis on motor vehicles.

Traffic calming employs physical measures to slow down motorists through changes to the horizontal and vertical alignment of the road while giving greater design priority to pedestrians, bicyclists, and community amenities. Traffic-calming measures are becoming

standardized in communities throughout the country. See Lesson 11 for a full explanation of the fundamental traffic calming techniques.

Transportation Demand Management (TDM) strategies, such as carpools, transit-oriented development, telecommuting, and staggered work hours, have proven popular.

Whereas the early 1980s saw engineers experimenting with ways to push more vehicles through an existing and expanding transportation network, the trend in the 1990s has turned toward getting people to make fewer single-occupant auto trips. Using the TDM concept, employers, government agencies, and others direct their energies into convincing the public to use the auto less and less for solo trips. This is done through pricing incentives (recouping the true cost of parking, for example), subsidies to more efficient transportation modes, helping people overcome perceived hurdles, pushing for improved land use policy, and flexible work hours.

IV. Public perception

Interviews with representatives of state and local land use and transportation agencies

Connectivity, as seen in the literature review, is generally accepted as necessary and desirable, particularly in terms of neighborhood place-making and traffic-diffusion/mitigation strategies. However, it is, by all rights, a fairly new concept. As such, the public at large is relatively unaware of both the concept and of the state's fledgling connectivity initiatives. Because it was unlikely that a survey of laypersons would yield usable data, several interviews were conducted with persons who deal with the concerned public over issues of connectivity.

The interviewees were asked

- What is your philosophy of transportation planning?
- How important is connectivity?
- What are the pros and cons of street connectivity?
- What are some good examples of connectivity in New Castle County?
- Is there a conflict between residents' concerns about safety and technical transportation planning; how can they be coordinated, and which should be given priority?
- What are the major perceived obstacles to connectivity (why do residents typically oppose connectors)?

Representatives from the following agencies were interviewed

- New Castle County Department of Land Use
- Delaware Department of Transportation (DelDOT)
- Delaware Transit Corporation (DTC), Delaware's transit provider
- (WILMAPCO) Wilmington Area Planning Council, the regional metropolitan planning organization (MPO).
- Transportation Management Association of Delaware (TMA)

Summary of Interviews

What is your philosophy of transportation planning?

- Transportation planning is based on community – a shared vision (what does the community want to be). Transportation networks should serve both the community and its vision with a variety of modes, including walking, telecommuting, and ease of access for both automobiles and larger vehicles, both for transit and freight (road and rail). An effective plan will coordinate all these demands and stresses on the planned system into a smooth and sensible environment.
- There is not enough attention paid to transportation planning, particularly in terms of money and overall resources. The needs of the customer/user must be weighed in tandem with vehicular safety, not simply as an afterthought. The planner needs to think in terms of the system: how various modes and systems should work together. Effective planning and design will emphasize the end user at the micro scale and simultaneously favor the system at the macro scale.

How important is connectivity?

- Although it necessitates physical connections, true connectivity needs to be viewed much more holistically, not simply in terms of the number of connections. At present, there is no system or methodology for street design above the local street level. Moreover, the process collapses when a local street is converted into a collector (because it was not originally designed to serve as a collector). From the outset, a street network needs to be designed to account for future connectivity. Stubs are not currently designed for the total connected traffic load. Interconnectivity should be the sign of a complete street network.
- From the efficiency point of view, connectivity reduces total trip distances, making it

easier to get from any given origin to the desired destination. This allows users of the transportation system to make efficient choices and efficient trips. Connectivity also benefits the user in that it typically favors a number of modes, as compared to the current system, which heavily favors the automobile. Not only does a well-connected system result in a system more conducive to alternative modes of travel, it also facilitate an improvement in the delivery of services—namely mail, trash, emergency medical services, police, and school busses.

- A cornerstone of effective connectivity is the degree to which it addresses issues of existing and future land use and the level of connectivity between modes (transit, bicycle, pedestrian and auto). Unfortunately, this has not historically been the case. Our current system represents almost an exclusive deference to the automobile, turning a blind eye to everything else.
- Aside from paper planning, interconnections need to be stressed and clearly communicated during both the development and public-outreach/persuasion processes. Most objections to interconnectivity improvements arise when an existing development is targeted for connectivity upgrades or retrofits, even when the connections were part of the original site plan. It must be made clear to homeowners/buyers that the stub streets they currently live on are planned *and will become* connected to future neighboring developments. Moreover, pedestrian and bicycle connections need to be considered and implemented in tandem with automotive interconnections. Where automobile interconnections are not viable, these connections should still be pursued.

What are the pros and cons of street connectivity?

Pros

- A primary benefit is efficiency. Interconnections minimize the distances between one location and another. It also facilitates a walkable transportation system (as pedestrians would prefer to walk as the crow flies, as opposed to circuitous routes where they must actively compete with other modes). For shorter trips, connectivity also minimizes the need for an automobile to access an arterial street for a purely local trip.
- Connectivity is a vital component to a place-making, or a sense-of-place approach, particularly as it applies to a neighborhood, village, hamlet, or development. By providing neighbors the opportunity to travel via “friendlier modes,” connectivity can foster and improve relationships among neighbors, lending to a sense of community. Fewer car trips also have the potential to improve air quality, reduce noise pollution, and improve the health of those who forego driving.

Cons:

- Connectivity can have the effect of luring non-local traffic onto local/residential streets, resulting in the increased volume and speed of automotive traffic. Common complaints are that connectivity can create an intrusion on the community and make the streets less safe for children.
- Neighborhood privacy is also a key issue. While many residents would answer that they favor connectivity, they are often quick to revert to a NIMBY (not-in-my-backyard) mentality when such connections are proposed in their neighborhood. Residents are commonly concerned with either a real, or simply perceived, safety issue that may arise if undesirable persons have access to and are able to cut through their neighborhoods.

What are some good examples of connectivity in New Castle County?

- Brandywine Hundred seems to work well as it incorporates relatively short block sizes.
- The commercial developments along Rt. 1 in Sussex County have proven good for both pedestrians and automobiles.
- Limestone Hills is a good example of interconnectivity within developments.
- Wilmington, Newark, New Castle and Brandywine Hundred

Is there a conflict between residents' concern about safety and technical transportation planning; how can they be coordinated and which should be given priority?

- Safety must remain the ultimate priority, however better technical transportation planning can be used to achieve this: they are not mutually exclusive.
- Master planning would certainly help in overcoming the obstacles associated with both technical planning and connectivity. Still, the goals remain difficult to reach. At a minimum, connectivity should be pursued for bicycles and pedestrians. Where auto-connectivity is pursued, traffic-calming techniques may be employed to diminish the danger automobile traffic presents to other modes.

What are the major obstacles to connectivity (why do residents so often fight it)?

- Public education, specifically the lack thereof, appears to be the major obstacle. We have not done a good job of education and allowing the public to make an informed decision regarding connectivity. People don't know what connections mean and what the benefits of it are. Because of this, interconnectivity continues to carry the stigma as an engine of crime, and a detriment to both safety and property values.
- Traffic and road design are the major obstacles. Many roads were not designed to support the connectivity we are now trying to implement. Specifically, many are directly

accessed by numerous driveways that are too narrow for cars to quickly and safely enter or exit the roadway. For example, people are using Quail Ridge Hollow in Mendenhall Village as a connector, but it was neither intended nor designed as a collector. Fox Mill Road connects to a village due to a left turn restriction at Rt. 7. Both of these illustrate reasons residents often oppose connectivity.

- Residents often cling to a desire for a level of isolation and privacy that any significant degree of connectivity threatens. Any amount of traffic, particularly on a road not designed to efficiently and safely carry such volumes, can quickly alienate the affected residents.

V. Analysis

Introduction to Analysis

Our review of the literature suggests the hypothesis to be tested. Will an increase in connectivity result in trips that are shorter both in total distance and duration? To this end, the connectivity indexes of 16 residential developments in Delaware were calculated. Eight communities with open interconnections were compared with eight developments where the interconnections were largely closed (see fig. 3 and 3a). In most cases, closed interconnections denote the presence of cul-de-sacs or stub streets.

The results, shown in figure 3, seem to support the initial hypothesis that grid-like development patterns tend to exhibit a greater degree of connectivity, as opposed to the more prevalent curvilinear pattern that has been favored for the past 30+ years. Not only do grid-like developments tend to incorporate fewer dead-ends, each node is likely to have at least three to four connecting links. Conversely, the curvilinear pattern typically offers fewer links per node. Moreover, cul-de-sacs and the terminus of stub streets count as nodes, while the streets they end at count as links. This often results in a one-to-one ratio which is technically accurate. However, in the current methodology, these dead-end links are given the same weight as a link ending at an intersection. The very real possibility that measuring connectivity in this way actually overstates a curvilinear development's degree of connectivity is explored in the recommendations for further research

As expected, the developments with opened interconnections scored higher than those with closed interconnections, averaging a full .12 higher on the connectivity index.

Figure 3 – Connectivity levels in subdivisions with open vs. closed connections

Subdivisions with Opened Interconnections

	Links	Nodes	C.I.
Scottfield	85	59	1.44
Thornwood	20	18	1.11
Salem Woods	91	76	1.20
Rose Hill	34	27	1.26
Marabou Meadows	40	28	1.43
Rosetree Hunt	23	19	1.21
Stone Mill	84	61	1.38
Wedgewood	73	58	1.26
Total	450	346	1.30

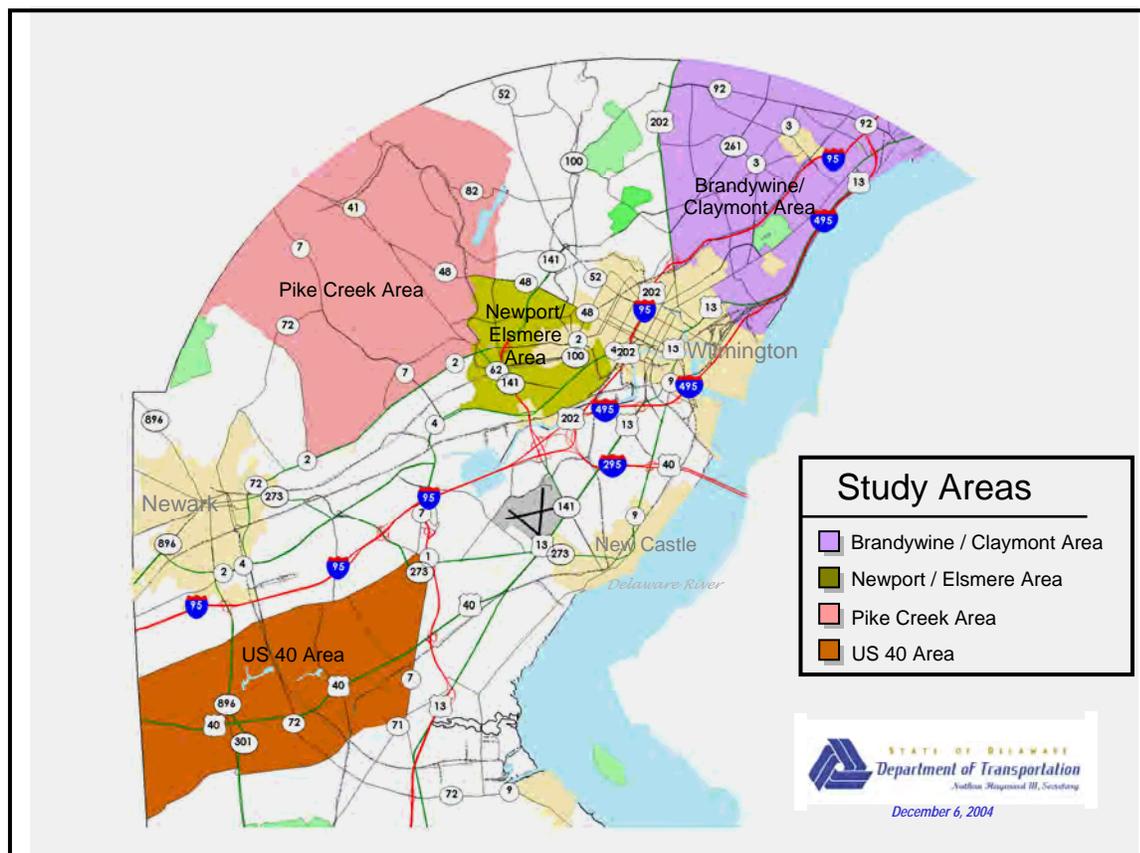
Subdivisions with Closed Interconnections

	Links	Nodes	C.I.
Sparrow Run	77	64	1.20
Timber Farms III	37	33	1.12
Birchwood	41	28	1.46
Jamestown	19	18	1.06
West Meadow	6	6	1.00
Hills of Skyline	17	16	1.06
Heather Woods	15	15	1.00
Hockessin Greene	9	8	1.13
Total	221	188	1.18

Methodology

Initially, the hope was to gather data on an extremely local scale, surveying residents of particular developments. Unfortunately, such precise, area-specific data was not available, nor was it practical to gather such information. To overcome this problem, the developments were geographically plotted by area. DelDOT planner Mike DuRoss suggested moving from a development-specific approach, to the tabulation of data based on modified grids. Four study areas were identified and subsequently classified as “more connected” (Brandywine/ Claymont area) and “connected” (Newport/ Elsmere area). Pike Creek and the U.S. Rt. 40 area were classified “less connected” (see fig. 3a).

Figure 3a – Four Primary Study Areas



Data Collection

The data for this analysis were collected over a seven-year period. Beginning in 1996, a monthly telephone survey was administered to 250 households. Between 1996 and 2002, over 31,000 total trips were logged statewide through the Delaware Travel Monitoring System (DTMS), administered by the Center for Applied Demography and Survey Research (CADSR) at the University of Delaware. Utilizing existing modified grids, trips beginning or ending within the study areas were spatially referenced by origin and destination grid. The four selected study areas, or subsets, accounted for 10,602 of the approximately 31,000 statewide trips logged during the collection period, or 34 percent. The *more-interconnected* areas included grids in and around Claymont and the Newport-Elsmere area. *Less-interconnected* areas included grids in and around Pike Creek and the U.S. Rt. 40 area.

Each subset was then analyzed with regard to trip type across three categories: trips beginning and ending within the selected area (intra-area), trips originating within the subset, but terminating elsewhere (inter-area), and trips beginning outside the subset, but ending within it (outside trips). For example, trips involving Claymont were categorized:

- Claymont to Claymont (within Claymont),
- Claymont to Other Areas
- Other Areas to Claymont

Below, figure 4 shows the average results for all 10,602 study area trips.

Fig 4 – Average work and nonwork trip distances and times for all trip types in all four study areas

AVERAGE OF SELECTED AREAS

<u># Trips</u>	<u>Purpose</u>	<i>Average Time (min)</i>	<i>Average Distance (miles)</i>
4230	Work	37.65	10.08
<u>6372</u>	Nonwork	28.41	8.41
10602	<i>Source: DTMS data from CADSR 1996-2002</i>		

For each trip type (intra, inter, and outside) the analysis began with a simple comparison of average times and distances to the overall averages (as seen in fig. 4). When significant differences were detected, they were explored in greater depth.

Preliminary Analysis of Intra-Area trips in the Four Study Areas

Fig 5 – Intra-Area Trip times and distances of Less-Interconnected areas as compared to the average of all trips studied

LESS-INTERCONNECTED AREAS

<i>“Pike Creek to Pike Creek”</i>					<i>Plus or minus the average of all trips studied</i>		
<u>#</u>		<i>Average</i>	<i>Average</i>	<i>Relative</i>	<i>Average</i>	<i>Average</i>	<i>Relative</i>
<u>Trips</u>	<u>Purpose</u>	<u>Time</u>	<u>Distance</u>	<u>Speed</u>	<u>Time</u>	<u>Distance</u>	<u>Speed</u>
		<u>(min)</u>	<u>(miles)</u>	<u>(mph)</u>	<u>(min)</u>	<u>(miles)</u>	<u>(mph)</u>
205	Work	21.10	5.82	16.55	-16.55	-4.26	0.49
<u>578</u>	Nonwork	16.99	13.27	46.86	-11.42	4.86	29.10
783							

<i>“US 40 to US 40”</i>					<i>Plus or minus the average of all trips studied</i>		
<u>#</u>		<i>Average</i>	<i>Average</i>	<i>Relative</i>	<i>Average</i>	<i>Average</i>	<i>Relative</i>
<u>Trips</u>	<u>Purpose</u>	<u>Time</u>	<u>Distance</u>	<u>Speed</u>	<u>Time</u>	<u>Distance</u>	<u>Speed</u>
		<u>(min)</u>	<u>(miles)</u>	<u>(mph)</u>	<u>(min)</u>	<u>(miles)</u>	<u>(mph)</u>
73	Work	20.09	6.06	18.10	-17.56	-4.02	2.03
<u>259</u>	Nonwork	16.80	4.90	17.50	-11.61	-3.51	-0.26
332							

Source: DTMS data from CADSR

Generally, intra-area trips take less time and are shorter in terms of distance than the average of all trips, but speeds tend to be lower. However, at first glance, the intra-area data appear to show an inverse correlation between the level of interconnectivity and the distance and duration of trips. While it is to be expected for intra-area, or purely local trips, to be considerably shorter and quicker than trips that, by definition, go beyond the study area, it would seem significant that trips within the more-interconnected areas, as compared to the average of all trips studied, are pronouncedly shorter in terms of distance than the less-interconnected areas compared to the same (figs 5&6). Compared directly to each other, the relationship between more-interconnected areas to less-interconnected areas, for both work and nonwork distances,

persists. Despite generally far greater travel speeds in the less-interconnected areas, the travel times for both appear comparable.

Figure 6 – Intra-area Trip times and distances of More-Interconnected areas as compared to the average of all trips studied

MORE-INTERCONNECTED AREAS

<i>“Claymont to Claymont”</i>					<i>Plus or minus the average of all trips studied</i>		
<u>#</u>	<u>Purpose</u>	<u>Average Time (min)</u>	<u>Average Distance (miles)</u>	<u>Relative Speed (mph)</u>	<u>Average Time (min)</u>	<u>Average Distance (miles)</u>	<u>Relative Speed (mph)</u>
329	Work	23.40	4.71	12.08	-14.25	-5.37	-3.99
1217	Nonwork	16.05	3.97	14.84	-12.36	-4.44	-2.92
1546							

<i>“Newport to Newport”</i>					<i>Plus or minus the average of all trips studied</i>		
<u>#</u>	<u>Purpose</u>	<u>Average Time (min)</u>	<u>Average Distance (miles)</u>	<u>Relative Speed (mph)</u>	<u>Average Time (min)</u>	<u>Average Distance (miles)</u>	<u>Relative Speed (mph)</u>
80	Work	20.88	3.51	10.09	-16.77	-6.57	-5.98
237	Nonwork	11.45	2.06	10.79	-16.96	-6.35	-6.97
317							

Source: DTMS data from CADSR, 1996-2002

Extended analysis of Intra-Area trips

A central assumption to this analysis is that trips beginning and ending within the particular study areas will be the most responsive and sensitive to differing levels of connectivity within each, because the entire trip takes place within an area with a known level of connectivity, as opposed to trips that originate in one study area and terminate in another, between which no data on connectivity are available. Obviously, these purely local trips trend well below the average length and duration of the average of all trips recorded, as the *all trips* average also includes all of the non-local trips (journeys both originating and ending much further away.)

While somewhat apparent, the distinctions are not totally clear. However, by weighting the number of trips and then averaging both more-interconnected areas together (Claymont & Newport), the comparison to the average of the less-interconnected areas (Pike Creek & U.S. Rt. 40) becomes more clear.

Fig 7 – Average Time, Distance & Speed for Intra-Area, Less-Connected Trips Weighted by number of trips

“Average – Less-Connected to Same”

<i>Source: DTMS data from CADSR</i>		<i>Average Time</i>	<i>Average Distance</i>	<i>Relative Speed</i>
<u># Trips</u>	<u>Purpose</u>	<u>(min)</u>	<u>(miles)</u>	<u>(mph)</u>
278	Work	20.83	5.88	16.94
837	Nonwork	16.93	10.68	37.85
1115	All trips	17.90	9.48	31.78

Fig 8 – Average Time, Distance & Speed for Intra-Area, More-Connected Trips Weighted by number of trips

“Average – More-Connected to Same”

<i>Source: DTMS data from CADSR</i>		<i>Average Time</i>	<i>Average Distance</i>	<i>Relative Speed</i>
<u># Trips</u>	<u>Purpose</u>	<u>(min)</u>	<u>(miles)</u>	<u>(mph)</u>
409	Work	22.91	4.48	11.72
1454	Nonwork	15.30	3.66	14.35
1863	All trips	16.97	3.84	13.57

What is immediately apparent is that the average distance of trips occurring within the more-connected areas is substantially shorter than both the work and nonwork distances for the less-connected areas (figs. 7 and 8). Less pronounced, but equally important is the shorter travel time in the more-connected areas (16.97 minutes) as compared to the equivalent figure for the less-connected areas (17.9 minutes). This is especially surprising, given the fact that average speeds in the less-connected areas are estimated as being well over twice as fast (18.26 mph greater) than the more-connected areas. Taken together, the analysis would seem to clearly indicate that increased connectivity allows people the option of choosing more direct routes,

traveling shorter distances, and spending less time in their cars. Conversely, although those traveling within less-connected areas are able to drive much faster, their inability to take a more direct route results in their traveling greater distances for a longer duration. Nowhere is this trend more strongly illustrated than in the nonwork trips. Not only are trips within the more-connected communities 1.63-minutes faster, they are an astounding seven miles shorter on average. While the patterns of development consistent with each type of community likely have some impact, it is doubtless that the individual's ability to drive more "as the crow flies" must play a significant role. The data suggest, but does not definitively prove, that the ability to utilize a variety of routes within well-connected areas results in very direct nonwork trips. A possible hypothesis for why work trips tend to be and to take longer could be that the singular destination reduces the number of potential routes.

As nonwork trips beginning and ending within the same areas illustrated the clearest trends, those trips were compared between the most well-connected study area, Claymont, and the least well-connected study area, Pike Creek (see fig. 9).

The connectivity levels for all of the modified grids within each of these study areas is shown below (see fig. 8a).

Fig 8a – Total Connectivity for all modified grids within the Pike Creek and Claymont Study Areas

Pike Creek Study Area Connectivity

Source: DelDOT

Grid #	External Links	Internal Links	External Nodes	Internal Nodes	Internal Connectivity	Overall Connectivity
6403600	15	38	13	37	1.03	1.06
6403620	14	52	13	43	1.21	1.18
6803640	9	25	9	24	1.04	1.03
6603600	15	66	13	62	1.06	1.08
7003660	14	34	14	26	1.31	1.20
7203640	13	38	13	36	1.06	1.04
Total	80	253	75	228	1.11	1.10

Claymont Study Area Connectivity

Grid #	External Links	Internal Links	External Nodes	Internal Nodes	Internal Connectivity	Overall Connectivity
12403662/						
12603680	17	90	14	67	1.34	1.32
12403680	35	41	31	23	1.78	1.41
12403720	14	48	14	23	2.09	1.68
12403700	15	75	15	50	1.50	1.38
12603700	20	33	20	15	2.20	1.51
12603720	6	41	4	36	1.14	1.18
Total	107	328	98	214	1.53	1.39

Each trip purpose from Pike Creek (34 in all) was cross-referenced to its exact counterpart from the Claymont area. Each trip type was compared in terms of total trip time and distance. As in the previous analysis, the results strongly indicate that connectivity levels have an impact on both (see fig. 9). The Pike Creek trips were longer in both time and distance for 15 trip types. These trips were shorter in both instances only six times, and half of those six were the result of very few trips available for analysis (in all cases four or fewer).

Fig 9 – Nonwork trip comparison between the most and least connected study areas, Claymont and Pike Creek respectively

From	ToClaymont.....		Pike Creek.....			Pike Creek is... than Claymont Time-Distance	
		Time	Distance	Trips	Time	Distance	Trips		
Drop-Off/Pick-Up	Social	21.6	6.1	7	24.3	5.3	3	Longer	Shorter
Home	Social	16.4	3.8	60	25.6	7.7	20	Longer	Longer
Shopping	Social	25.3	4.9	8	9.4	2.8	2	Shorter	Shorter
Social	Social	14.9	4.1	10	16.2	6.5	2	Longer	Longer
Drop-Off/Pick-Up	Shopping	43.9	9.6	7	11.4	2.5	6	Shorter	Shorter
Home	Shopping	15.5	4.1	208	18.0	4.1	95	Longer	Same
Other	Shopping	14.2	3.5	17	12.8	2.2	10	Shorter	Shorter
Recreational	Shopping	12.3	3.5	5					
Shopping	Shopping	16.0	4.0	49	11.7	3.9	10	Shorter	Shorter
Work	Shopping	19.4	3.6	12	19.0	5.9	6	Shorter	Longer
Home	School	19.8	4.7	31	36.1	9.0	12	Longer	Longer
Home	Recreational	14.3	3.7	31	20.6	6.5	10	Longer	Longer
Other	Recreational	16.8	3.5	5	15.6	3.1	1	Shorter	Shorter
Drop-Off/Pick-Up	Other	8.0	3.0	6	16.5	2.6	2	Longer	Shorter
Home	Other	16.3	4.1	66	14.3	4.8	37	Shorter	Longer
Other	Other	20.3	3.5	7	19.6	7.1	4	Shorter	Longer
School	Other	13.4	3.6	17	6.2	7.1	1	Shorter	Longer
Child Care	Other	13.5	4.1	5	18.5	4.5	8	Longer	Longer
Drop-Off/Pick-Up	Home	12.4	3.3	66	18.1	5.7	28	Longer	Longer
Eat-Out	Home	16.8	4.3	27	19.4	6.0	14	Longer	Longer
Other	Home	16.7	3.7	56	19.8	5.5	32	Longer	Longer
Recreation	Home	17.5	4.3	34	11.6	5.0	12	Shorter	Longer
School	Home	26.7	5.0	23	58.3	9.6	11	Longer	Longer
Shopping	Home	16.6	3.9	230	14.6	4.0	128	Shorter	Longer
Social	Home	18.2	4.0	60	20.1	5.0	18	Longer	Longer
Home	Eat Out	13.8	4.3	31	19.1	4.6	18	Longer	Longer
Shopping	Eat Out	56.1	6.4	2	15.0	1.8	4	Shorter	Shorter
Social	Eat Out	13.6	4.5	4	10.2	9.3	1	Shorter	Longer
Work	Eat Out	5.7	0.8	3	9.7	2.3	1	Longer	Longer
Drop-Off/Pick-Up	Drop-Off/Pick-Up	10.3	3.0	8	12.7	4.6	11	Longer	Longer
Home	Drop-Off/Pick-Up	13.3	3.8	78	13.7	4.8	32	Longer	Longer
Shopping	Drop-Off/Pick-Up	18.1	4.6	10	18.1	4.1	7	Same	Shorter
Social	Drop-Off/Pick-Up	14.0	2.7	6	18.6	5.4	3	Longer	Longer
Work	Drop-Off/Pick-Up	19.7	5.1	7	14.8	5.3	10	Shorter	Longer

The analysis of trips longer and shorter by time alone reinforces the earlier analysis.

Although surveyed drivers traveling within less-connected areas typically averaged over twice the speed of those in more connected areas, the total amount of time spent in the car continues to be longer on trips within less-well-connected areas. Trips inside the Pike Creek study area took longer than those within the Claymont study area 18 times. They were shorter only 14.

However, what is particularly telling, and strongly supported by earlier findings, are the

significantly shorter travel distances within well-connected areas, as compared to less well-connected areas. Trips within the Pike Creek study area were longer in terms of distance than the same trip type in the Claymont area 23 out of 34 times. Only nine times were they shorter.

Analysis of Inter-Area trips compared to the average of all trips studied

Fig 10 – Inter-Area Trip times and distances of Less-Interconnected areas as compared to the average of all trips studied

LESS-INTERCONNECTED AREAS

“Pike Creek to Other Areas”

<u>#</u> <u>Trips</u>	<u>Purpose</u>	<u>Average</u>	<u>Average</u>	<u>Relative</u>	<i>Plus or minus the average of all trips studied</i>		
		<u>Time</u>	<u>Distance</u>	<u>Speed</u>	<u>Average</u>	<u>Average</u>	<u>Relative</u>
		<u>(min)</u>	<u>(miles)</u>	<u>(mph)</u>	<u>(min)</u>	<u>(miles)</u>	<u>(mph)</u>
515	Work	39.76	9.36	14.12	2.11	-0.72	-1.94
<u>622</u>	Nonwork	54.66	10.56	11.59	26.25	2.15	-6.17
1137							

“US 40 to Other Areas”

<u>#</u> <u>Trips</u>	<u>Purpose</u>	<u>Average</u>	<u>Average</u>	<u>Relative</u>	<i>Plus or minus the average of all trips studied</i>		
		<u>Time</u>	<u>Distance</u>	<u>Speed</u>	<u>Average</u>	<u>Average</u>	<u>Relative</u>
		<u>(min)</u>	<u>(miles)</u>	<u>(mph)</u>	<u>(min)</u>	<u>(miles)</u>	<u>(mph)</u>
424	Work	34.14	10.53	18.51	-3.51	0.45	2.44
<u>453</u>	Nonwork	32.44	12.06	22.31	4.03	3.65	4.54
877							

Source: DTMS data from CADSR

Although the level of connectivity demonstrated clear trends when applied to intra-area trips, the trends were much weaker for inter-area and outside trips. The data from inter-area and outside trips compared both trips originating from the selected areas and ending elsewhere, and trips originating outside the study areas and terminating within them. Clear patterns and trends were not apparent in either instance when compared to the average length and duration of all trips. For example, looking at *U.S. Rt. 40 to Other Areas*, (see fig. #10) one would expect the area’s lack of interconnectivity to cause trips originating from it to take longer than average.

However, the duration of work trips was actually 3.51 minutes faster than the overall average. Even accounting for the fact that nonwork trips averaged 4.03 minutes longer, the net result shows virtually no difference.

Similarly, looking at *Claymont to Other Areas* (see fig. #11) the expected result for a better-connected area would be that trips originating from it would be shorter in either duration or absolute distance than the overall average. This is not the case. Work and nonwork trips beginning in Claymont were 2.33 and 6.62 minutes longer than average respectively, and in both cases the absolute distances were longer as well. Presumably, trip length and time are being more strongly influenced by other factors in these situations.

Fig 11 – Inter-Area Trip times and distances of More-Interconnected areas as compared to the average of all trips studied

MORE-INTERCONNECTED AREAS

<i>“Claymont to Other Areas”</i>					<i>Plus or minus the average of all trips studied</i>		
<u>#</u>	<u>Purpose</u>	<u>Average Time (min)</u>	<u>Average Distance (miles)</u>	<u>Relative Speed (mph)</u>	<u>Average Time (min)</u>	<u>Average Distance (miles)</u>	<u>Relative Speed (mph)</u>
728	Work	39.98	10.79	16.19	2.33	0.71	0.13
<u>708</u>	Nonwork	35.03	11.57	19.82	6.62	3.16	2.06
1436							

<i>“Newport to Other Areas”</i>					<i>Plus or minus the average of all trips studied</i>		
<u>#</u>	<u>Purpose</u>	<u>Average Time (min)</u>	<u>Average Distance (miles)</u>	<u>Relative Speed (mph)</u>	<u>Average Time (min)</u>	<u>Average Distance (miles)</u>	<u>Relative Speed (mph)</u>
430	Work	34.54	9.70	16.85	-3.11	-0.38	0.79
<u>436</u>	Nonwork	28.78	9.20	19.18	0.37	0.79	1.42
866							

Source: DTMS data from CADSR

Analysis of outside trips compared to the average of all trips studied

The results from trips originating outside the subsets and terminating within them were equally mixed and largely inconclusive. As a more-connected area, the expected outcome of outside trips ending in the Newport area (see fig. #13) should be for shorter trips, in terms of both time and distance. However, work trips are barely 90 seconds shorter than the average of all trips. Nonwork trips took approximately 30 seconds longer. Similarly, the average distances of both work and nonwork trips vary negligibly from the overall averages. The only trend that emerges at all is that drivers beginning or ending at a less-connected area are either able to, or choose to, drive marginally faster. However, this does not translate into significantly different travel times.

Fig 12 – Outside-Area Trip times and distances of Less-Interconnected areas as compared to the average of all trips studied

LESS-INTERCONNECTED AREAS

<i>“Other Areas to Pike Creek”</i>					<i>Plus or minus the average of all trips studied</i>		
<u>#</u>		<i>Average</i>	<i>Average</i>	<i>Relative</i>	<i>Average</i>	<i>Average</i>	<i>Relative</i>
<u>Trips</u>	<u>Purpose</u>	<u>Time</u>	<u>Distance</u>	<u>Speed</u>	<u>Time</u>	<u>Distance</u>	<u>Speed</u>
		<u>(min)</u>	<u>(miles)</u>	<u>(mph)</u>	<u>(min)</u>	<u>(miles)</u>	<u>(mph)</u>
367	Work	43.98	10.78	14.71	6.33	0.70	-1.36
494	Nonwork	25.39	8.59	20.30	-3.02	0.18	2.54
861							

<i>“Other Areas to US 40”</i>					<i>Plus or minus the average of all trips studied</i>		
<u>#</u>		<i>Average</i>	<i>Average</i>	<i>Relative</i>	<i>Average</i>	<i>Average</i>	<i>Relative</i>
<u>Trips</u>	<u>Purpose</u>	<u>Time</u>	<u>Distance</u>	<u>Speed</u>	<u>Time</u>	<u>Distance</u>	<u>Speed</u>
		<u>(min)</u>	<u>(miles)</u>	<u>(mph)</u>	<u>(min)</u>	<u>(miles)</u>	<u>(mph)</u>
320	Work	41.40	11.20	16.23	3.75	1.12	0.17
427	Nonwork	33.56	11.43	20.44	5.15	3.02	2.67
747							

Source: DTMS data from CADSR

Figure 13 – Outside-Area Trip times and distances of More-Interconnected areas as compared to the average of all trips studied

MORE INTERCONNECTED AREAS

<i>“Other Areas to Claymont”</i>					<i>Plus or minus the average of all trips studied</i>		
<i>#</i>		<i>Average</i>	<i>Average</i>	<i>Relative</i>	<i>Average</i>	<i>Average</i>	<i>Relative</i>
<i>Trips</i>	<i>Purpose</i>	<i>Time</i>	<i>Distance</i>	<i>Speed</i>	<i>Time</i>	<i>Distance</i>	<i>Speed</i>
		<i>(min)</i>	<i>(miles)</i>	<i>(mph)</i>	<i>(min)</i>	<i>(miles)</i>	<i>(mph)</i>
536	Work	43.08	10.13	14.11	5.43	0.05	-1.96
642	Nonwork	38.32	10.92	17.10	9.91	2.51	-0.66
1178							

<i>“Other Areas to Newport”</i>					<i>Plus or minus the average of all trips studied</i>		
<i>#</i>		<i>Average</i>	<i>Average</i>	<i>Relative</i>	<i>Average</i>	<i>Average</i>	<i>Relative</i>
<i>Trips</i>	<i>Purpose</i>	<i>Time</i>	<i>Distance</i>	<i>Speed</i>	<i>Time</i>	<i>Distance</i>	<i>Speed</i>
		<i>(min)</i>	<i>(miles)</i>	<i>(mph)</i>	<i>(min)</i>	<i>(miles)</i>	<i>(mph)</i>
275	Work	36.27	10.13	16.76	-1.38	0.05	0.69
290	Nonwork	28.76	8.35	17.42	0.35	-0.06	-0.34
565							

Source: DTMS data from CADSR

Trip-Data Conclusions

The data at hand does not undermine interconnectivity as a concept, but neither does it definitively substantiate it. Certainly the strong relationship between trip distance and duration that was seen in the intra-area analysis is encouraging. While it is possible that an area’s level of connectivity is not a significant factor in trip length or duration when applied to non-local trips, its impact may simply be marginalized by longer trips. Also possible is that the survey instrument utilized in gathering trip data was too blunt a tool to detect what in reality is a significant, if yet undetected, difference in travel behavior. Still another possibility is that while *true* levels of connectivity have an effect on trip distance and duration, the accepted methodology used to measure an area’s level of connectivity is either flawed or lacking. This topic is explored next.

VI. Recommendations for Future Research

1. Interconnectivity-Index Refinement - Investigate optional methods for revising and/or refining the “traditional connectivity index,” such as the one described in WILMAPCO’s 1997 study pertaining to Middletown, Del. The traditional index is calculated by simply dividing the total number of links by the number of nodes within a study area. The index is somewhat limited in its application in that it does not account for incentives or disincentives for increasing the utility of nodes by designing them to have more than one link. Accordingly, it can be swayed upward by study areas that appear to have higher connectivity to the regional-roadway system while at the same time having relatively limited internal connectivity (typically a curvilinear street system making substantial use of cul-de-sacs). Essentially, the development scores fairly well on the connectivity index. However, the connectivity it provides is largely external, meaning that it encourages, or even forces local trips to access arterial streets. This is contrary to the entire goal of connectivity. Similarly, it can overstate the connectivity of a street design or development which is, functionally, very poorly connected. An example of this is when a street ends at a node, with four or five other links radiating off, like spokes on a wheel, to cul-de-sac heads. The links leading to cul-de-sac heads count positively towards the connectivity index score, but their effect on real connectivity is nil.

Some optional methods could include:

- Weighting the “nodes” denominator by the number of “links” connected to each node.

This type of factor would provide an incentive for a higher index as nodes with three and four link connections would have more weight. As an example, many suburban “cul-de-sac” communities have indexes in the 1.0 to 1.1 range while typical “grid” communities have indexes in the 1.4 to 1.6 range. While 1.4 is about 30 percent higher than the 1.1

index, such a weighting factor would push the index above 2.0. Not only would this method better measure the actual level of “connectivity” present in a study area, it could also serve to further validate connectivity as a paramount measurement. A wider and more justifiable disparity between “well connected” and “less well connected” would give the researcher a far more precise tool. While it is difficult to definitively prove that a .03 difference in the “traditional” level of connectivity has a demonstrable impact on travel times and distances, it could be much easier and more understandable if the difference were .8. Simply put, the connectivity index must be a reasonably accurate abstraction of what kind of a system the typical driver faces.

- Develop a weighting method to classify “internal” versus “external” connectivity. For example, some of the grids examined in this report (in both the Pike Creek and Claymont areas) had high numbers of regional-system-node connections and relatively few internal connections but the overall indexes appeared to show a high level of connectivity. Although both types of connectivity are important, thus far our findings clearly show that intra-area trips are acutely affected by an area’s level of connectivity, presumably internal. Moreover, one of the presumed benefits of interconnectivity is that its presence should allow some portion of an area’s traffic volume to forego accessing arterial and major roadways. An area with poor internal, but excellent external, connectivity would seem far less likely to offer this advantage. Because the current index does not account separately for internal and external levels, it cannot easily be made to assess the varying benefits of the two types of connectivity.

- Weigh the connections between communities with only one or two regional-system nodes versus “grid” system connections to surrounding roadways. This could involve developing several indexes for each study area to better measure how individual components of “internal vs. external” connectivity are affecting overall indexes simply based on “total nodes and links.”

2. *Interconnectivity as traffic calming* - Explore any possible relationship between levels of interconnectivity and the speed of vehicles traveling on connected and poorly connected street networks. One of the most common complaints concerning interconnectivity is “speeding, cut-through traffic.” Can it be demonstrated that properly implemented connectivity serves as a form of traffic calming and, if properly implemented, actually serves to slow traffic? Also, work to explain the apparent correlation between interconnectivity, development patterns, density and mode split, particularly regarding intra-area trips. If the relationship between density and the transportation network in Delaware could be shown to facilitate walking and transit, interconnectivity could blossom into a favored policy.

3. *Delaware Travel Monitoring System (DTMS) Refinement* - DTMS is a monthly travel-polling system conducted by the University of Delaware’s Center for Applied Demography and Survey Research for DelDOT Planning. It has conducted about 250 surveys statewide each month since 1997.

Although an extensive review of DTMS data conducted for this study identified that differences in travel patterns (as measured by travel times in minutes and travel distances in miles) appear to exist throughout New Castle County, at least in two areas that could be described as “better connected,” such as the Claymont area, or “less connected,” such as Pike

Creek, the survey instrument currently does not capture detailed data on attitudinal or behavioral aspects of connectivity in Delaware.

The survey does include a question on whether various trips made during the day are “linked” to other trips but does not capture detailed data on attitudes or actual patterns for how street form affects the degree of trip linking.

To gather this type of information, the DTMS survey could easily be refined to include either questions on the instrument itself, or placeholders on the retrospective trip diary. This would be helpful in that local, Delaware-based data would be collected relative to the connectivity topic and could help determine how the structure of the transportation network affects how individuals choose to travel. Simply put, at present, data were extrapolated from the general DTMS survey to study interconnectivity. A survey instrument designed specifically for interconnectivity could provide more useful data.

4. *Expanded Application of Connectivity Indexes* - Additional work could include applying the traditional connectivity index, or variations thereof, on a much wider scale than was done for this study. While this effort focused on selected modified grids in the Pike Creek and Claymont areas, a GIS-based approach would permit examination of the connectivity formula on grids throughout Delaware, either individually or collectively.

The goals of a wider application could include:

- Identifying a range of connectivity indexes throughout Delaware in order to understand the scope of potential connectivity improvements that could be achieved through various policy methods to incorporate better connectivity in new subdivision construction.

- Identifying which areas in Delaware have “higher” or “lower” indexes and stratifying those according to “build-out” or growth areas described in the Delaware Strategies for State Policies and Spending.

VII. References

Books

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Appendix

The following are the relevant portions of DelDOT's proposed Standards and Regulations for Subdivision Streets and State Highway Access, as they pertain to interconnectivity. As of March 2006, they had been the subject of a public workshop, with adoption anticipated in May 2006. They represent the most feasible existing course of action available to increase connectivity in Delaware. However, as noted in findings, while the data tend to support the case for interconnectivity, the link between connectivity, travel time, trip distance, and congestion is not so demonstrable as to conclude the existence of a conditional, or direct cause- and- effect relationship. Moreover, the guidelines, at present, may not reflect a variety of code and legislative changes soon to be proposed by the state's Mobility Friendly Design Committee. Many of these proposals specifically concern interconnectivity, and, when completed, should address some of the recommendations. A list of action items follows the present guidelines.

STANDARDS AND REGULATIONS
FOR
SUBDIVISION STREETS AND STATE HIGHWAY ACCESS



DRAFT

3.5.7 Interconnectivity

Linkages shall be provided among adjoining subdivisions in order to allow convenient and effective travel among neighborhoods. Benefits include ease of access, association with neighbors, alternative travel routes for residents, sidewalk networks on local streets and internal circulation routes for service providers such as school buses, sanitation vehicles, and emergency management personnel.

3.5.7.1 Linkages to Existing Adjacent Developments with no Connection

When proposed development is being planned adjacent to previously developed land and the previously developed land has not incorporated linkage street stubs to its perimeter as part of its recorded plan, the proposed development shall provide access-way connections if possible.

The Applicant shall also provide for a reservation of right of way for a future access-way connection, and if required by DelDOT, for a full street connection, within the span of each such property boundary line.

3.5.7.2 Linkages to Existing Adjacent Developments with Connection

When proposed development is being planned adjacent to previously developed land and the previously developed land has incorporated linkage street stubs to its perimeter as part of its recorded plan, the proposed development must incorporate street connections to the existing linkage street right-of-way stubs as part of its street system.

3.5.7.2.1 Sidewalk Interconnections. All development plans shall provide for sidewalks along future public street connections to adjacent developable parcels along each property boundary that abuts potentially developable or re-developable land in accordance with the provisions for sidewalks.

3.5.7.2.2 Access-ways or Walkways for bicycles, pedestrians, and emergency vehicles shall connect the on-site circulation system to existing adjacent bicycle and pedestrian connections, and to entrances open to the public that abut the property. Connections may approach parking lots on adjoining properties if the adjoining property used for such connection is open to public pedestrian and bicycle use, is paved, and is unobstructed.

3.5.7.3 Linkages to Undeveloped or Re-developable Property

Where abutting properties are undeveloped or can be expected to be redeveloped within the next ten years, the location and potential arrangement of streets, bicycle and/or pedestrian connections shall be provided at the following spacing to provide for the continuation of these connections into surrounding areas:

3.5.7.3.1 Subdivision Street Type I and II Interconnections. All development plans shall provide for linkage street stubs at a ratio of one per 660 linear feet of the boundary line or fraction thereof, which adjoins potentially developable or re-developable land.

- 3.5.7.3.2 Subdivision Street Type III or Higher Order Road. All development plans shall provide for future public street connections to adjacent developable parcels by providing a collector road street connection as a continuation of the site circulation and spaced at intervals: 1) in accordance with an approved DeIDOT and County local traffic circulation plan; or 2) if no such plan exists, not to exceed 1320 feet along each development plan boundary or as measured from the nearest parallel collector road to the site.
- 3.5.7.3.3 Development Adjacent to Vacant Land. Where new development is adjacent to vacant land likely to be subdivided in the future, all streets, sidewalks bicycle lanes, and access-ways in the development's proposed street system shall continue through to the boundary lines of the area under the same ownership as the subdivision, if directed by DeIDOT or the appropriate land use authority to provide for the orderly subdivision of such adjacent land or the transportation and access needs of the community.
- 3.5.7.3.4 Redevelopment Projects. All redevelopment projects shall retrofit existing streets to provide increased vehicular and pedestrian connectivity.
- 3.5.7.3.5 Sidewalk Interconnections. All development plans shall provide for sidewalks along future public street connections to adjacent developable parcels along each development plan boundary that abuts potentially developable or re-developable land in accordance with the provisions for sidewalks.
- 3.5.7.3.6 Walkway and Access-way Interconnections. All development plans shall provide for future public walkways and/or access-ways, as applicable, to connect to adjacent developable parcels by providing such connections as a continuation of the walkways or access-ways provided for the development in accordance with the walkway and access-way standards for each development plan boundary that abuts potentially developable or re-developable land.
- 3.5.7.3.7. Stub Street Turn-Around Area. The right-of-way stubs shall be planned and constructed to the subdivision boundary line for future connections. Street stubs shall be identified by signage which reads "FUTURE STREET CONNECTION -NO OUTLET". If the stub is in excess of 100 feet in length, then a temporary paved turnaround area shall be provided in accordance with the provisions of 5.1.4.2., Temporary Dead End Streets.

3.5.7.4 Cross-Access Interconnectivity

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

- 3.5.7.4.1 Cross-Access Requirement. In order to reduce dependency on vehicular access to major collector streets and to promote efficient and convenient access to destination points along roadway corridors, shared entrances, cross-access easements, connecting driveways and street linkages are required wherever practicable.

3.5.7.4.2 Aisle length between Cross-access and Street. A minimum distance of 60 feet shall be required between a cross-access-way and an intersection or driveway entrance to allow for car storage between the cross-access and the driveway.

3.5.7.4.3 Cross-Access Types and Locations. Locations and types of cross-access will vary from site to site and are dependent upon a number of factors including: overall size of the properties involved, building types and land uses of the properties being served, locations of the existing and proposed buildings, locations of existing and proposed parking lots and site utility and landscape requirements.

3.5.7.4.4 Non-residential, Mixed Use and Multi-family Housing. Each property containing or designated for nonresidential or multi-family dwelling units should provide at least one vehicular access to each abutting property. This should most often be accomplished by joining adjacent parking lots and sharing entrances.

3.5.7.4.5 Recordation. Cross-access easements shall be shown on the site plan for the development and recorded at the applicable local recordation office.

3.5.7.4.6 Cross-Access Construction.

3.5.7.4.6.1 Development plans shall indicate the location of cross-access easement(s).

3.5.7.4.6.2 The access connection shall be completed if an immediate or near term benefit (as determined by DelDOT) can be derived by completing the link.

3.5.7.4.6.3 If no immediate or near term benefit would be derived, development plans should provide cross access and construction easements and arrange the site design so that when the adjoining property owner extends the connection to the property line, the link will be completed. If the link is to be completed in the future, the grade of the connection, parking, landscaping and other improvements must be set to allow for extension into the adjacent lot.

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

3.5.7.4.8 Waiver. When cross-access is deemed impractical by DelDOT on the basis of topography, the presence of natural features, or vehicular safety factors, this requirement may be waived provided that appropriate bicycle and pedestrian connections are provided between adjacent developments or land uses.

3.5.7.5 Street and Bicycle and Pedestrian Connection Hindrances

3.5.7.5.1 Street, bicycle, and/or pedestrian connections are not required where one or more of the following conditions exist:

3.5.7.5.1.1 Where a community facility location, or physical or topographic conditions make a general street, access-way or walkway connection impracticable. Such conditions include but are not limited to the alignments of existing connecting streets, freeways, railroads, slopes in excess of DeIDOT standards, wetlands or other bodies of water where a connection could not reasonably be provided;

3.5.7.5.1.2 Existing buildings or other development on adjacent lands physically preclude a connection now and in the future, considering the potential for redevelopment; or,

3.5.7.1.3 Where the installation of a street, bicycle, and/or pedestrian connections would violate provisions of leases, easements, covenants, or restrictions written and put into affect prior to the effective date of these regulations.

3.5.7.5.2 DeIDOT shall make the final determination as to whether or not a connection shall be made.

3.5.8 Alternative Compliance

Upon request by an applicant, DeIDOT may approve an alternative SSP for a development that may be substituted in whole or in part for a plan meeting the standards of this Section.

3.5.8.1 Procedure

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

3.5.8.2 Review Criteria

To approve an alternative plan, DeIDOT must first find that the proposed alternative plan:

- Has a minimum circulation ratio of 1.8; and
- Accomplishes the purposes of this Connectivity Section equally well or better than would a plan and design which complies with the standards of the Manual; and
- That any reduction in access and circulation for vehicles maintains facilities for bicycle, pedestrian, and transit, to the maximum extent feasible.

In reviewing the proposed alternative plan, DeIDOT shall take into account whether the alternative design minimizes the impacts on natural areas and features, fosters non-vehicular access, enhances neighborhood continuity and connectivity, and provides direct, sub-arterial street access to any parks, schools, neighborhood centers, commercial uses, employment uses,

and Neighborhood Commercial Districts within or adjacent to the development from existing or future adjacent development within the same section mile.

3.5.9 Developer SSP Checklist

Developers should assess the checklist that follows early during the site street plan development. The questions that follow can help design professionals create site plans that meet the connectivity requirements of this section.

Overall System Review

- Has the Plan attained required Connectivity Index minimums?
- Have all adjacent stub streets been identified and connected?
- Does the plan meet ADA standards?
- Are utilitarian paths direct? Do they provide for connections to pedestrian magnets nearby? Can pedestrians take advantage of "shortcut paths" that encourage walking instead of driving?
- Does the pedestrian system consider the type and probable location of future development on adjacent or nearby parcels of land? Is there flexibility to provide direct connections to adjacent parcels; should that be desired in the future?
- Are building entrance areas convenient to the pedestrian? Are they clearly evident through design features, topography, signing, or marking?
- Are walkways along the street buffered from traffic as much as possible?

Travel Safety

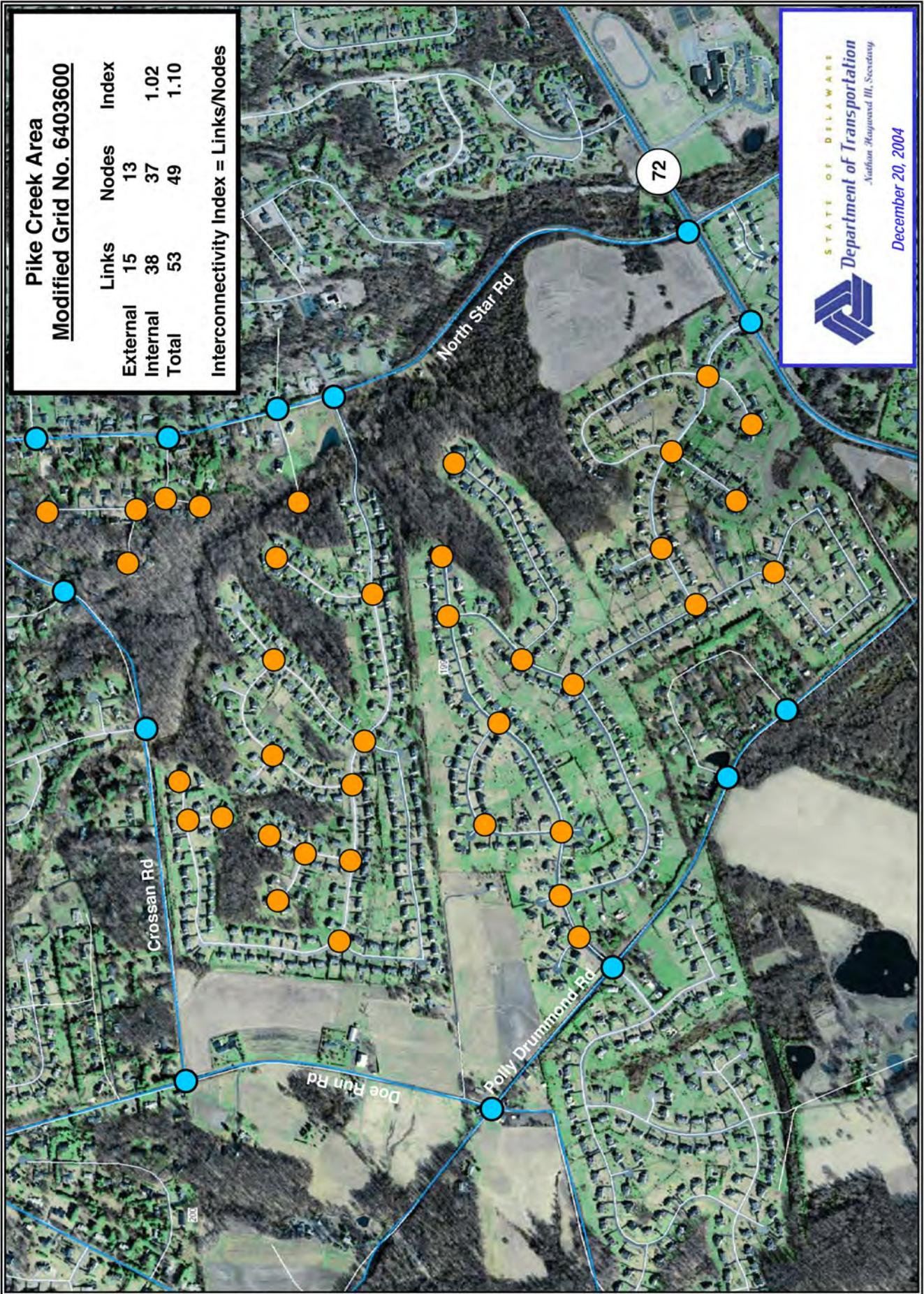
- Are crossings of wide expanses of parking lot held to a minimum?
- Are pathways generally visible from nearby buildings and free from dark, narrow passageways?
- Are sight lines at intersections adequate for pedestrian and motorist visibility?
- Are pedestrians able to see on-coming traffic, given typical speeds?
- Do Access-ways and Walkways lead to road crossing points with the least conflict?
- In general, are pedestrian/vehicle conflict points kept to a minimum?
- Are pedestrians given adequate time to cross the road at signalized intersections?

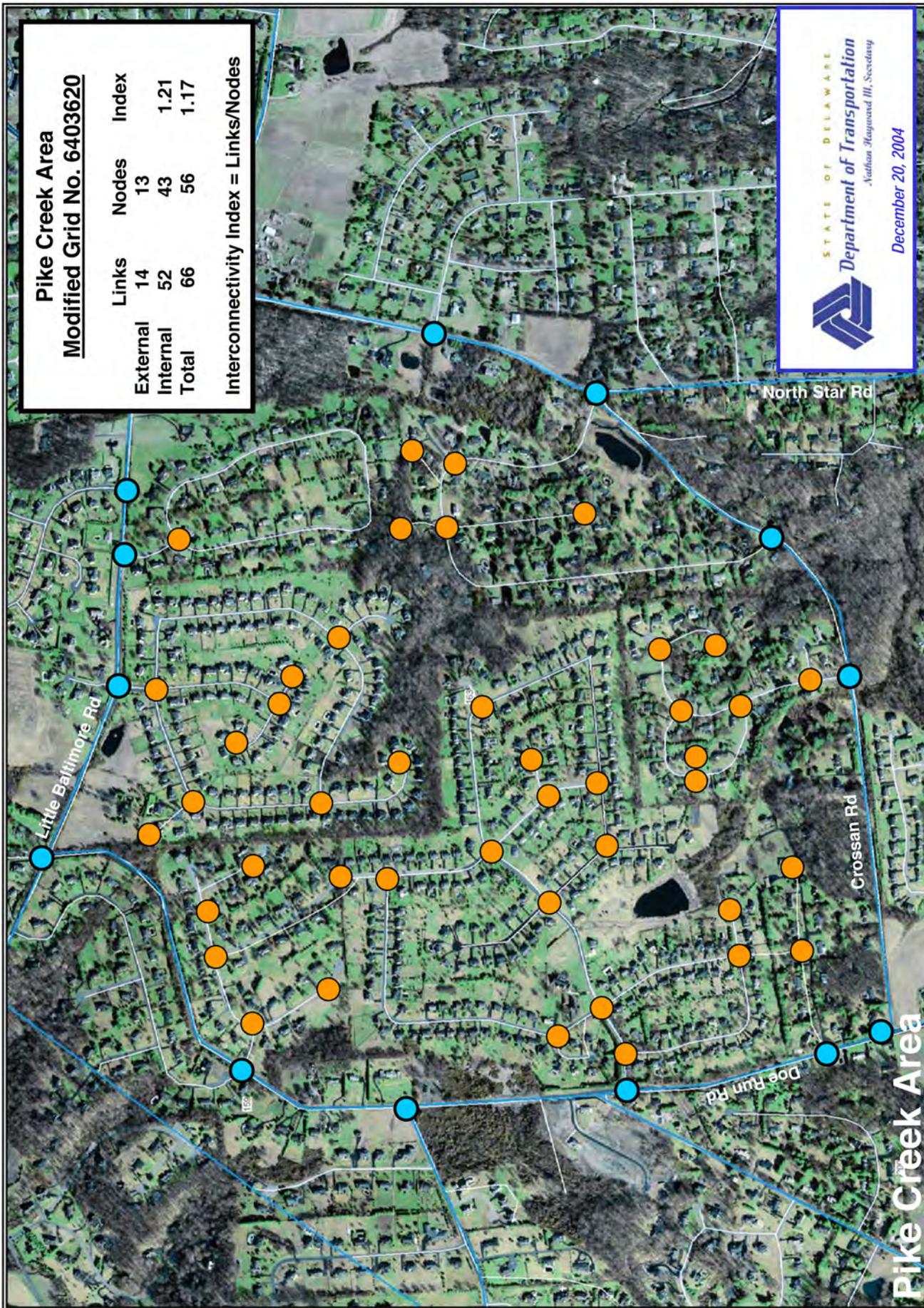
Implementation Plan

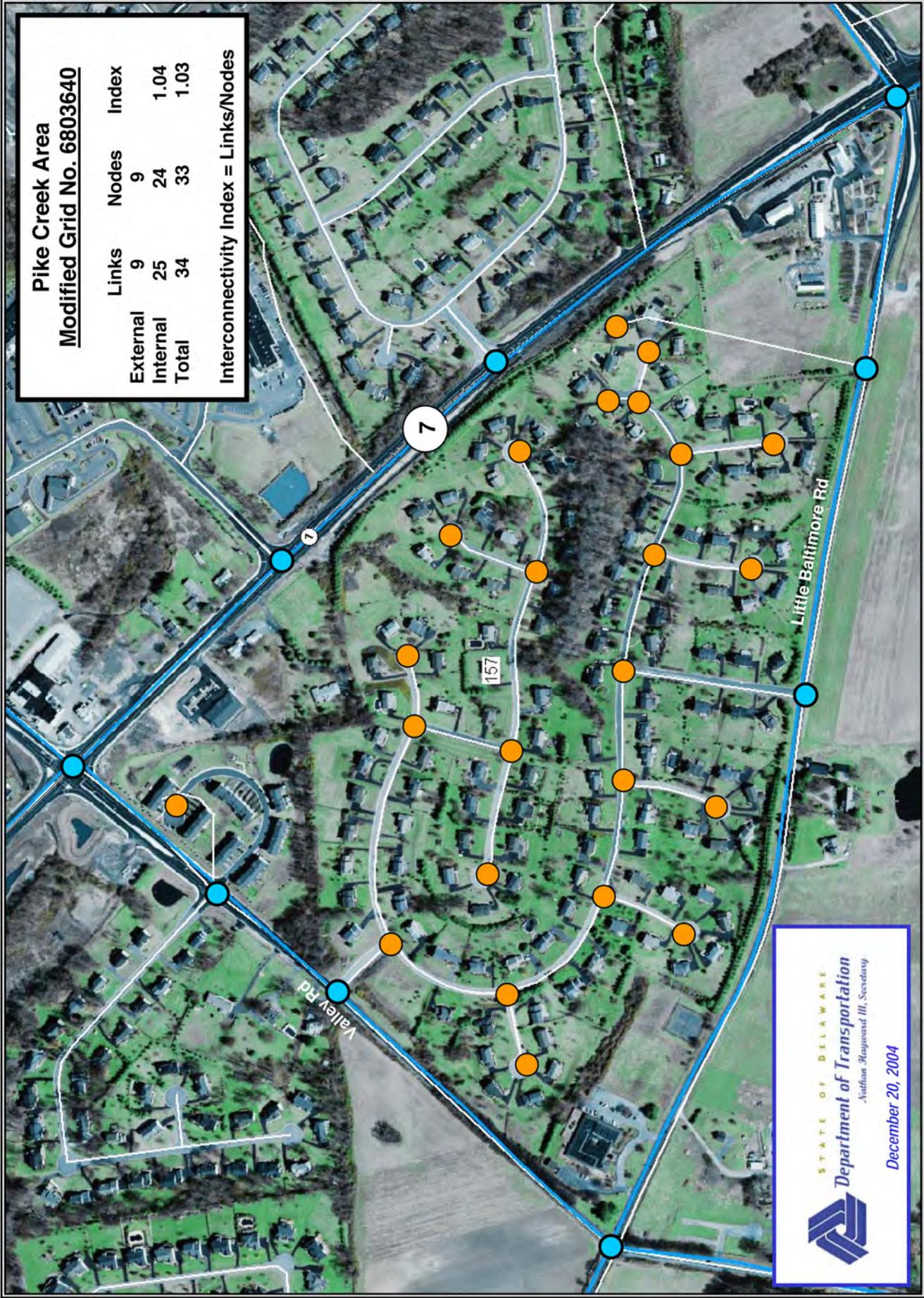
- 1) Augment the DTMS survey instrument to ensure that future data collection will be of increased utility to study the role of connectivity, as it relates to the number, type, duration, and distance of respondents' vehicular trips. At present, the surveys are done at random and rely on the participant's memory of trips for a given period of time. More frequent solicitations or working with a set group of volunteers may add to the instrument's accuracy.
- 2) Comparatively analyze several approaches of measuring interconnectivity (see recommendations for future research) to determine which methodology is superior or under what circumstances each best applies. If a certain measurement tool, or tools, is proven more effective in relation to certain street patterns, they should be utilized in any further analysis. The increased sensitivity, resulting from an improved measurement, could result in a more demonstrable correlation between connectivity and trip distance and duration.
- 3) Definitively prove the relationship between interconnectivity and trip type, frequency, distance and duration by combining an improved survey instrument with an improved measurement tool of "true" connectivity (see #2 above).
- 4) Where not already addressed, recommend that DelDOT's revise its interconnection policies to reflect this research and the recommendations, where appropriate.
- 5) Present additional research to the Mobility Friendly Design Committee (or ad-hoc committee of policy-level representatives from concerned agencies within Delaware) for discussion and recommendations, and also to increase public awareness. This could also take the form of an interconnectivity forum.

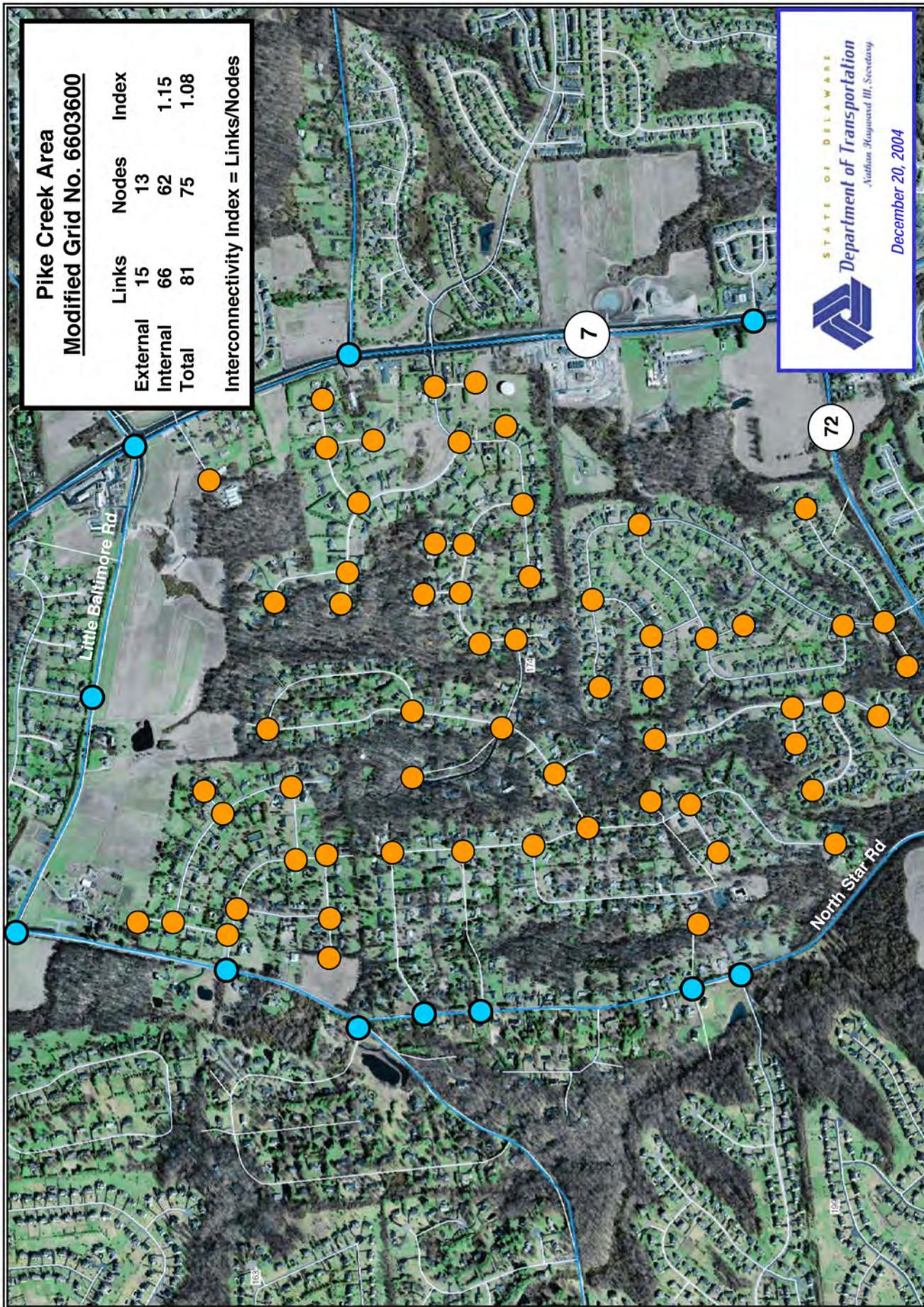
Aerials of Study Areas

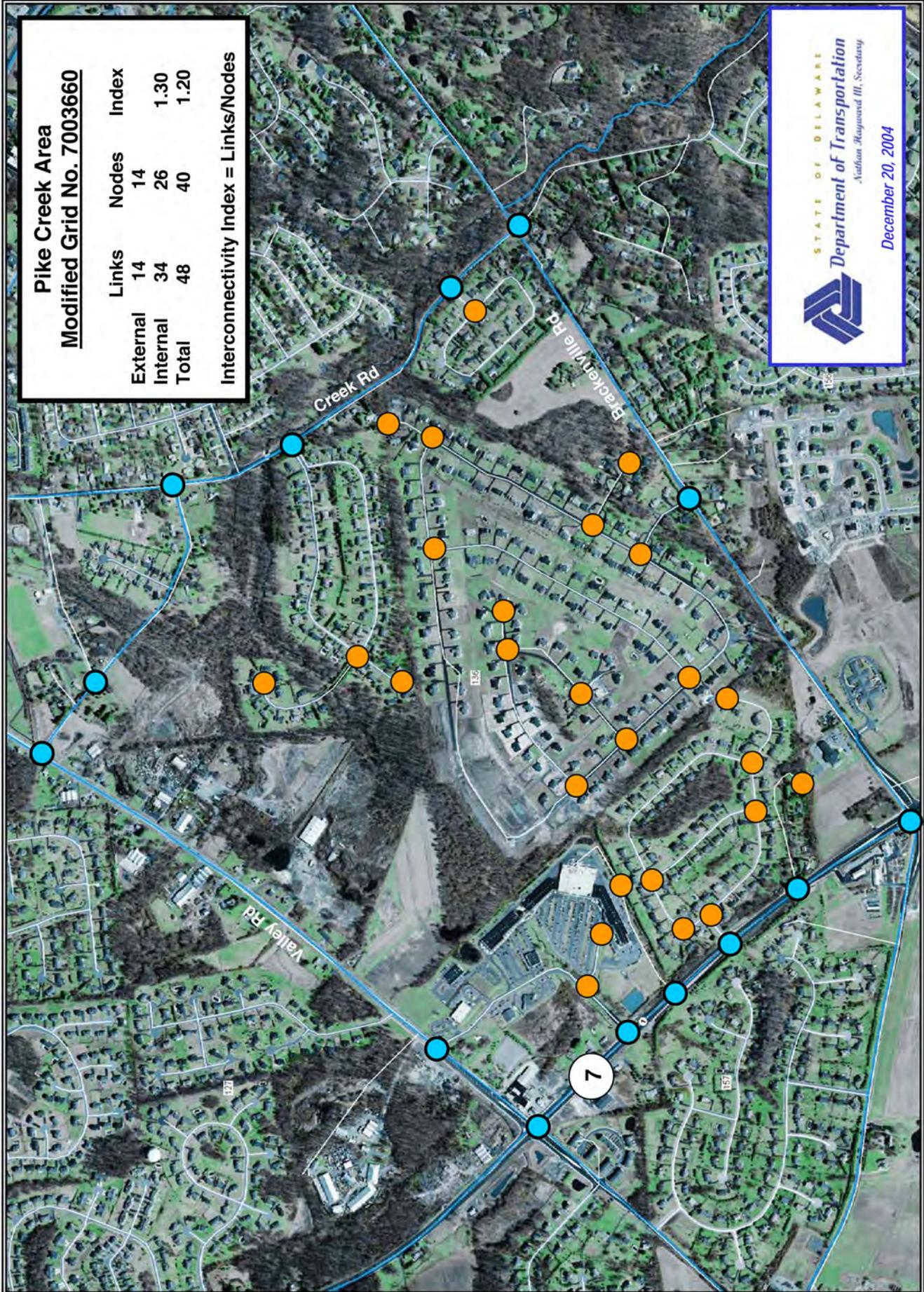
Pages 51–60 include modified grids of Pike Creek and Claymont.

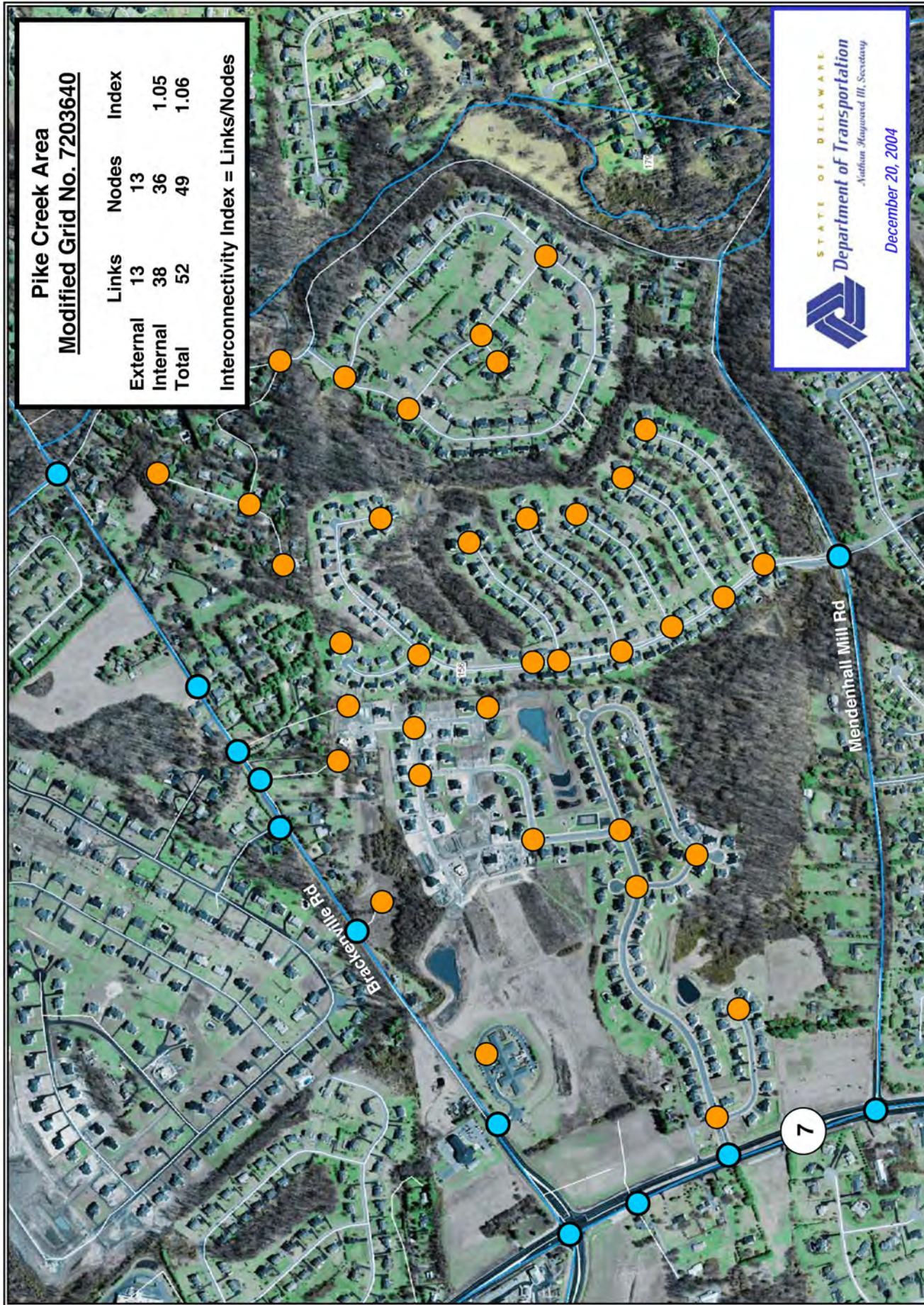


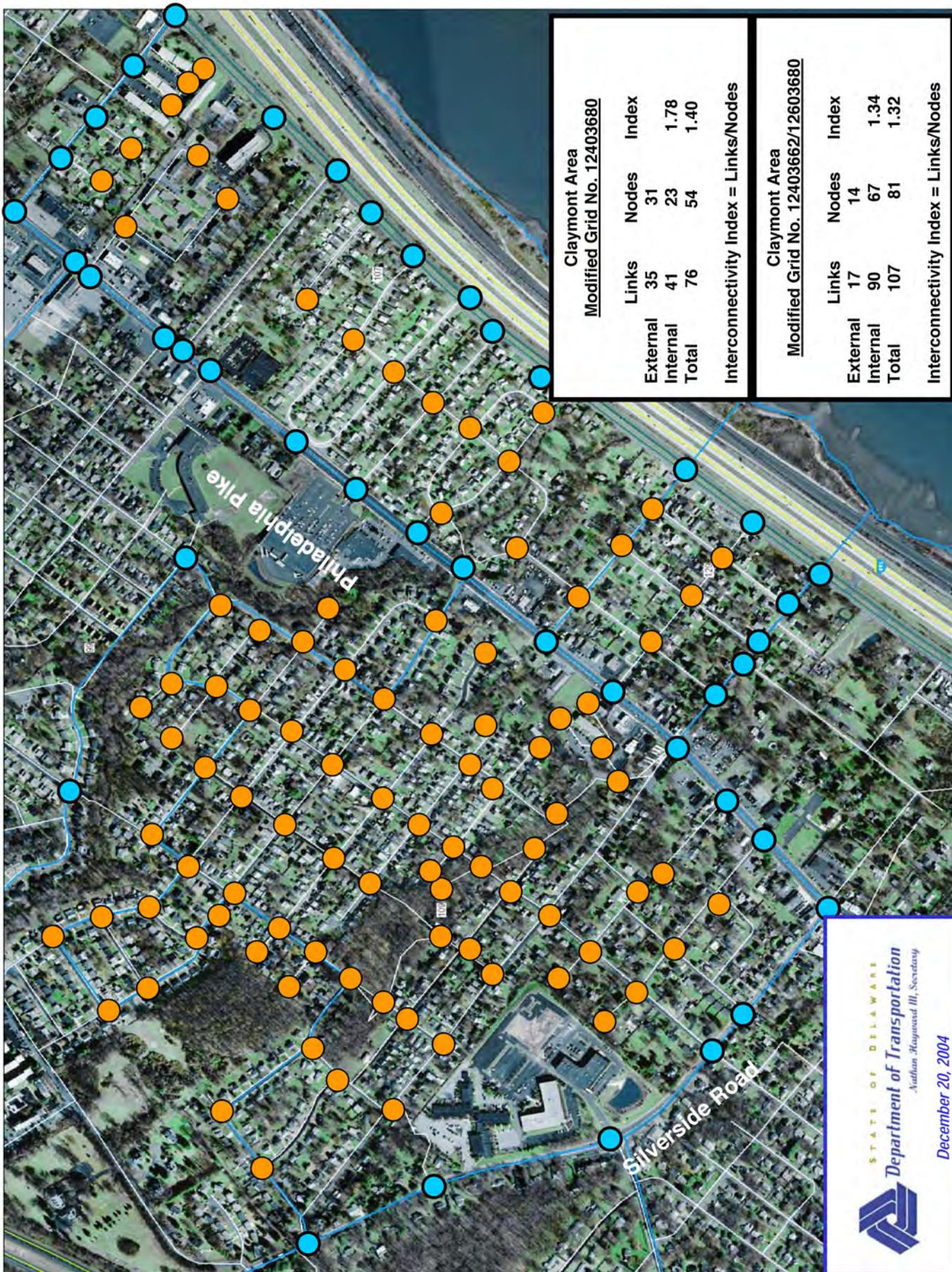












Claymont Area
Modified Grid No. 12403680

	Links	Nodes	Index
External	35	31	1.78
Internal	41	23	1.40
Total	76	54	1.40

Interconnectivity Index = Links/Nodes

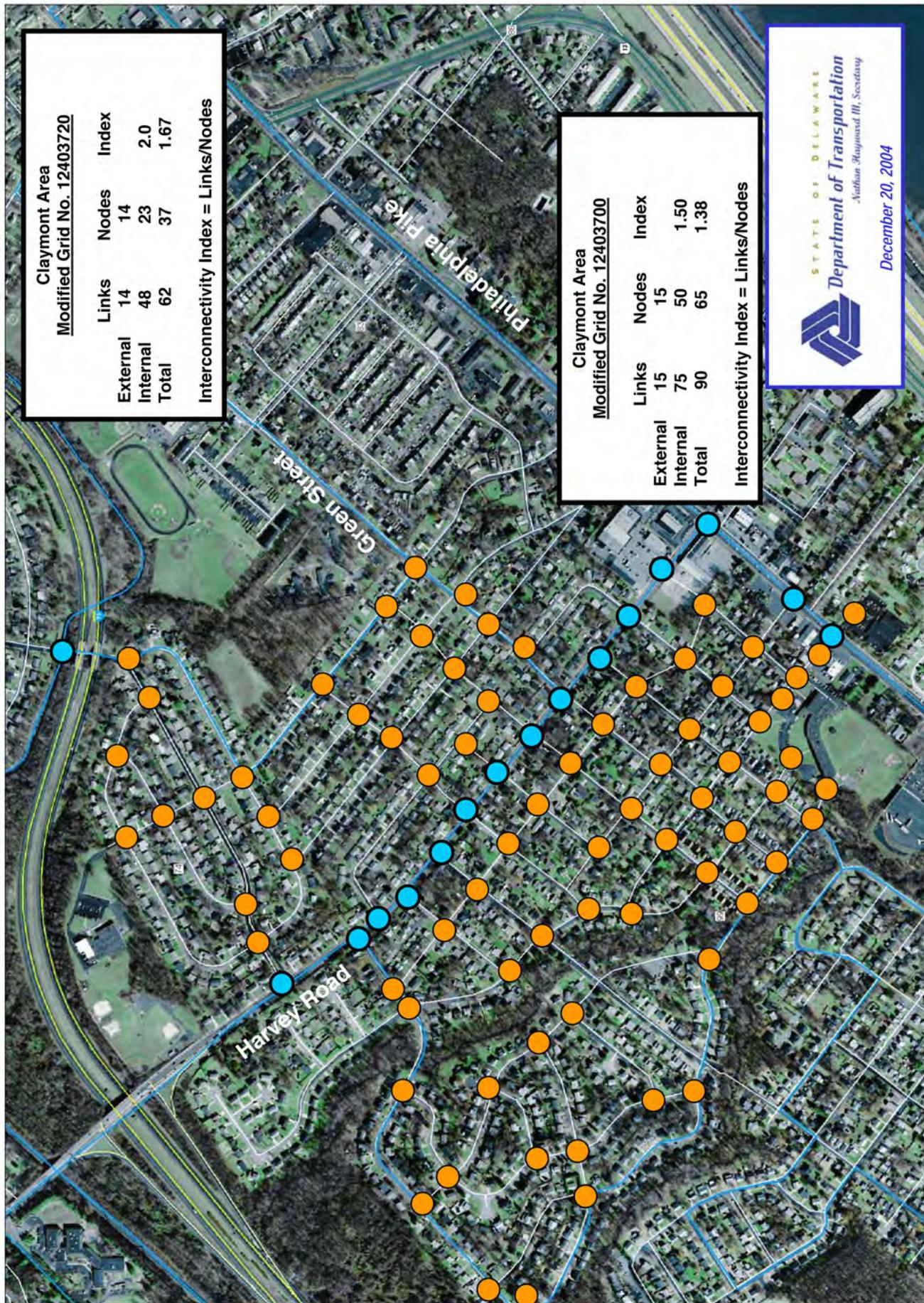
Claymont Area
Modified Grid No. 12403662/12603680

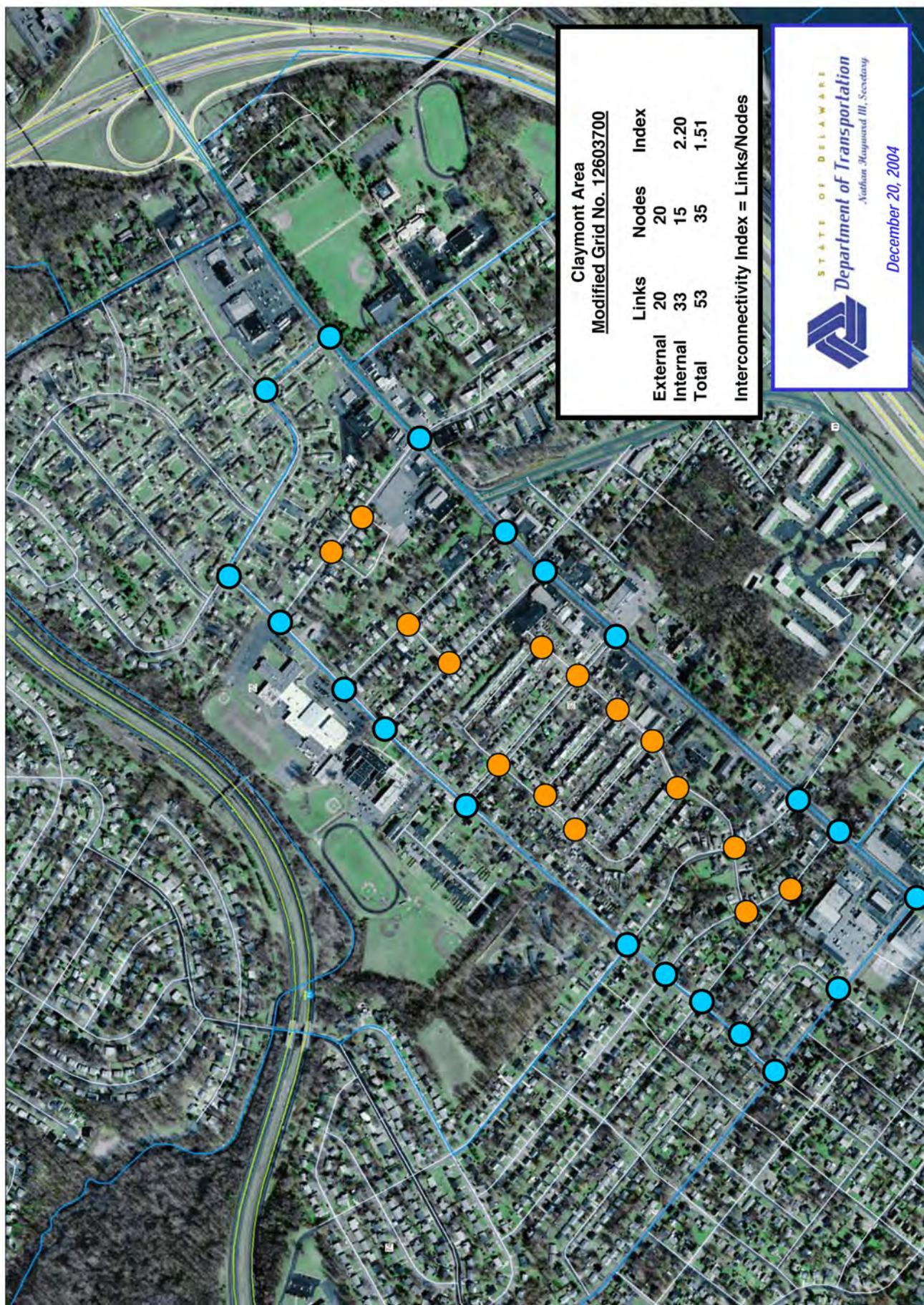
	Links	Nodes	Index
External	17	14	1.34
Internal	90	67	1.32
Total	107	81	1.32

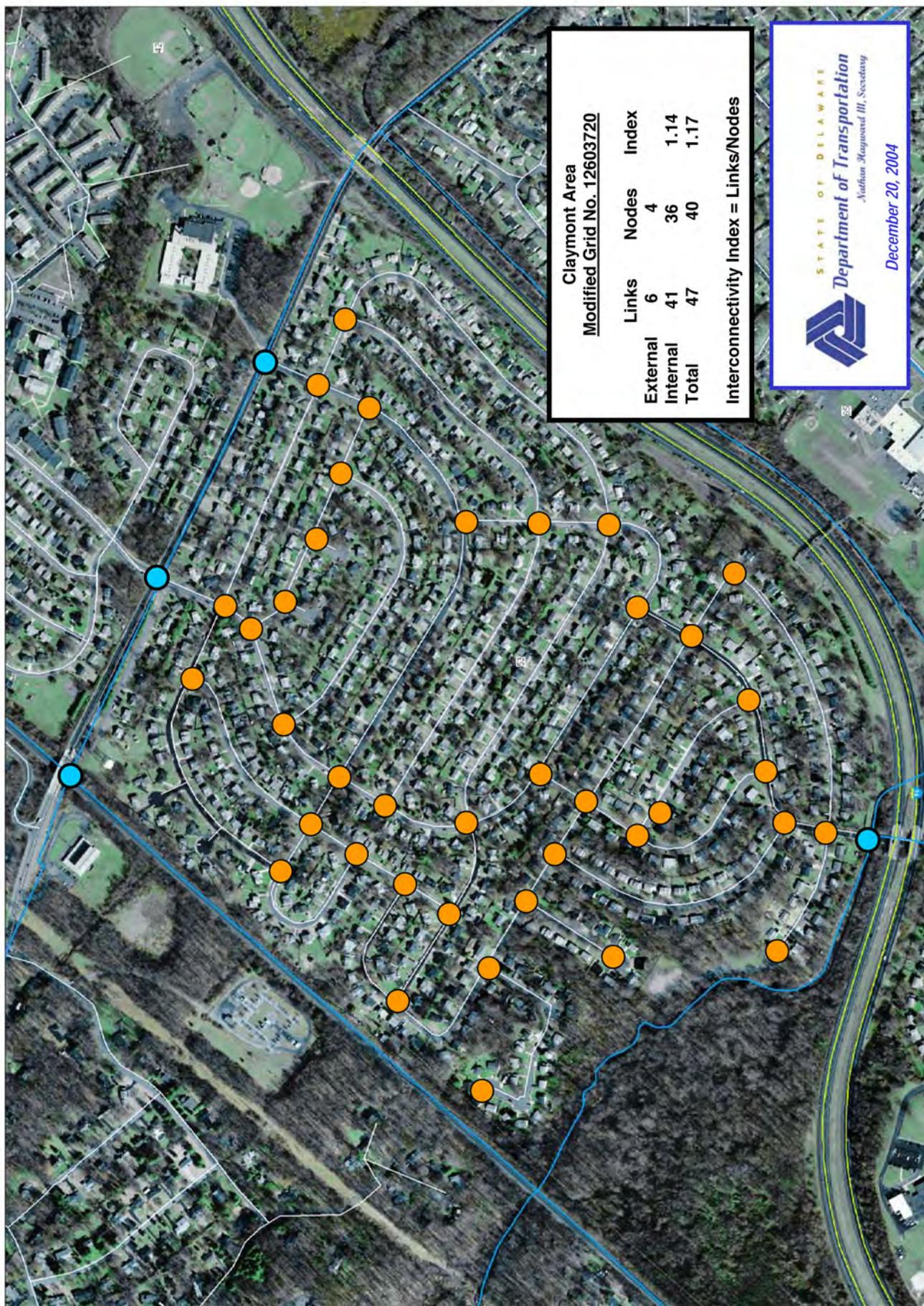
Interconnectivity Index = Links/Nodes

STATE OF DELAWARE
Department of Transportation
Arthur Baywood III, Secretary

December 20, 2004







Delaware Center for Transportation University of Delaware Newark, Delaware 19716

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