Research Report
Research Project T1803, Task 11
"Pedestrian Infrastructure"

TARGETING PEDESTRIAN INFRASTRUCTURE IMPROVEMENTS:

A Methodology to Assist Providers in Identifying Suburban Locations with Potential Increases in Pedestrian Travel

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STRUCTURE OF THE REPORT

This report is in three parts. The first part addresses the research context within which the project took place. It includes a statement of the problem, the research objectives, the methodological approach, the benefits accrued by the research, and its applications. The second part contains training manuals for the three tools developed by the project. A conclusion section assesses the strengths and limitations of the tools developed and outlines specific needs for future research.

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15. SUPPLEMENTARY NOTES

This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. ABSTRACT

This project yielded three tools for allocating investments to improve pedestrian infrastructure. The tools are tailored to suburban clusters and corridors where past research has shown that the potential exists for substantial volumes of pedestrian travel. The first two tools, Pedestrian Location Identification (PLI) tools 1 and 2, help differentiate between suburban areas that do and do not have potential for pedestrian travel. The third tool, Pedestrian Infrastructure Prioritization (PIP) Decision System, supports decision-making processes to allocate investments in infrastructure improvement to areas that do have potential for pedestrian travel. The tools generally yield benefits at the policy, implementation, and scientific levels.

PLI-1 and PLI-2 focus on medium-density residential land development, areas that have been neglected in the past as locations with potential for pedestrian travel. By considering combinations of land uses that are generators and attractors of pedestrian travel, they capture the characteristics of land-use mixes that have the highest potential for substantial volumes of pedestrian trips. By using small spatial units of land-use data, they adequately capture the characteristics of actual development on the ground and, specifically, those characteristics that support pedestrian travel. The small units of data also allow a precise and accurate measurement of the land-use characteristics of the small areas that correspond to short walking distances.

PIP is a synthesis of previous efforts to identify the environmental and policy variables that affect pedestrian travel. It acknowledges three types of environmental factors known to affect pedestrian travel demand: area-wide characteristics defined by land uses and development patterns, characteristics of the transportation facilities, and policies that determine the level of support for pedestrian travel. PIP provides a complete yet flexible framework for making decisions regarding infrastructure. It allows jurisdictions to work with their own internal set of priorities.

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PART ONE: RESEARCH CONTEXT

OBJECTIVES

This research had the following objectives:

- to support walking as a transportation mode
- to promote the increased use of non-motorized transport and to encourage planners and engineers to accommodate pedestrian needs in designing transportation facilities in suburban areas
- to increase pedestrian travel and, indirectly, to increase transit use in suburban locations other than designated suburban employment centers that already have the necessary land-use characteristics necessary to foster walking
- to provide a methodology and develop tools that assist state and local jurisdictions in identifying suburban locations where investments in pedestrian infrastructure improvements will yield the highest potential increases in pedestrian travel.

PROBLEM STATEMENT

Current theory and practice in urban and transportation planning assume that most non-motorized travel will take place in older central cities and in the major suburban employment centers (Frank and Pivo 1994; Downs 1994; Antonakos 1995; Leinberger 1996; Gottdiener and Kephart 1996; Cervero and Kockelman 1996; Jencks et al. 1996; Ercolano et al. 1997). As a result, infrastructure investments to promote non-motorized travel and transit use are directed principally at central cities and suburban employment centers (PSRC 1996). In suburban areas outside of major employment centers, such infrastructure investments generally focus on the safety of pedestrians rather than on increasing their numbers or their mobility (WSDOT 1995).

Several recent research projects have indicated that opportunities exist, at least in the Puget Sound region, to increase pedestrian travel in suburban areas beyond the recognized suburban employment centers. A methodology and tools were developed to assist state and local jurisdictions in identifying suburban locations where investments in pedestrian infrastructure improvements would yield the highest potential increases and benefits in pedestrian travel and, indirectly, support transit use.

PAST RESEARCH

Research has shown that, controlling for population density and land use mix, the presence of pedestrian facilities is related to a higher incidence of pedestrian travel. Specifically, the presence of continuous sidewalks and small street blocks corresponds to a three-fold increase in the number of people walking to their neighborhood commercial center (Moudon et al. 1997a, b; Hess et al. 1999, Hess 2001). At the same time, a surprisingly high number of pedestrians—between 80 and 120 pedestrians per hour—enter small suburban neighborhood centers that have incomplete or non-existent pedestrian facilities and a high supply of free parking but are characterized by pedestrian-supportive development densities and mixes of land uses within a "walking shed" of one-half mile.

These results indicate that targeting pedestrian infrastructure improvement programs to existing and emerging suburban clusters and corridors with appropriate concentrations of development and mixes of land uses can affect pedestrian travel volumes positively and significantly.

Parallel research has shown that 20 percent of the suburban population (outside of the Puget Sound's central cities) resides in *clusters* or *corridors* of relatively dense apartment complexes that are often close to retail (Moudon and Hess 2000). In King, Snohomish, and Pierce counties, 85 such clusters and corridors ranging from 1,500 to almost 9,000 people are within areas smaller than a mile square. This research has indicated that existing suburban land-use patterns offer unsuspected opportunities to support pedestrian travel and, indirectly, transit use. An article in *The Seattle Times* suggested that, along with the region's designated Urban Centers, these suburban clusters be the backbone of the region's transit system (McOmber 1999).

The combined findings of these projects indicate that judicious investments in pedestrian infrastructure directed to the numerous suburban locations with high population densities and with a mix of land uses clustered within a small, walkable area could increase pedestrian travel considerably.

METHODOLOGY AND TOOLS

New methods and tools were developed in this project to identify the locations of small, yet fast-growing concentrations of retail, employment, and medium-density housing that can generate significant pedestrian travel volumes.

Until now, commonly used methods of zonal land-use analysis have been able to identify only the largest regional concentrations of residential and commercial development (Frank and Pivo 1994; Cervero 1995; Cervero and Kockelman 1996). These methods have relied on geographic information systems (GIS) whose data are aggregated into large spatial units (Census Tract or TAZ). The average suburban TAZ in the Puget Sound covers 1.6 square miles or 1,030 acres (Stanilov 1997). In contrast, the average suburban cluster or corridor identified in the research covers 400 acres. As a result, clusters and corridors are too small to be detected by using TAZs. The clusters also often occur at the intersections of main roadways that act as the boundaries of analysis zones. They therefore fall into several Census Tracts or TAZs, which further dilute their density and land-use characteristics. The limitations of these methods are likely the principal reason why the clusters have not been recognized in planning and transportation research to date.

Two methods and tools, called *Pedestrian Location Identification* tools (PLI), were developed to identify clusters and corridors. The first tool, PLI_1, was derived from a previously tested, mixed method that uses socio-demographic Census data at the block level complemented by interpretations of aerial photographs (Moudon et al. 1997b). The method was revised and tested in PLI_1 for ease of application by local jurisdictions.

A second method and tool, PLI_2, uses new databases now available for several of the urbanized Washington State counties. These data are at the level of the tax lot or parcel, a spatial unit of data that is small enough to appropriately identify the population concentrations and land-use mix of the suburban clusters.

King, Snohomish, Pierce, Kitsap, Clark, and Thurston counties now have operational parcel databases, which they use to monitor their land supply at the parcel level in response to the Buildable Lands amendment of the Growth Management Acts (HB 6097) (Moudon and Hubner 2000). Similar databases are being integrated into multi-purpose GIS and Land Information Systems in urbanized areas across the U.S. because they effectively serve many levels and parts of government (Tosta 1995, Tulloch et al. 1996). Tax lot level GIS databases include detailed information on land use and development densities that allow the identification of agglomeration of suburban multi-family housing and commercial land uses. Because these GIS databases are fairly new, little work has been carried out to test their analytical capabilities (Chrisman 1997, Newcomb 1994). In this respect, PLI_2 contributes to an approach to land use analysis that few have pioneered so far (Moudon forthcoming).

PLI_2 is an automated method based on GIS routines (Hess et al in press). The methods used in PLI_1 and PLI_2 are explained in the second part of this report. The effectiveness and relative difficulty in using the two tools can be compared, as the same study area is analyzed in both methods.

A third tool was developed, the *Pedestrian Infrastructure Prioritization Decision System* tool (PIP). This tool serves to help jurisdictions prioritize pedestrian infrastructure improvement projects in clusters or corridors identified with PLI_1 and PLI_2. PIP is a checklist of criteria to consider in the prioritization process. Criteria cover the characteristics of existing land use and transportation infrastructure, as well as the policy context of clusters and corridors.

PLI_1 and PLI_2 and PIP have been reviewed by staff in planning and engineering departments in several workshops organized as part of the project. PLI_1 and PLI_2 have been applied to different contexts (see Applications below).

BENEFITS

The use of these tools ensures that limited funds for pedestrian infrastructure are targeted to suburban sites that hold the greatest promise of increased pedestrian travel.

At the *policy level,* the tools support local and national efforts to reduce dependence on motor vehicles (Downs 1994; Peirce 1997). Research has shown that a 10 percent reduction in vehicle miles traveled can be achieved by improving the pedestrian environment (Cambridge Systematics 1994). Increasing the incidence of pedestrian travel also helps reduce the number of trips by auto; improve air quality; improve travel conditions for the less-advantaged portions of the population; support public transit; and complement current transportation demand management (TDM) methods (Replogle 1995). The tools support our state's comprehensive planning under the Growth Management Acts and parallel implementation of Sound Transit.

At the *implementation level*, the tools directly assist state and local jurisdictions in the allocation of their capital budgets. It provides them with an objective and scientifically valid method for prioritizing locations that will yield the highest benefits in terms of increased pedestrian volumes, improved pedestrian safety (Roth 1994), and support of transit (Replogle 1992).

At the *scientific level,* the methods behind the tools contribute to developing theory and methods for understanding the relationship between land use and transportation (Hess et al in press). Specifically, they provide needed enhanced measures of metropolitan population density distribution and land-use mix (Holtzclaw 1994; Replogle 1995; Cervero and Kockelman 1996).The methodology contributes to parallel efforts in modeling pedestrian volume generation on the basis of land-use conditions (Cove 1993; Loevas 1994; Otis et al. 1995; Loutzenheiser 1997).

APPLICATIONS

The tools have been presented and discussed in several settings as part of this project:

- Urban Traffic Engineers (UTEC), Kent, October 5, 2000

- Vancouver, Washington, WSDOT Headquarters, February 27, 2001
- Seattle, Washington, University of Washington, June 14, 2001.

Valuable feedback was provided from participants (approximately 60 in total) both during and after these events.

We also shared the work with the Puget Sound Regional Council (PSCR). Several presentations were made to the PSRC regional staff council and to the Growth Management and Transportation Boards during the course of the project. PLI_1 was used to expand the original cluster research and include Kitsap County, Tacoma, and Everett, for a total of 100 clusters in the region. PSRC staff updated the analyses of some 13 clusters in preparation for the Metropolitan Transportation Plan Update (PSRC 2000). In addition, the clusters were integrated into the land-use component of *Destination 2030* as part of the designation of areas of concentrated development in the region (PSRC 2001). Finally, methods developed for PLI_2 will be used as part of the PSRC Transit Oriented Development (TOD) program to establish benchmark measures of TODs. PSRC and other agencies at the state level have indicated an interest in using PIP for prioritizing their pedestrian infrastructure investments.

We have also had two requests to use PLI_1, one from the Northeastern Illinois Planning Commission, working with Northeastern Illinois University, and the other from the Michigan Grand Valley Metropolitan Council. We are receiving valuable feedback from these organizations and anticipate being able to soon compare the results of applying the tools in different states.

The tools were presented in several venues outside of Washington state. Two working papers were discussed at the annual conference of the Association of Collegiate Schools of Planning (Atlanta, November 2000):

Hess, M.P., Moudon, A. V., and Logsdon, M.. “Applications of Landscape Pattern Methods to the Measurement of Suburban Form and Land Use Mix.”

Piro, R., Bakkenta, B., Moudon, A. V. and Hess, P. M. “Shaping Future Land Use: Suburban Apartment Clusters and Transportation.”

One paper was presented and accepted for publication by the Transportation Research Board:

Hess, M.P., Moudon, A. V., and Logsdon, M. “Measuring Land Use Patterns for Transportation Research.” Transportation Research Board. January 2001.

One paper has been submitted to the TRB on PLI_1 and PLI-2:

Moudon, Anne V., Paul M. Hess, Julie M. Matlick, and Nicholas Pergakes. (2001). Pedestrian Location Identification Tools: Identifying Suburban Areas with Potentially High Latent Demand for Pedestrian Travel. Submitted to the Transportation research Board.

A second paper on PIP will be drafted as well.

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PART TWO: TRAINING MANUALS

The manuals refer to three tools to assist local jurisdictions in targeting suburban locations for pedestrian infrastructure improvements. The tools address two basic questions:

1. Where are the suburban locations that have a high potential to generate pedestrian travel?
2. Given several such areas in my jurisdiction, to which area or areas should improvement funds be allocated first?

The tools that address the first question are called *Pedestrian Location Identification Tool* (**PLI**). And those that address the second question are called *Pedestrian Infrastructure Prioritization Decision System* (**PIP**).

WHY ARE THESE TOOLS NEEDED?

Suburban centers are now well recognized in the State of Washington as areas of concentrated development that require special attention in transportation planning and capital improvement and expenditure planning (PSRC 2001). Furthermore, recent research in the central Puget Sound has shown that approximately 100 suburban locations exist—beyond the centers recognized in Vision 2020—where people live in dense housing conditions. These housing "clusters" can often be found close to neighborhood retail and school facilities (McOmber 1999). These conditions have been shown to generate substantial amounts of pedestrian travel to and from the different land uses and activities (Moudon et. al 1997, Hess et. al 1999). Investments in pedestrian infrastructure in and near these clusters will encourage more people to walk rather than drive the short distances between housing, retail, schools, and transit. Capital investments in such locations will help reduce motorized traffic congestion, enhance environmental quality, and foster livable communities.

<u>WHAT IS A CLUSTER?</u>

A cluster is a small area where dense housing, usually multifamily complexes, is concentrated. Often, these concentrations of dense housing are close to neighborhood retail facilities, local public institutions, and educational facilities.

The central Puget Sound region's four counties contain approximately 100 clusters (Figure 1). In previous research, the clusters were defined as areas smaller than 500 acres (slightly smaller than one square mile) with at least 1, 400 residents (Moudon and Hess 2000, PSRC 2000). A third of the clusters have more than 5,000 residents and a few as many as 10,000 residents. Examples of small clusters in the central Puget Sound are Winslow in Kitsap County and Dash Point in Federal Way. Examples of large clusters include Crossroads in Bellevue, Kent East Hill in Kent, Mariner in Snohomish County, and the Sherwood area in Pierce County (Figure 2).

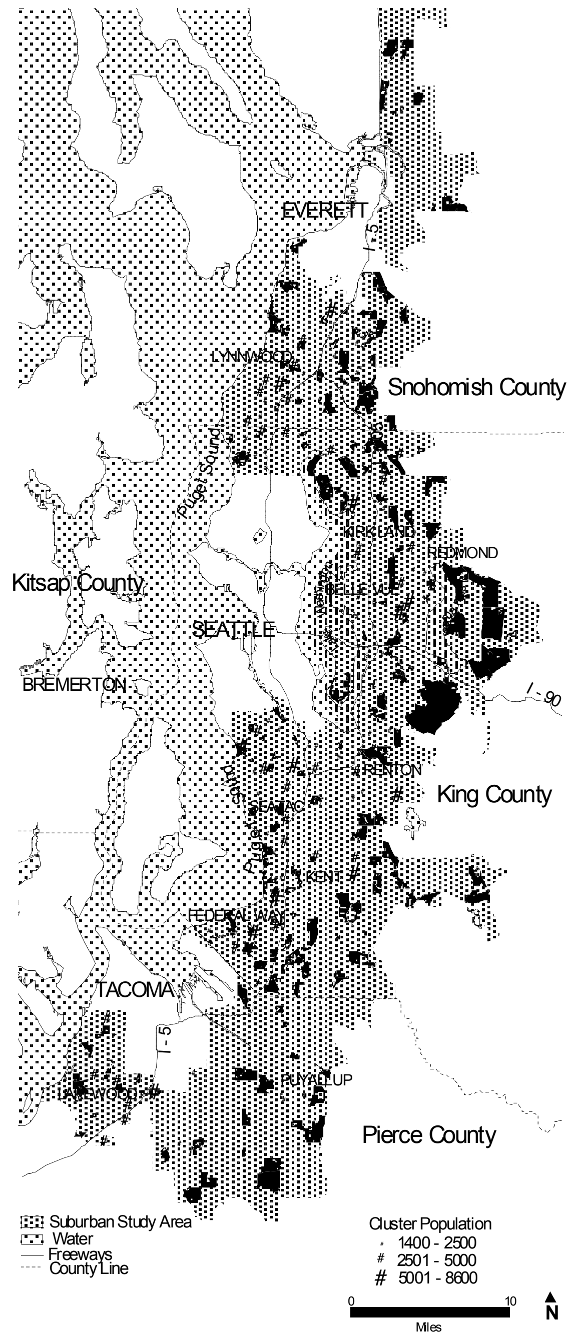

Figure 1: Suburban clusters in King, Snohomish, and Pierce counties

Figure 2: Land use and development patterns in Mariner

CLUSTERS AS PEDESTRIAN-FRIENDLY COMMUNITIES

Clusters in the central Puget Sound reach densities and have mixes of land uses that are similar to the ones found in more urban neighborhoods. As such, they represent communities with great potential for pedestrian travel (Figure 3). However, previous studies comparing suburban clusters (in King, Snohomish, and Pierce counties) with urban clusters (in Seattle and Tacoma) showed that three times as many pedestrians walked to the neighborhood commercial area in urban clusters than in suburban ones (Moudon et al 1997, Hess et al 1999, Hess 2001). Given the fact that densities and land use mix are similar in the suburban and urban clusters studied, the lower volumes of pedestrians in suburban clusters can be attributed to deficiencies in the pedestrian infrastructure of suburban clusters. Specifically, suburban clusters have large and very large street-blocks, which increase the length of pedestrian routes. They also lack the continuous sidewalk networks necessary for pedestrian travel safety and comfort (Figure 4).

Targeted investments in a cluster's pedestrian infrastructure can improve *pedestrian route directness* (by decreasing pedestrian travel distances between activities in the cluster) as well as achieve *pedestrian network completeness* (by building a continuous network of sidewalks or pedestrian trails).

Figure 3a: Multifamily housing next to retail in Factoria

Figure 3b: Multifamily housing next to retail in Juanita

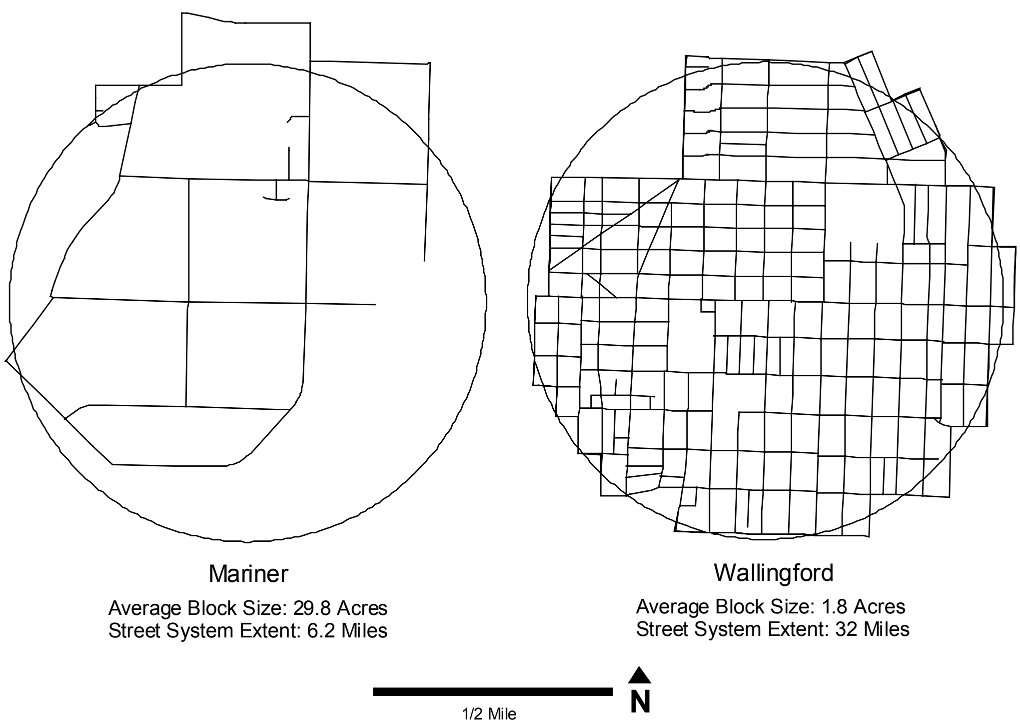

Figure 4: Illustration of street-blocks in urban and suburban clusters

TOOLS DESCRIBED IN THESE MANUALS

The first two tools are *Pedestrian Location Identification Tools* (PLI). They will help urban and transportation planners identify the clusters that exist in their jurisdictions. Some clusters overlap the boundaries of several jurisdictions and will require inter-jurisdictional involvement. The third tool, the *Pedestrian Infrastructure Prioritization Decision System* (PIP), will assist jurisdictions in deciding which of several clusters should take priority for infrastructure improvement funding.

Pedestrian Location Identification Tools (PLI)

Two methods of identifying clusters are outlined below to assist jurisdictions with access to two different data sets. The first tool, PLI_1, relies on readily available census GIS data and aerial photo analysis. The second tool, PLI_2, is based on an operational parcel-level GIS of the type that many jurisdictions have built in our state. PLI_1 and PLI_2 yield similar results in that they help identify the same clusters.

Pedestrian Infrastructure Prioritization Decision System (PIP)

PIP is used after clusters have been identified with PLI_1 and PLI_2. With PIP, each cluster is subjected to a rigorous analysis. PIP lists all of the clusters' individual characteristics and conditions that must be considered to assess the clusters' potential for increased pedestrian volumes. Characteristics and conditions represent criteria for prioritization. Each can be weighted according to priorities assigned by local jurisdictions. A tally of all weighted criteria yields a value for each cluster. This value represents each cluster's potential for increased pedestrian volume as a result of infrastructure improvement, and as such, helps rank the clusters as candidates for infrastructure investment.

An abbreviated, step-by-step illustrated version of these manuals will be available on the Web at **http://www.urbanformlab.net** and http://www.dot.wa/gov. Further discussions of the methods used in PLI_2 are in Hess et al in press.

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PL_1: PEDESTRIAN LOCATION IDENTIFICATION TOOL—METHOD 1 USING CENSUS GIS DATA AND AERIAL PHOTO ANALYSIS

Contents

** Note that specific steps to be taken are listed in indented text*

TASK I. Create the Information Base

The project information base will draw from two principal data sources:

- census block data in the form of GIS and tabular data; and
- aerial photographs

You will need ArcView to assemble your information base. In addition, you may also use MS Excel.

1. Census Data

- Obtain the census **block** shape file for the entire area to be analyzed (likely your jurisdiction).

- For each census block, all data **must** be referenced to the tract-block number, as this is the only way data can be linked to the GIS block polygon. The following population and housing data are necessary: acres, total population, total housing units, number of single-family units, number of units in structures with ten or more units.

2. Other GIS Data

- Roads
- Waterbodies—lakes, rivers, sounds
- Jurisdictional boundaries and/or urban growth boundary

3. Create Additional Data Fields

Additional data fields are pivotal for identifying the clusters. The following fields can be created within your database (dbf) in ArcView (or Excel). Instructions for creating the fields are provided in *italics*.

- Total acres in each block

  Divide the given field 'Area,' which is in square feet, by 43,560 (the number of square feet in an acre).
- Population density (per acre)

  Divide the given population field by the new 'Acres' field.
- Number of non-single family units

  Created from the census information, subtract the '1 unit per structure' from the 'total units in block'.

- Percentage of non-single family units out of the total units
  Divide the 'non-single family housing unit' field by the 'total units' and multiply the results by 100.
- Percentage of units in structures with more than 10 units
  Divide the 'structures with 10 or more units' field by the 'total units' and multiply the results by 100.

4. Aerial Photographs

Collect aerial photographs to cover the study area. Note that aerial photos are likely to be of a different date than the census data and inconsistencies may be found. For example, a census block may show dwellings, while the photographs show a newly built apartment complex.

TASK II. Identify Potential Cluster Blocks by Using GIS Analyses

Step 1: Conduct GIS Queries to Identify Blocks with High Population and Housing Densities

Several queries of the census block database will highlight census blocks containing housing densities and types that are common in clusters.

Figure 1 shows the results of the three queries described below. The first query selects blocks with appropriate density levels; it helps to identify blocks of medium density residential development—and, conversely, helps to eliminate from further consideration blocks with low densities. The second query identifies blocks that have more duplexes, triplexes, and apartments than single-family development. This query focuses on the distribution of development types that are known to yield higher densities than single-family development. However, the blocks identified in this query may yield densities lower than 10 people per acre because they may also contain non-residential development or vacant lands. A high proportion of non-single-family housing has been shown to be the best indicator of blocks that belong to potential clusters. The third query helps identify the presence of large apartment complexes.

The queries in the GIS are sequential, and the information generated by each query must be saved. The results of the queries are shown as cumulative in Figure 2. The light color shows blocks that meet the density criteria. The medium gray shows blocks that meet the distribution of development type criteria. The dark areas show blocks with many dwelling units in structures of more than 10 apartments—usually indicating large apartment complexes.

Queries

1.1 From the main census block database, query for all blocks with **population density equal to or more than 10 people per acre.**

- Make the main block theme active, then type the query in the query builder.

  (Example: 'pop_den' >= 10)

- After the results are highlighted, under '*Theme,'* click on *'convert to shapefile.'*

- Name the shapefile something like "popden.shp".

1.2 From the main census block database (or "popden.shp"), query for all blocks where **the percentage of non-single family housing is greater than or equal to 50%.**

- Make the "popden.shp" theme active, then write the query in the query builder.

  (Example: 'pct_nonsf' >= 50 [or .5])

- After the results are highlighted, under '*Theme,'* click on *'convert to shapefile.'*
- Name the shapefile something like "50nonsf.shp".

1.3 From the main census block database (or "50nonsf.shp"), query for all blocks where the **percentage of structures containing 10 units (apartments) is greater than or equal to 40%.**

- Make the "50nonsf.shp" theme active, then write the query in the query builder.

  (Example: '50nonsf' >= 40 [or .4])

- After the results are highlighted, under '*Theme,'* click on *'convert to shapefile.'*
- Name the shapefile something like "40pctmf.shp".

<u>Step 2: Analyze Census Blocks Clustering Patterns</u>

Step 2 refines the selection of census blocks identified in the Step 1 GIS queries, and narrows the selection to those census blocks most likely to represent clusters. Step 2 begins by visually reviewing the patterns created by the highlighted blocks in ArcView (Figure 2). As mentioned, displaying the blocks resulting from Step 1 in varying color intensities helps visually locate potential cluster sites. Two measures are used as lower and upper thresholds. The first is a lower threshold of 1,400 residents as the population of one or more census blocks; this indicates that the area covered by the census blocks contains too few people to have a cluster. The second is an upper threshold of 1-mile in diameter or less as maximum geographic expanse. The following guidelines help to narrow the search for cluster census blocks.

2.1 Narrow the selection of census blocks or groups of census blocks that will constitute **clusters** (figure 3).

- Eliminate from further analysis single or multiple contiguous blocks that are both isolated from other identified blocks and do not have more than 1,400 people. Note that combinations of as many as three census blocks may house fewer than 1,400 people. It is also possible to find a single block that houses more than 1,400 people and hence is a cluster.
- Note groups of blocks that cover an area wider than 1 mile in diameter as potentially multiple clusters.
- **Print an area map** of all blocks and groups of blocks defined under 2.1 and Figure 3 and that have high population and housing densities. The map should include the following layers: the potential cluster blocks, census block outlines, and any water bodies.

2.2 Draw a 1/2-mile diameter circle around each group of blocks to estimate the size of the cluster. For groups of elongated blocks that cover an area larger than 1 mile in diameter, position the 1/2-mile circle at what appears to be a main street intersection. Use 1 mile to define linear (corridor) clusters.

2.3 Make and print **area maps** (you may want to print subarea maps) of blocks or groups of blocks that form potential clusters (figure 4).

- Layers will include census block outlines, the selected potential cluster blocks (labeled with tract and block #), roads (labeled as the main or surrounding roads).
- Preferably use the same scale as that of aerial photographs, to help identify block boundaries "on the ground." For photos flown in the NW-95 series use 1:12,000. Always check the exact scale of the photos.

2.4 Print out necessary census data for each highlighted block in sub-area maps (see example of Table 1).

- Data to be printed include total acres, total population, population density, total housing units, total single-family units, total units in structures with 10 or more units, percentage of non-single-family units, percentage of units in structures with more than 10 apartments, age of population, ethnic background, etc. (see Table 1).

TASK III. Delineate Actual Clusters, Defining the Clusters' Outer Boundary from Aerial Photographs

Step 3: Cluster Patterns of Development from Aerial Photographs

Select aerial photographs for the census blocks identified in Step 2. An analysis of these photos will provide information about the spatial distribution of land uses. The purpose is to delineate the clusters based on actual development on the ground. The photographs will reveal the locations of groups of apartment complexes that generate the high population and housing densities found in the census data. They will also show commercial development that often accompanies multifamily accommodations in clusters but cannot be detected in the census data (figures 6 through 9).

It is sometimes difficult at first to match the maps derived from census information with the photographs. Follow the guidelines below, understanding that the boundaries of census blocks usually correspond to streets, freeways, or rivers. Also, census blocks often contain different land uses and land covers—for example, multifamily development and undeveloped land. Visually scanning the photos will provide information about the spatial distribution area layout of the different land uses and development patterns, roads as elements connecting spaces, as well as barriers to access (e.g., major highways).

3.1 Mosaic the photo tiles together, if needed, to cover the area of the census blocks identified as potential cluster(s) (Figure 5). To match maps and photos, make sure they are both oriented to the same reference point. Using road networks, rivers, or shorelines, look for distinct diagonal lines or curves in the landscape and in the census blocks to match up actual development patterns shown in the photographs with the boundaries of the census blocks.

3.2 Make copies of the photographs and draw on them an outline of the selected census blocks.

3.3 Visually scan the areas of the census blocks on the photographs—using a loupe is helpful. Focus on identifying large apartment complexes as well as commercial development in and near the blocks identified in the GIS analysis (figures 6 and 7). Outline the major apartment and commercial developments on the copied photo **and** in the area census maps—using different colors for apartments and commercial developments is helpful. Look for schools (Figure 8), offices (Figure 9), and other uses that may complete the cluster as a neighborhood.

3.4 Development patterns on the photos may not match well with the census blocks; some blocks may, for example, include large areas of undeveloped land and only one apartment complex. Conversely, apartment complexes may be located in census blocks **adjacent** to the ones identified in the GIS analysis.

3.5 Review the boundaries of the clusters of apartments and commercial development as the photos show them to appear on the ground and compare them with census block boundaries.

- How well do census blocks capture development on the ground? Consider whether to add or subtract census blocks from the previous delineation of clusters to capture the actual development patterns.
- In the case of large clusters of census blocks, does the area outlined cover more than one cluster? Look for **commercial development** as a center for larger clusters *and* **main street** intersections as a center for smaller clusters (Figure 10).
- The final shape and size of the cluster or clusters should relate to average walking distances between housing and commercial development, approximately 1/2 mile. Single-use clusters should also be contained within an area smaller than 1 square mile.

TASK IV. Finalize the Selection of Census Blocks That Best Match the Cluster's Boundary

Finalizing the selection of census blocks that best represent the cluster may involve adding or subtracting blocks. The following rules apply:

- Clusters need to be represented by a set of **contiguous** blocks.
- **Add** blocks that show dense development in aerial photos and form a continuous shape with other elongated blocks. Census blocks may need to be added to complete the continuous coverage of the cluster as developed on the ground. The photographs show areas in commercial development, vacant lands, schools, offices, low-density residential or mixed uses that could not be identified in Step 2. The cluster is then analyzed for continuity and spatial coverage (Figure 10)
- However, whenever possible, **exclude** blocks that do not have residential land and that are not needed to make a continuous cluster. Those uses will unnecessarily lower estimates of population density for the cluster. For example, census blocks with exclusively non-residential uses should not be included as part of the cluster unless one or several of these blocks is necessary to create a set of contiguous census blocks for the cluster. Including such blocks lowers density figures considerably, resulting in erroneous information on the cluster's demographic characteristics.
- In some cases, blocks must be included that do not have a regular shape and extend far beyond walking distances because they include a substantial amount of residential development relating to the cluster.

1. Create the final cluster using GIS (Figure 11)

- Display the original shapefile of census blocks in the View and make this layer active.
- Select the blocks that make up each cluster by clicking on the "select tool" and holding down the shift key when clicking on each block in your cluster.
- Convert to a shapefile, as in Step 1.

2. Name each individual cluster and make a table of relevant census data for each cluster.

Table 1: Relevant census data for selected blocks of sub area/Cluster A

Tract No.	Block	Pop.	Acres	Pop. Density	Total Housing Units	1 Unit per structure	10+ Units per Structure	# Non-Single Family HU	% Non-SF	HU Density	% Non-white	% Less 18YR
029404	212	1140	77.6	14.7	431.0	79	183	352.0	81.7	5.6	19.1	38.3
029404	208	73	5.9	12.3	21.0	20	0	1.0	4.8	3.5	11.0	32.9
029404	304	50	4.9	10.1	17.0	17	0	0.0	0.0	3.4	0.0	26.0
029404	303	82	4.2	19.5	21.0	21	0	0.0	0.0	5.0	19.5	36.6
029404	301B	229	11.9	19.3	75.0	45	26	30.0	40.0	6.3	14.0	30.6
029404	301A	994	45.2	22.0	515.0	11	360	504.0	97.9	11.4	9.5	23.5
029404	306	97	6.9	14.0	31.0	30	0	1.0	3.2	4.5	15.5	32.0
029404	307	95	8.6	11.0	32.0	32	0	0.0	0.0	3.7	6.3	26.3
029404	309	74	6.7	11.1	24.0	24	0	0.0	0.0	3.6	18.9	29.7
029404	310B	105	3.5	30.4	35.0	17	17	18.0	51.4	10.1	3.8	30.5
029404	213	83	17.3	4.8	52.0	2	5	50.0	96.2	3.0	6.0	8.4
029404	310A	54	3.5	15.6	16.0	16	0	0.0	0.0	4.6	38.9	33.3
029404	312	271	32.6	8.3	120.0	16	34	104.0	86.7	3.7	16.6	28.4
029404	311	47	3.7	12.7	23.0	19	0	4.0	17.4	6.2	4.3	29.8
029404	302	140	5.7	24.6	92.0	0	74	92.0	100.0	16.2	11.4	15.7
029404	214	47	5.4	8.6	28.0	0	27	28.0	100.0	5.2	10.6	14.9
029501	201	211	114.9	1.8	116.0	54	61	62.0	53.4	1.0	0.5	22.3
029501	901	858	119.3	7.2	422.0	39	322	383.0	90.8	3.5	14.3	26.3
Totals		**4650**	**477.89**	**13.06**	**2071**	**442**	**1109**	**1629**	**43.34**	**5.29**	**11.59**	**25.56**

Figure 5: Mapping the Three Queries

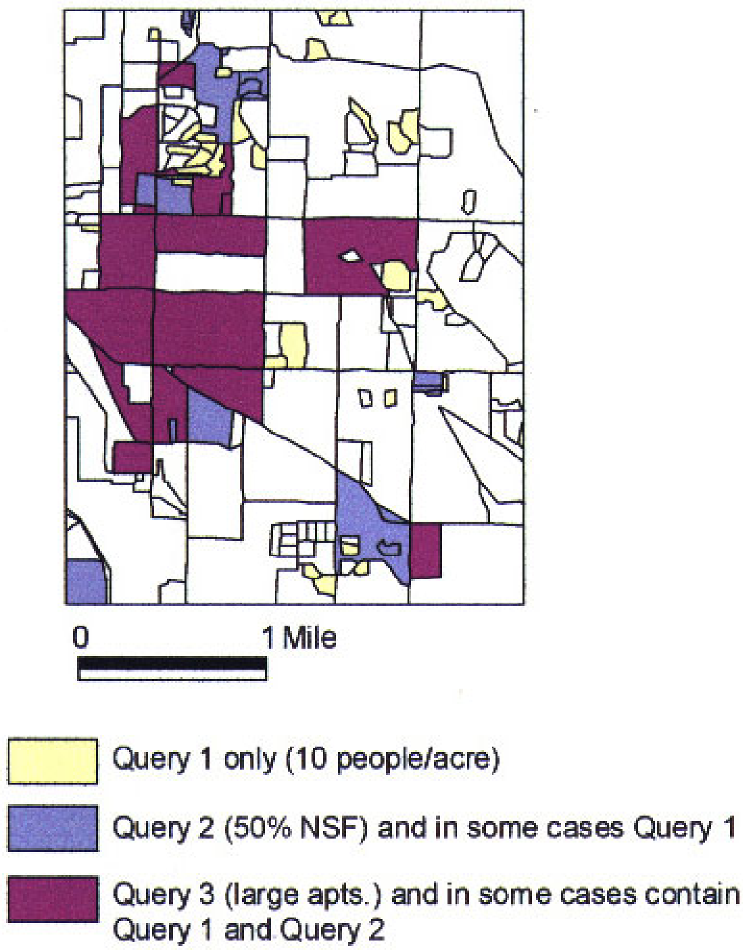


Figure 6: Composite of Blocks Identified from Queries One to Three

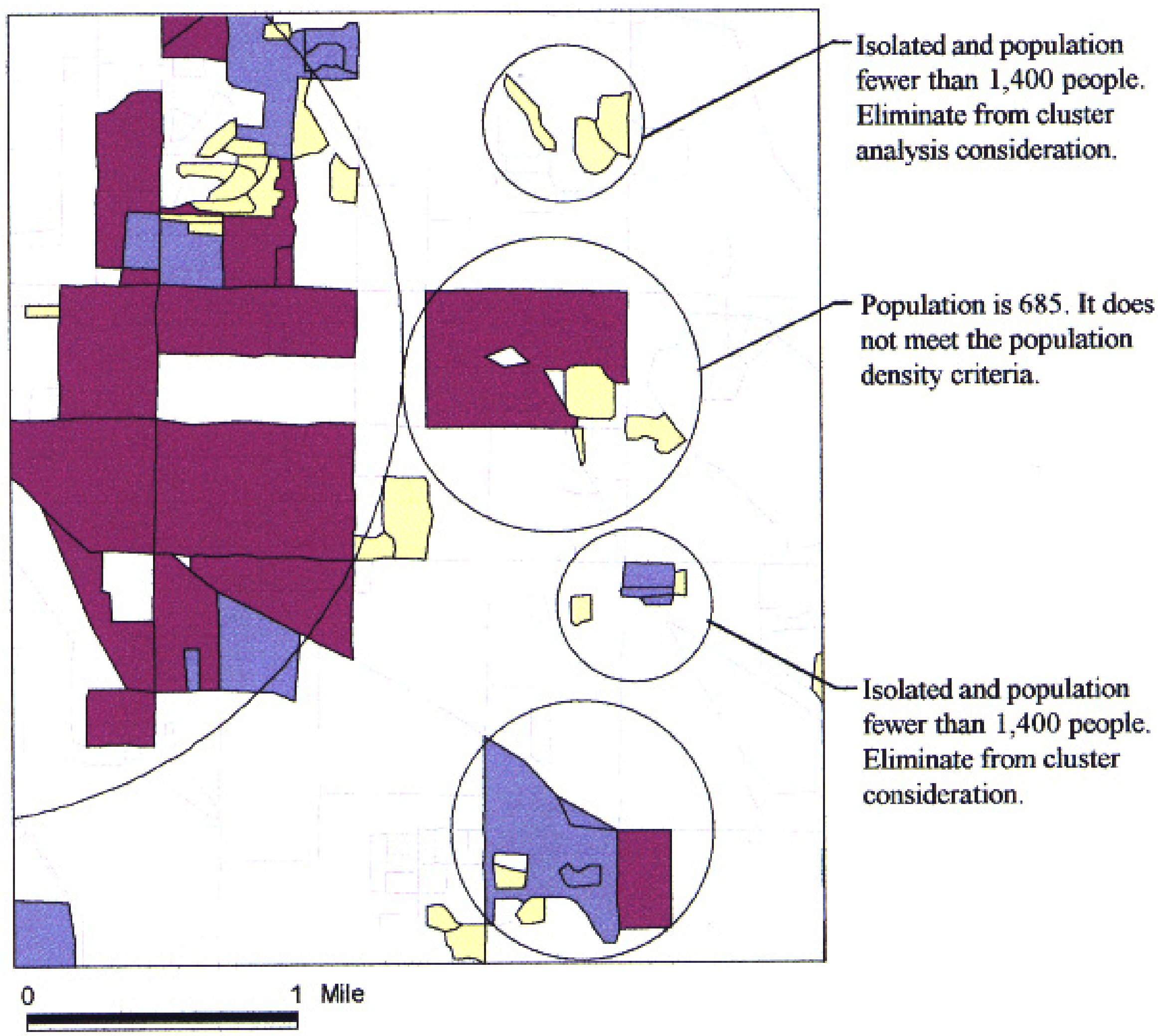


Figure 7: Blocks to eliminate from cluster consideration (Step 2.1)

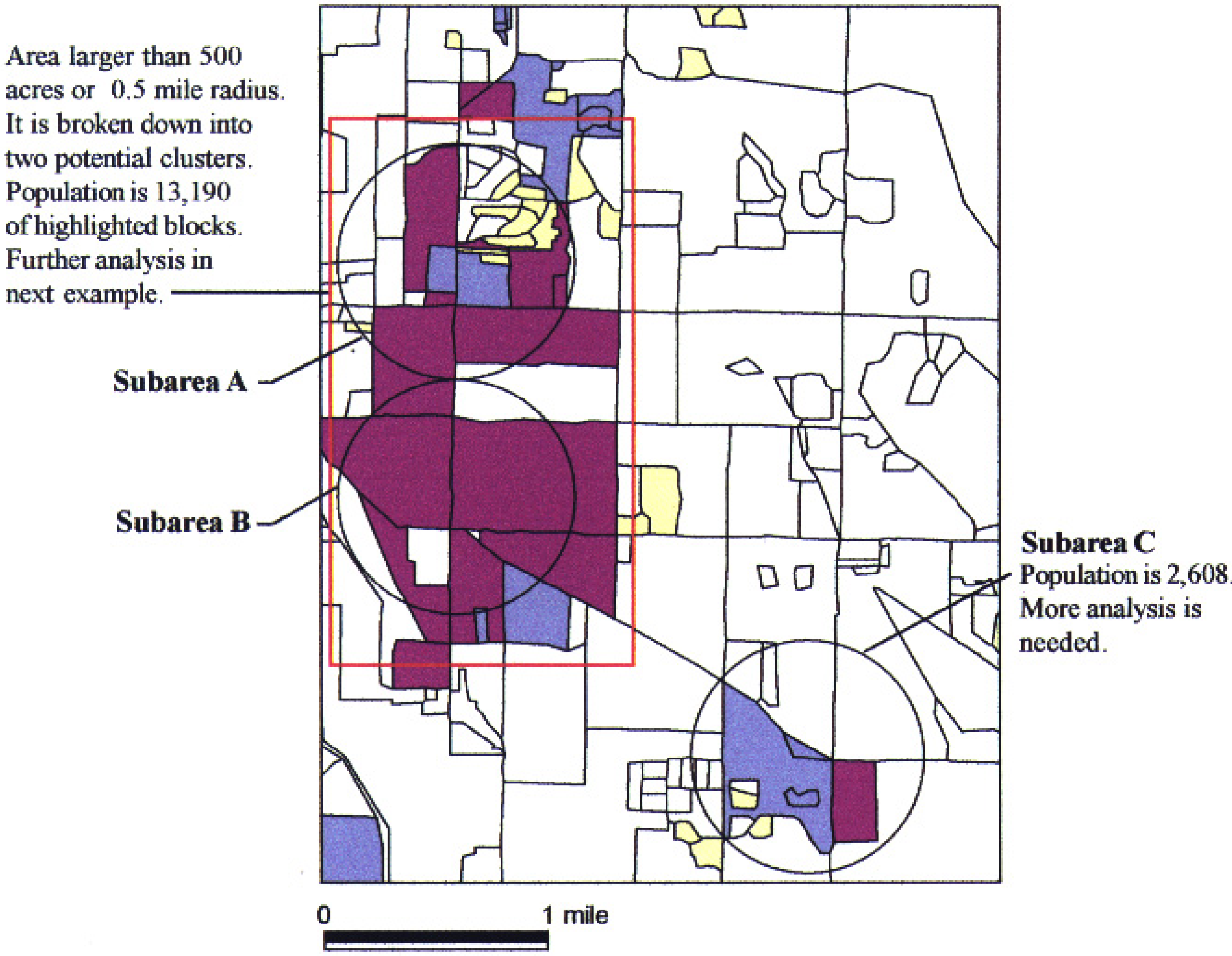


Figure 8: Area map of potential cluster blocks

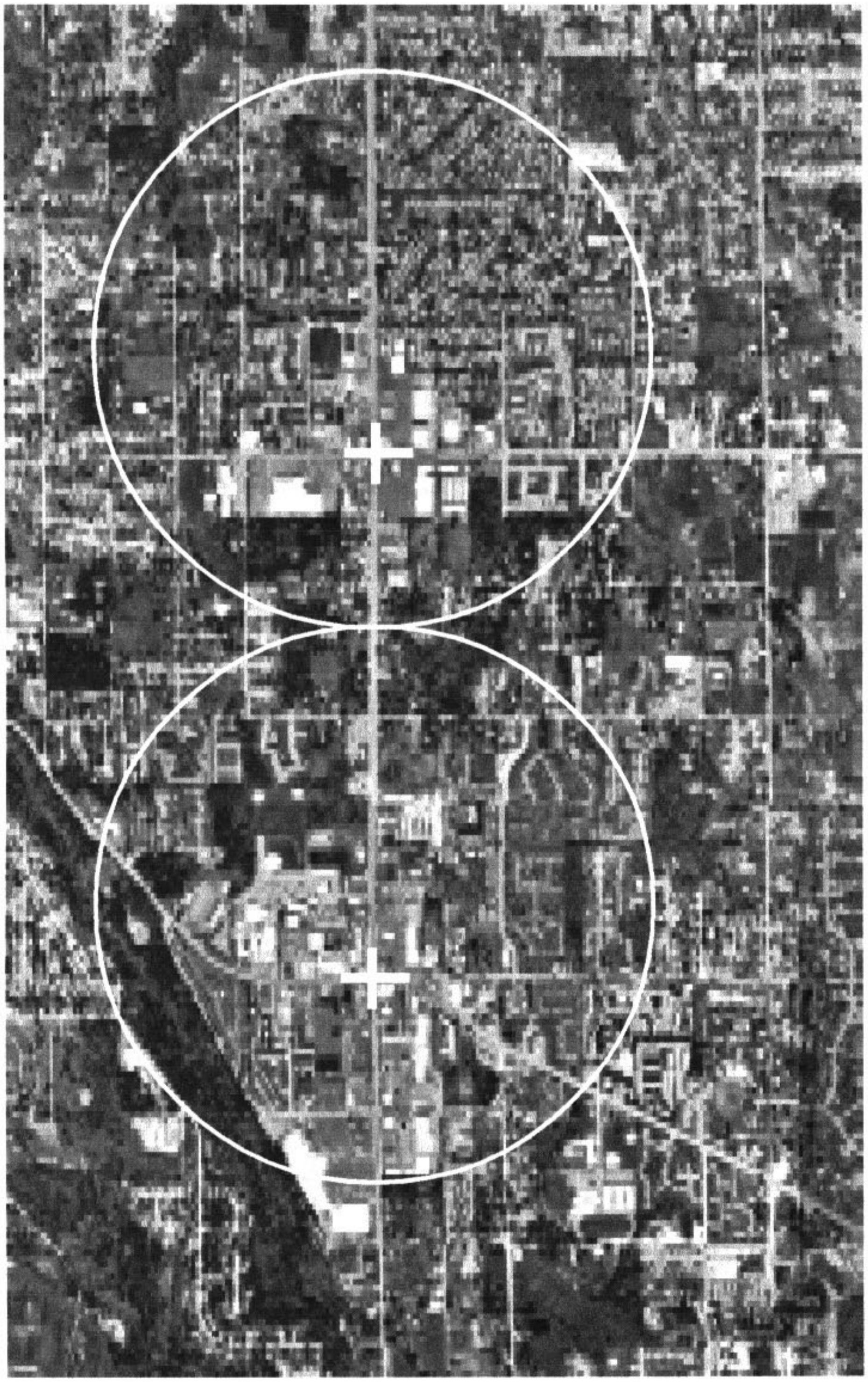
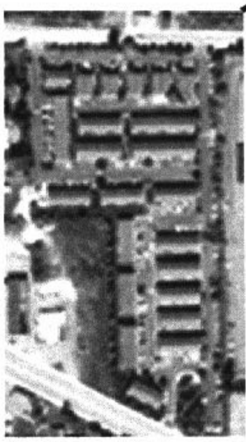
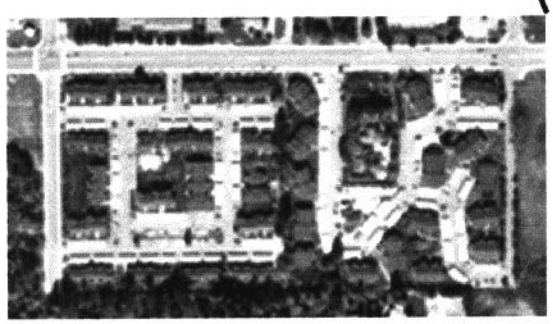


Figure 9: Aerial photograph of subareas

Apartments
Scale: 1"=400'



Apartments
Scale: 1"=400'

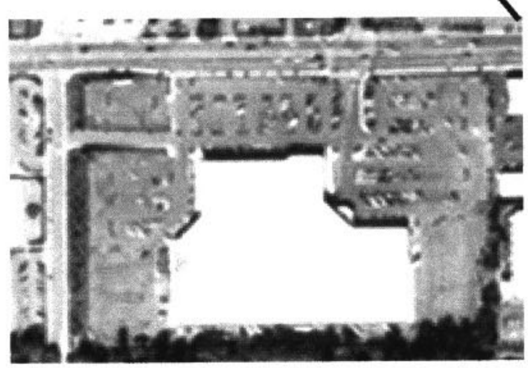


Apartments
Scale: 1"=400'

Figure 10: Identification of multifamily uses on aerial photographs

Retail Stores
Scale: 1"=400'

Shopping Center
Scale: 1"=400'



Retail (Discount)
Scale: 1"=400'

Figure 11: Identification of retail uses on aerial photographs

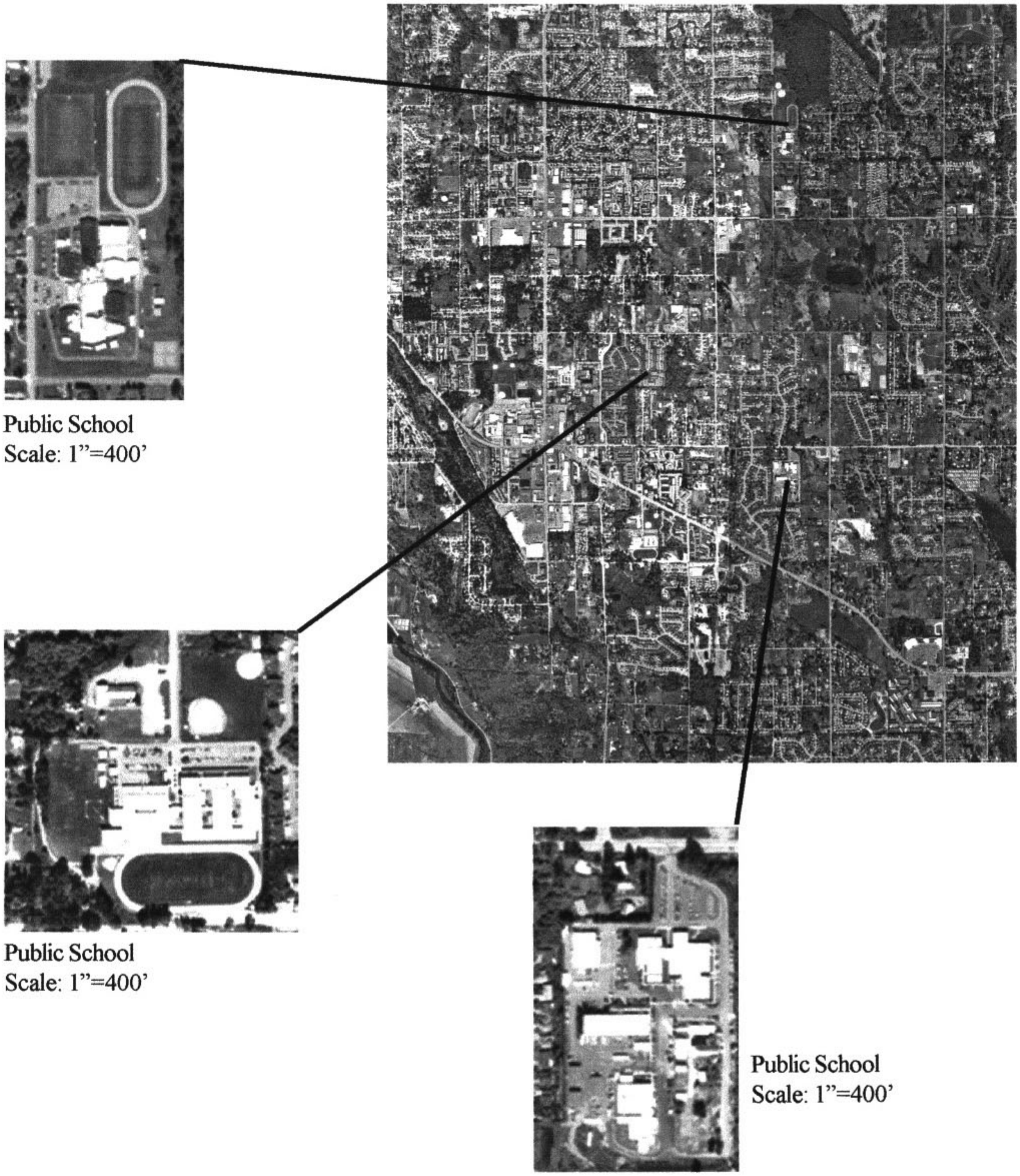
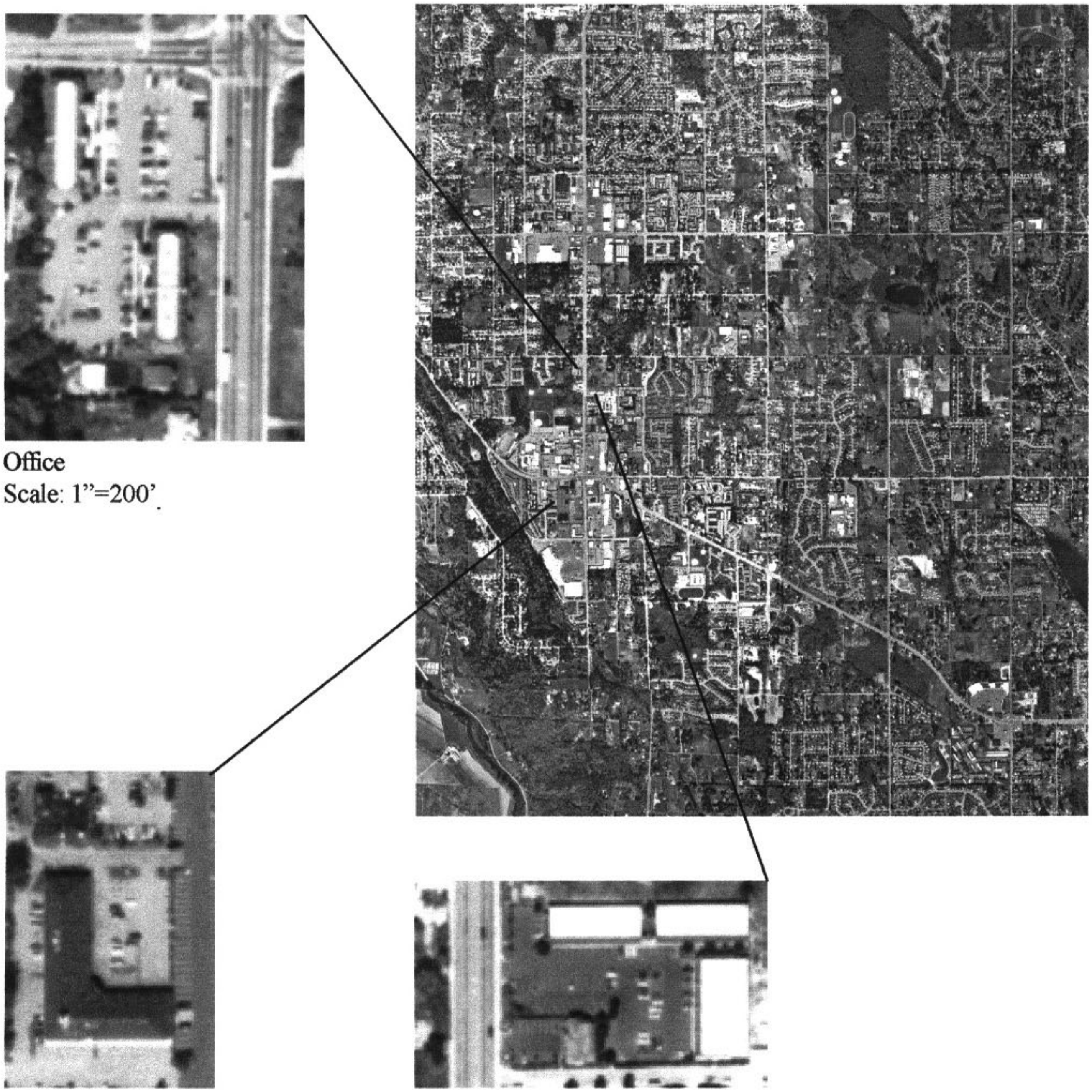


Figure 12: Identification of schools on aerial photographs



Office
Scale: 1"=200'

Office
Scale: 1"=200'

Office Park
1"=200'

Figure 13: Identification of office uses on aerial photographs

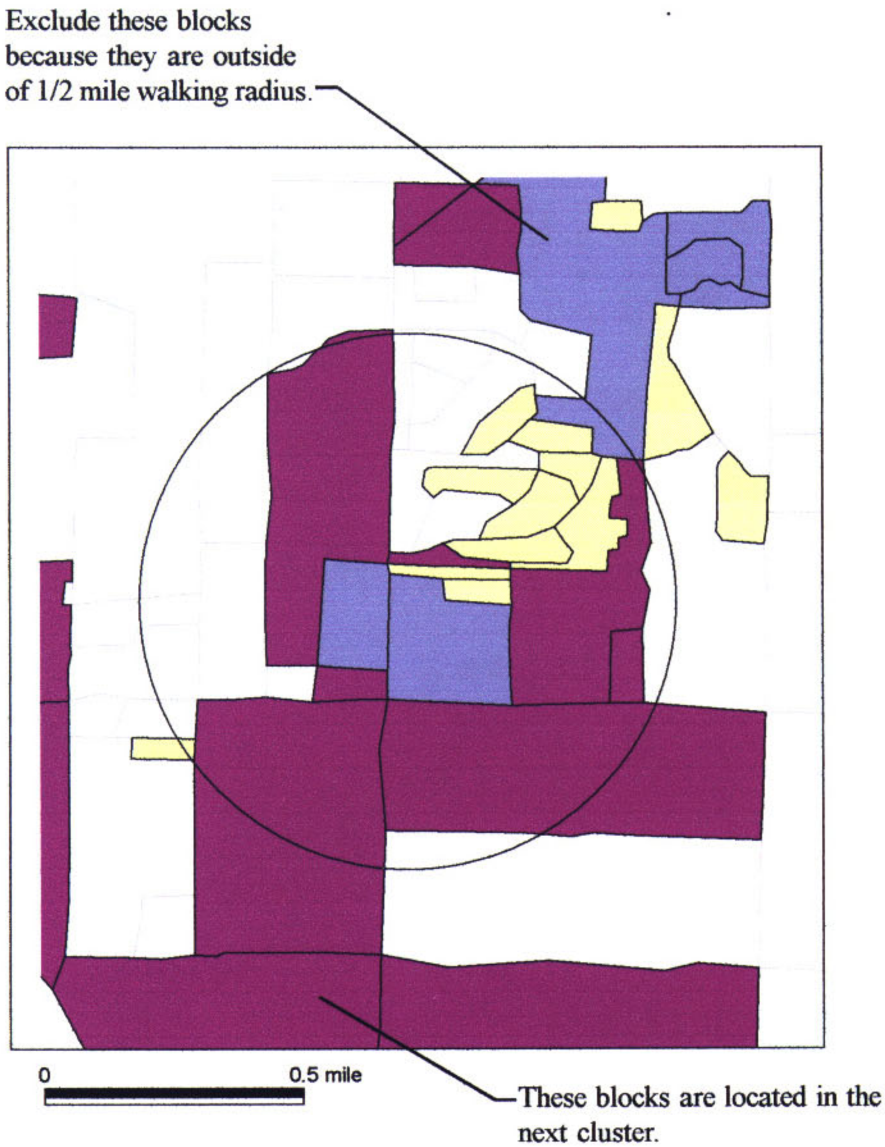


Figure 14: Finalizing the selection of census blocks

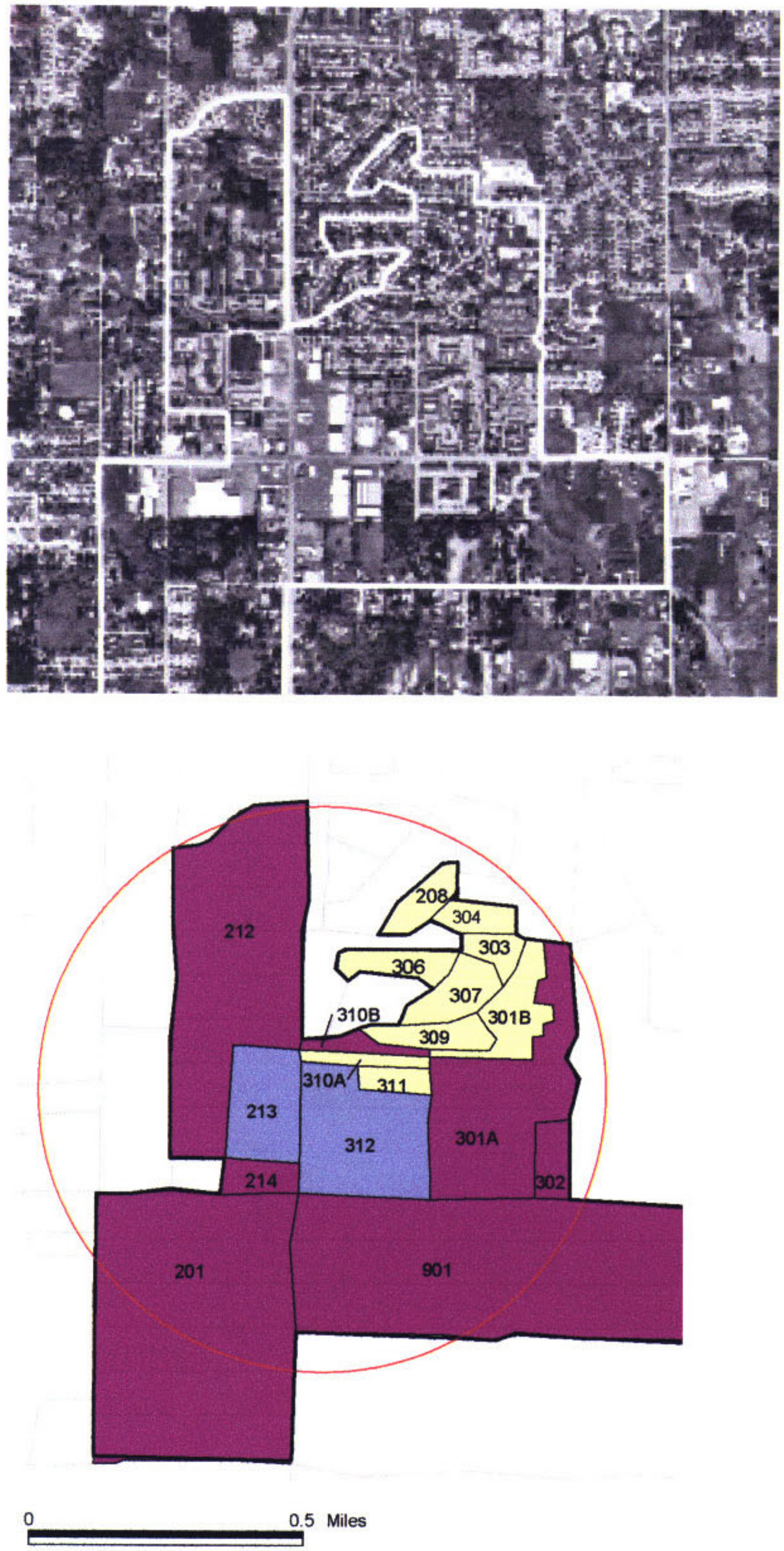


Figure 15: Subarea A cluster example

PL_2: PEDESTRIAN LOCATION IDENTIFICATION TOOL—METHOD 2 USING PARCEL DATA AND GIS SPATIAL ANALYSIS

Contents

** Note that specific steps to be taken are listed in indented text*

Introduction

This section describes PLI_2. PLI_2 uses parcel data to delineate clusters by using a series of GIS routines. The method works by selecting parcels with land uses that define clusters, namely medium to high-density residential uses, neighborhood retail and service uses, and schools. When these parcels are located within a specified distance from each other, they are grouped together into larger areas. Areas of grouped parcels are potential clusters that should be considered for pedestrian infrastructure improvement. If workable data are available, PLI_2 may require less staff time and delineate clusters with more precision and consistency than PLI_1.

A series of GIS commands are used to carry out the method. The basic tasks are described below. Each task discussed is accompanied by a figure. The figures show the same sample area of King County as shown for PLI_1 to illustrate the results of the task. GIS terms and background for grid-based analysis are in Appendix A at the end of this section. Appendix B includes the list of GIS commands, and Appendix C shows the input and output data layers. In outline, the method has the following tasks:

- Task I: **Assemble** parcel data.
- Task II: **Select** parcels with land uses that define clusters.
- Task III: **Convert** parcel polygons (vector data) to raster data using land-use codes for cell values. Cells corresponding to the areas of selected parcels are referred to as land-use patches.
- Task IV: **Change** the values of cells in land-use patches to a single value.
- Task V: Extend or **buffer** patch areas to fill areas located between close patches. This delineates potential clusters.

Task VI: **Infill** holes within potential clusters.

Task VII: **Shrink** areas of potential clusters the same distance they were extended in Task V. Areas between close patches are retained as interior areas and continue to define the potential clusters.

Task VIII: **Reestablish** land-use codes for areas of potential clusters.

A more detailed, technical discussion of the issues related to PLI_2 can be found in Hess, Moudon, and Logsdon, "Measuring Land Use Patterns for Transportation Research," *Transportation Research Record*, (in press).

TASK I. Assemble Data

A database is needed that consists of the following:

- GIS data that spatially represent parcels or tax lots as polygons
- attribute data that include basic land-use information that are linked to parcel polygons.

Most parcel data sets will require cleaning to make them usable. For instance, the King County data we used to develop the method represent condominium developments as single parcels in the parcel coverage, but each unit has a separate tax record in the assessor's attribute data. Thus, calculating unit counts for condominium polygons required several steps. We also needed to estimate some housing counts where data for parcels were missing. Not all residential records in the attribute data could be matched to polygons in the geo-spatial coverage. Even so, the data were adequate for our purposes. For the analysis of small areas, where data accuracy can affect the size and shape of individual clusters, additional data correction may be required. Data preparation is by far the most time intensive task of the method.

Figure 16 illustrates a section of King County with parcel polygons shaded by land-use class.

GIS data layers used in Task I

- **kcparcel**. Parcels associated with neighborhood retail and services

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TASK II. Select Parcels

Once data are usable, parcels containing land uses associated with clusters are selected. We selected the following types of parcels:

- residential parcels associated with medium to high density housing or mobile homes
- parcels associated with neighborhood retail and services
- parcels associated with school campuses.

Residential Parcels

We selected all residential parcels with medium to high densities as candidates for forming clusters. These included the following:

- single family residential parcels above 25 units per hectare (roughly 10 units per acre)
- all types of attached housing units
- mobile home parks.

Non-Residential Parcels

We selected all parcels with the types of neighborhood retail and services that are likely to generate walking trips. These include supermarkets, dry cleaners, restaurants, banks, and convenience stores. We also included institutional uses such as post-offices and libraries.

Because of broad land use classifications in the database, it may not be possible to exclude some retail uses that are unlikely to generate walking trips. For example, in the King County data set, we could not exclude large, single-use shopping centers without also excluding more neighborhood-oriented shopping centers. Some jurisdictions may have access to business license or other data sources with more precise land-use classifications. These may be used to supplement or substitute the land-use codes common in assessor's data.

Finally, we selected school campuses, including college and university campuses. Because different types of schools have different travel implications, schools should be distinguished by type where possible. For example, elementary schools are important because of potential walk trips between them and surrounding residential development, but high schools will also generate trips to nearby retail areas. Distinguishing school by type was not possible with our data set.

Coverage with Selected Parcels

A section of the coverage with selected parcels is illustrated in Figure 17. The coverage contains all parcels with the land uses that define clusters**.** Many clusters of selected parcels are recognizable just by looking at a map of the data. The remaining steps of PLI_2 refine this visual inspection by defining the distance parcels must be from each other to be combined into larger units or clusters. These steps also enable precise quantification of the land-use patterns for analytical purposes.

GIS data layers used in Task II

- **kcparcel** is used to create **select_par**.

TASK III. Convert Vector Data into Raster Data

The remainder of PLI_2 relies on the use of raster data. This task converts the vector data in **select_par** to grid or raster data. A raster data model, with a two-dimensional matrix of cells containing values, aids in the types of spatial analysis used in the rest of the method. The appendix supplies additional information on raster analysis.

The cells are given values that are derived from their land-use code. Cluster delineation does not rely on these values. The method only requires that cells corresponding to the areas of selected parcels are distinguished from those that do not. Indeed, in Task IV cells corresponding to areas of selected parcels will be given a single value. During data conversion, however, it is useful to create a grid layer with land-use codes because these values will be reestablished once clusters have been delineated to aid in their visualization (Task VIII). For visualization purposes, we used only three classifications: one for residential, one for retail, and one for school land uses.

The data conversion is done in two steps. Step one creates the grid with cells containing values corresponding to the land use codes of the selected parcels. Cells that do not correspond to selected parcels contain no data. In step 2 these “nodata” cells are converted to cells with a value of 0.

Figure 18 shows the vector data in **select_par** converted to raster data in a grid called **landuse1**. Note that once polygon data have been converted to raster data there are no parcel boundaries. Instead, adjoining parcels in the same use are indistinguishable from each other. As a result, the data now represent areas of homogeneous land uses. We refer to these areas as land use patches.

GIS data layers used in Task III

- **selectpar** (vector data) are converted to **landuse1** (raster data)
- **landuse1** (containing nodata cells) is used to create **landuse2** (with no data cells converted to cells with 0's)

TASK IV. Give Cells Representing Selected Parcels One Value

Cells representing selected parcels are given a single value. This is shown in Figure 19 with all selected parcel cells shown in black. Areas of black cells now represent any of the types of land-use patches created in Task III. All other cells have a value of 0. The grid is named **1value**.

GIS layers used in Task IV

- **landuse2** (containing land use values) is used to create **1value** (containing only one value for cells corresponding to selected parcels).

TASK V. Delineate Potential Clusters by Expanding the Areas of Patches

In this task, the areas of land use patches are expanded outward from their edges. Places that have close but disconnected areas in black in Figure 19, are now connected into larger areas. This is shown in Figure 20 as **expanded1**. The land-use patches shown in Figure 19 are still shown in black. The areas in purple show the new buffers. Black patches connected by purple buffers are potential clusters.

The expanded distance patches will affect the number and size of clusters created in the delineation process. Larger distances will create fewer, larger clusters. Larger distances will also create clusters with more land in uses other than those selected to define the clusters in the first place. We found 120 meters to be a good distance to create appropriately scaled clusters, but the appropriate distance will depend on local land use patterns. Several buffering distances should be tried.

GIS layer used in Task V

- **lvalue** is used to create **expanded1**.

TASK VI. Fill Holes or Sinks in Potential Clusters

Some areas in the potential clusters of the grid **expanded1** are not designated as cluster cells, yet are entirely surrounded by them. These areas are in the middle of a number of land-use patches but are farther from any of the patches than the expansion or buffering distance used to create the potential clusters. These "holes" or "sinks" may be lakes, large pieces of undeveloped land, or other non-cluster uses.

The holes or sinks are filled and made into parts of the potential clusters as shown in **fill1** (Figure 21). In Task VII, the areas of potential clusters will be shrunk inward around their edges. Sinks must be filled in Step 6 so that there are no edges in the interiors of potential clusters.

GIS layer used in Task VI

- **expanded1** is used to create **fill1**.

TASK VII. Shrink Areas of Potential Clusters

At the end of Task VI, the potential clusters in the grid **fill1** closely resemble the final definition of clusters, but they are still too large. Areas between close land-use patches have been filled, connecting the patches and defining potential clusters. The outer edges of potential clusters, however, need to be shrunk back to define the final clusters.

This is shown in **shrink1** (Figure 22). The black line shows the former outer edges of the potential clusters. The black areas show the new, smaller areas of the actual clusters.

<u>GIS layers used in Task VII</u>

- **fill1** is used to create **shrink1.**

TASK VIII. Reestablish Land-Use Codes

The grid **shrink1** shows areas in black that represent the area of clusters but have no land-use codes. This task reestablishes these codes. In addition, the "connecting cells" created in the expansion process (Task V) and the "filled sinks" (from Task VI) are identified with unique codes. Task 8 contains four steps. In step one, land-use codes from **landuse2** (from Task III) are combined with **shrink1** to create **cluster1**. Cluster 1 delineates cluster areas and has land-use values but does not identify sinks. Steps 2 and 3 create a grid with unique values for the sink areas. Finally, Step IV combines these unique values for sink areas with **clusters1**. The result is the final grid called **clusters_lu.**

The final grid **clusters_lu** is shown in Figure 23.

<u>GIS layers used in Task VIII</u>

- **landuse2** (from Task III) and **shrink1** (from Task VII) are used to create **clusters1.**
- **expand1** (with holes or sink areas from Task V) and **fill1** (from Task VI) are used to create **sink_id** that identifies sinks but still contains land use patches and connecting areas**.**

- **sink_id** is used to create **fill_only**, which only contains filled sink areas.
- **fill_only** and **clusters1** are combined to create **clusters_lu.**

Table 2: Sample of data available for sububarea clusters A and B

	Acres	Housing Units	Units/acre	Pop (est)	Density People/acre	Sq. ft commercial land
Cluster A	182	1,833	10.1	4,033	22.2	553,402
Cluster B	524	4,232	8.1	9,310	17.8	1,459,938

These data can be compared with those from the census available for cluster A in PLI_1 (Table 1). Among other attributes also available in the parcel data are average lot size, area in other uses such as office, vacant land, assessed improvement and land values, size of zones by major land use category.

Final Notes

The grid **clusters_lu** delineates clusters as areas of land uses within specified categories that are within a specified distance of each other. As seen in Figure 23, not all of the delineated areas will have land use patterns that are likely to generate pedestrian activity. Some of the delineated areas are in only one use. Others are too small to create large amounts of walking activity. Simple visual inspection of the final grid will allow the analyst to eliminate many of these. The final grid may also show, however, larger, mixed use areas. These larger, mixed areas should form the basis for further analysis. They likely generate current pedestrian activity. They are also be places where additional walking and safer walking conditions can be promoted with appropriate infrastructure investment.

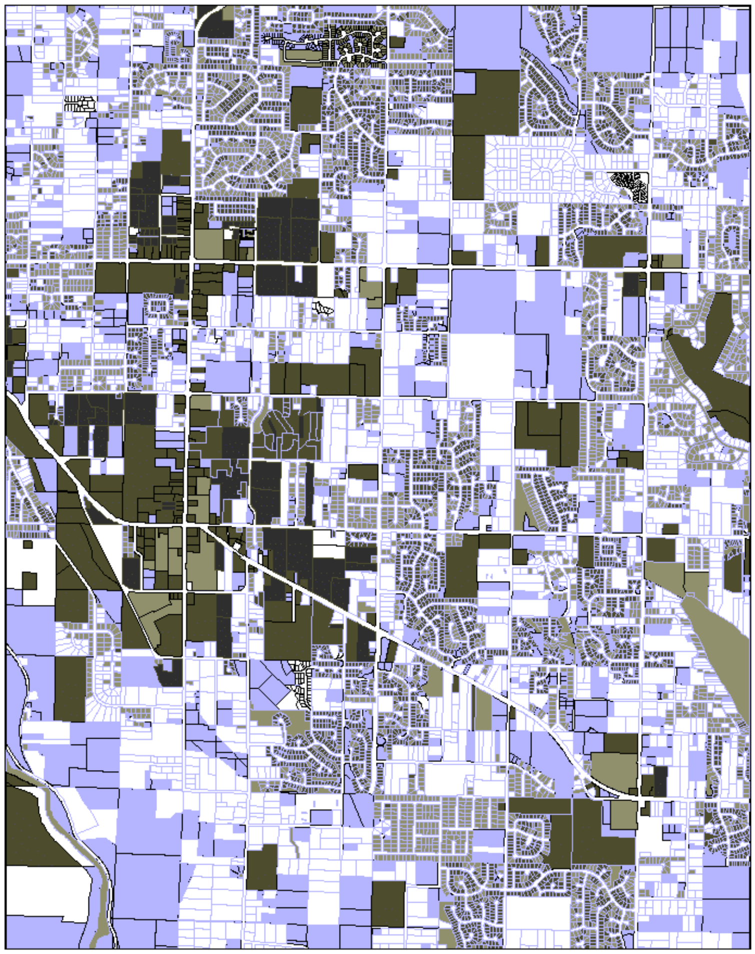

Figure 16. Parcel polygon coverage

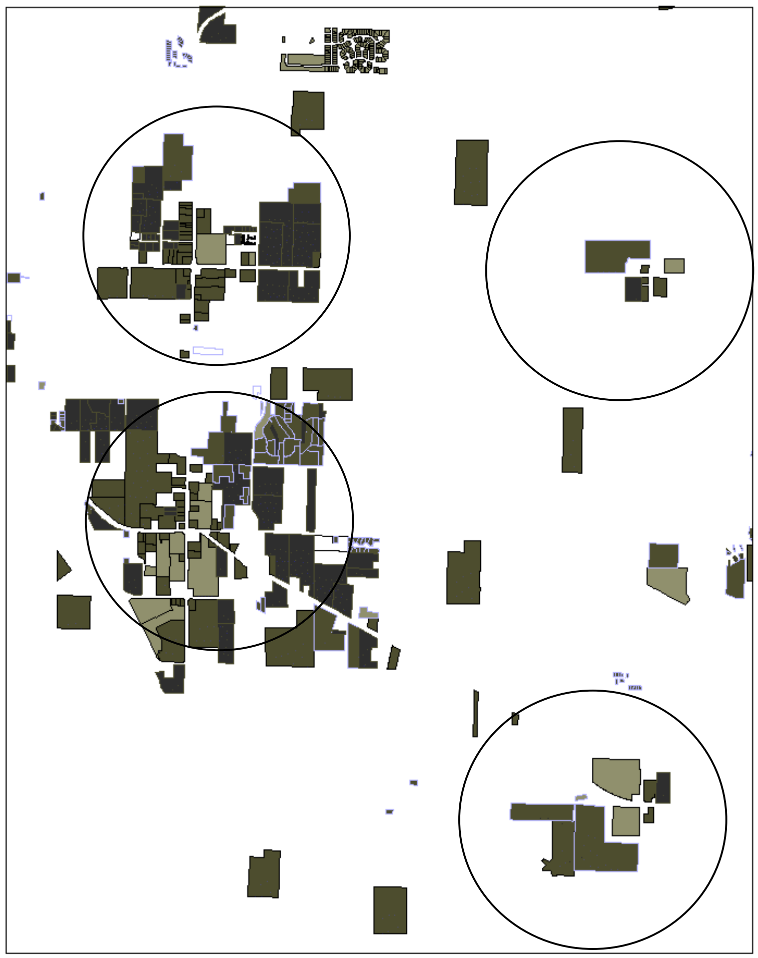

Figure 17. Polygon coverage parcels in selected land uses.

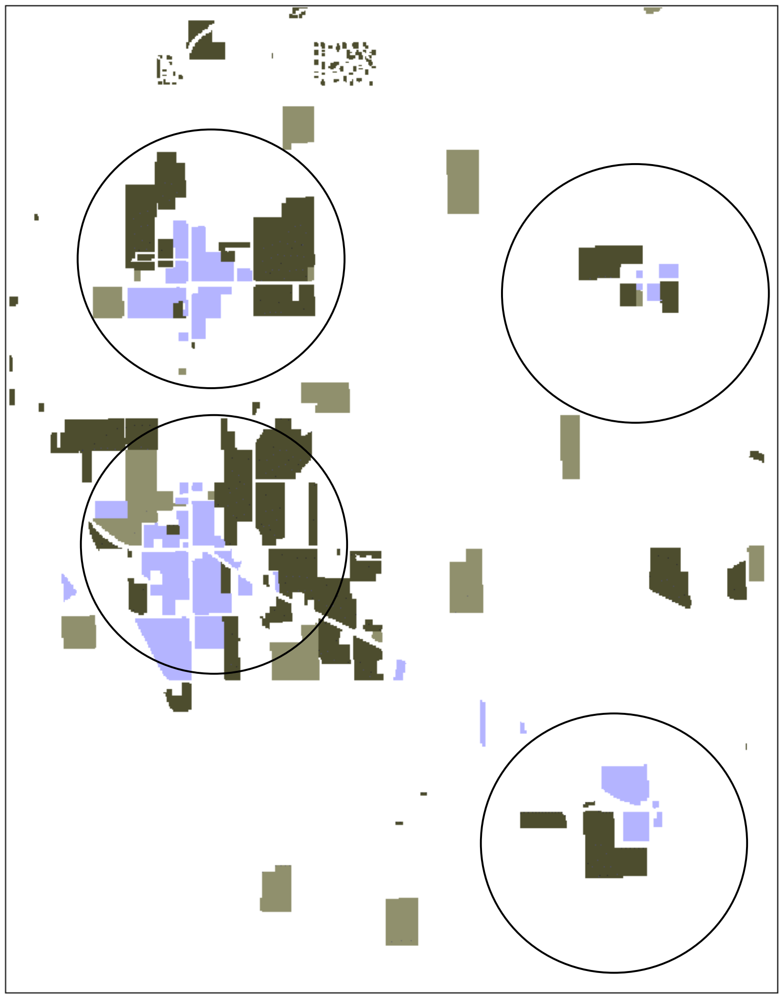

Figure 18. Land use patches. Vector data have been converted to raster data. The different colors no longer represent parcels. Instead, they are areas with similar uses.

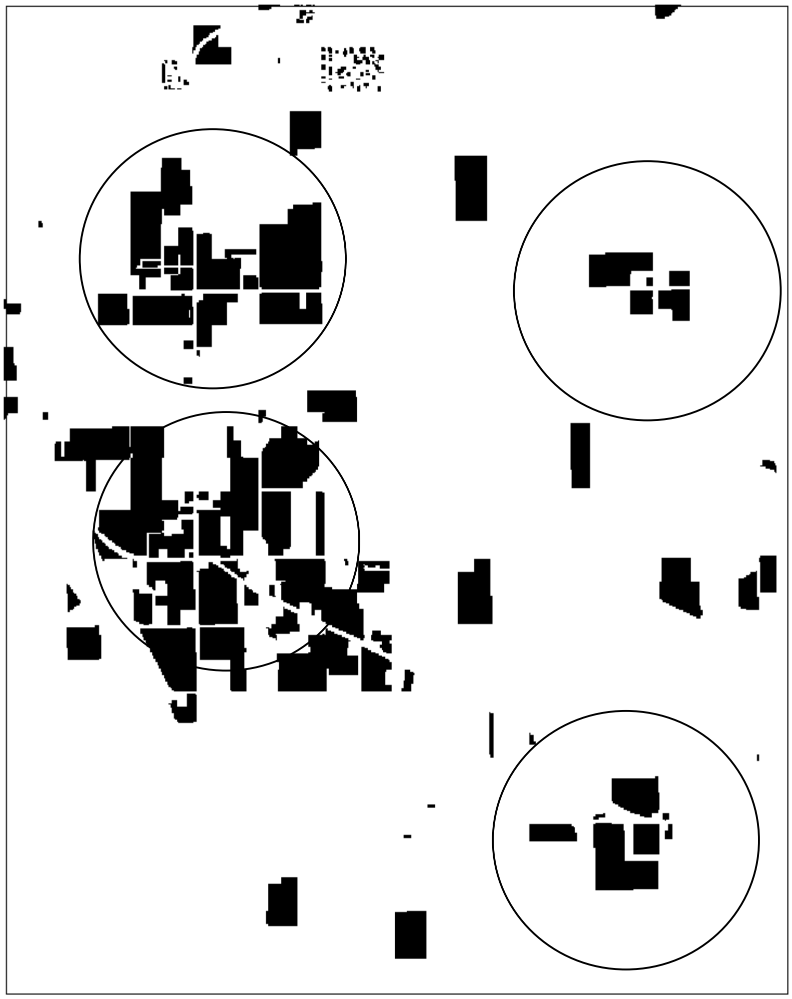

Figure 19. Patches in different selected land uses are converted to raster cells with one value. This helps extend the areas of the patches in Task V.

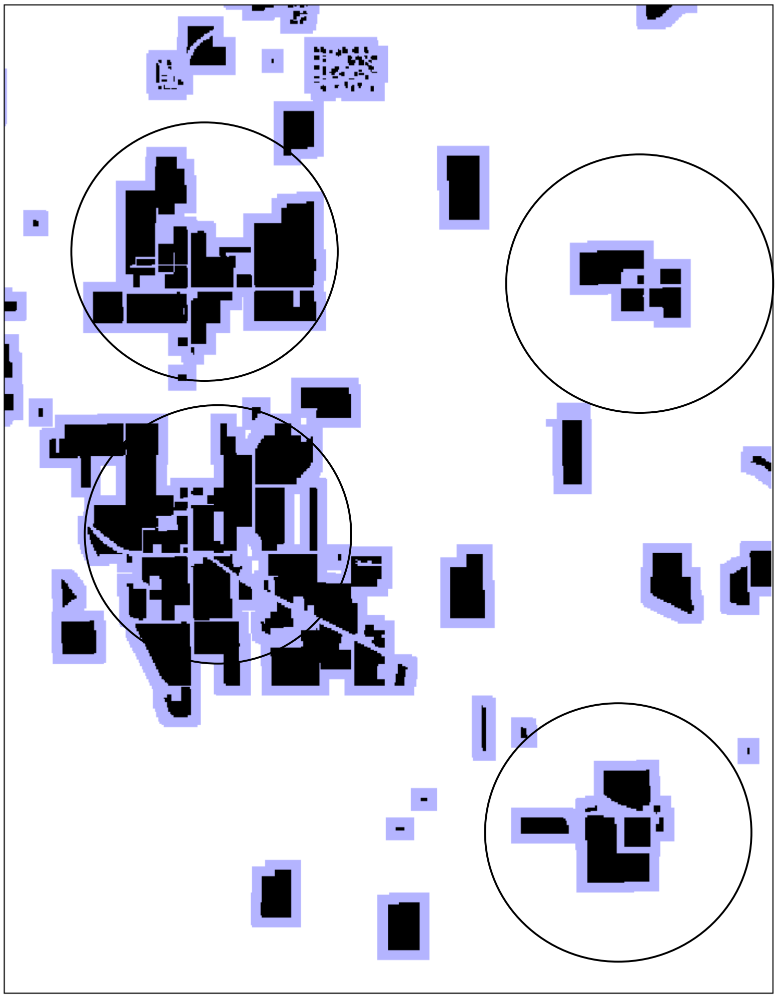

Figure 20. Patch areas are extended to create "potential clusters." Black areas show patches. Grey areas show extended areas of patches (buffers). Both patches and buffers are given the same value in the data set.

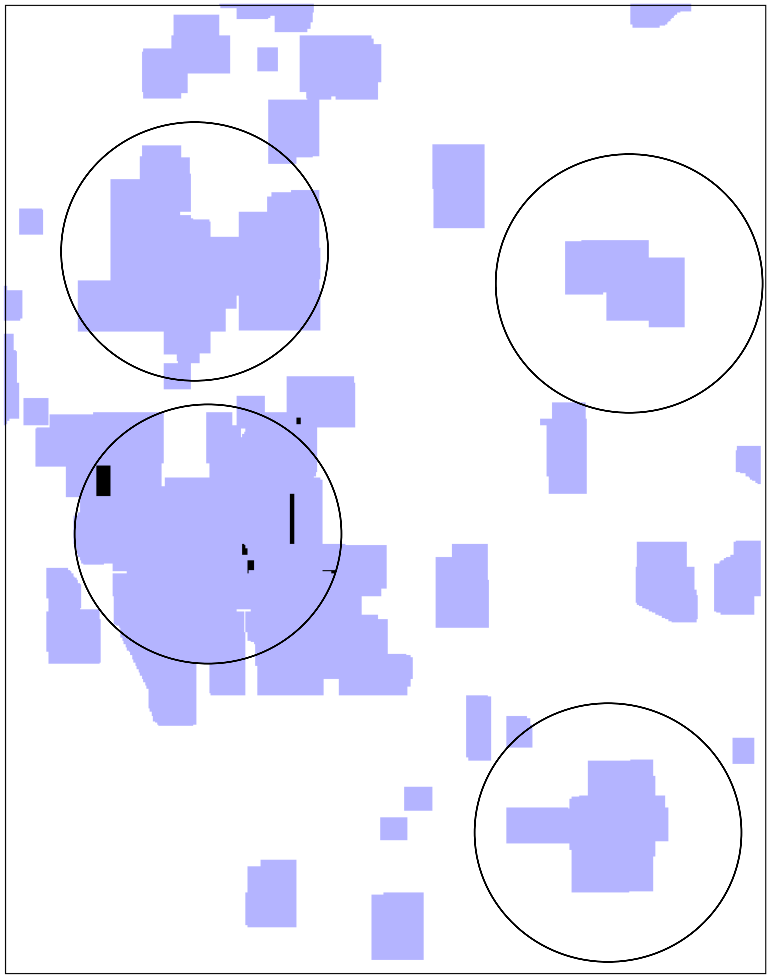

Figure 21. Holes or sinks in potential clusters are filled. Potential clusters are shown in gray and filled sinks are shown in black. Both are given the same value in the data set. Filling sinks is necessary so that there are no edges in the interiors of the potential clusters.

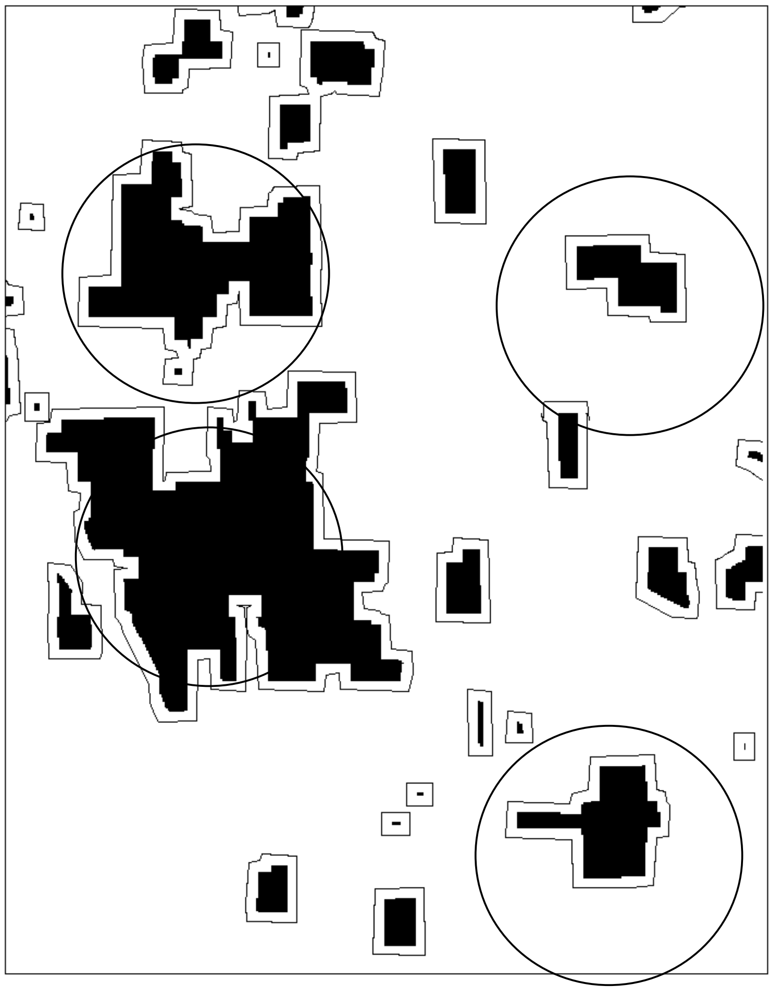

Figure 22. Grid layer **shrink1**. Combined patches are shrunk back from their edges by the same distance that patches were extended in Task V. The black *lines* show the old boundaries of potential clusters. The black *areas* show the new potential clusters that result from shrinking.

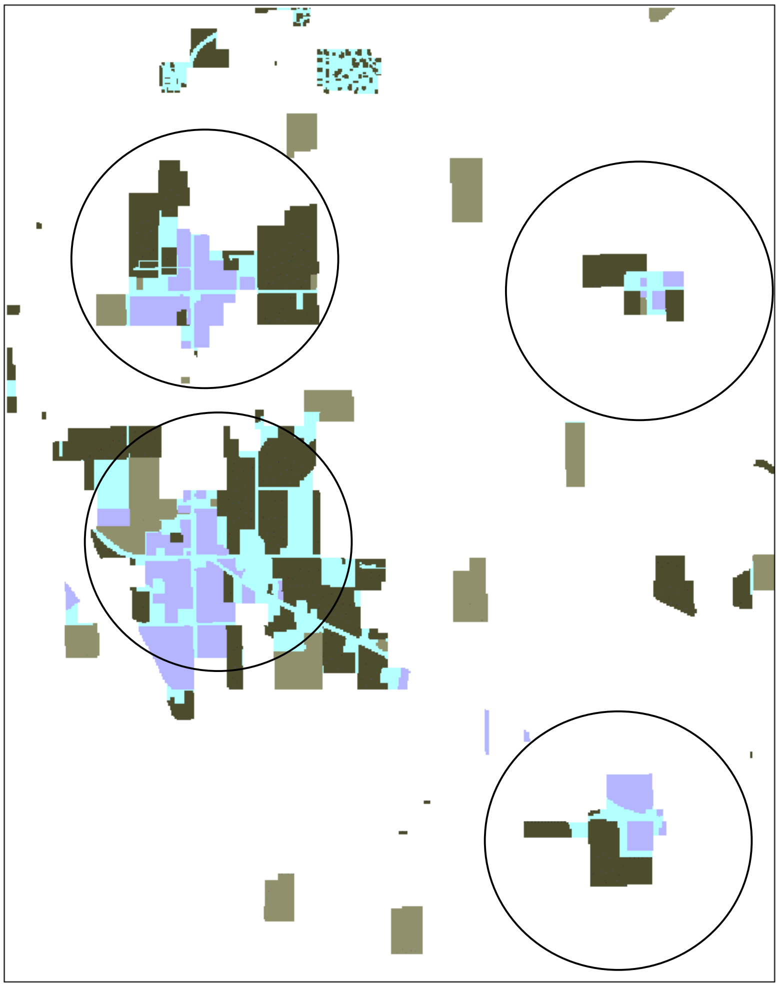

Figure 23. Final grid layer with land-use classifications reestablished. Note that some potential clusters are not likely to generate pedestrian activity because they are single use or are too small. There are, however, several large, mixed-use clusters that are good candidates for pedestrian infrastructure investment.

APPENDIX A.
GIS Terms and Background for Grid-Based Analysis

Grid or raster analysis in a GIS works by performing a command sequence on an input grid or grids. The input grid(s) is the source data. The command sequence mathematically transforms the values in the input grid(s) and writes them to an output grid. The data in the input grid(s) are not changed. The output grid is often used as an input grid in a new command sequence.

Each grid consists of cells arranged in a spatial matrix. Each cell in the matrix contains either some value or consists of "no data." When a command function is used to transform these values, their spatial relationship is maintained. By way of example, values in an output grid may be the result of adding together the values in two input grids. The value of each cell in one input grid is added to the value of the cell in the same spatial position in the other input grid. This sum is written to the cell in the same spatial position in the output grid (Figure 24). One value of using a raster GIS is that it facilitates neighborhood analysis. In neighborhood analysis, the data in the output grid are determined by the values of a number of cells that form a spatially defined neighborhood in the input grid. The user defines the size and shape of the neighborhood. For example, the neighborhood may be a cell in an input grid plus the adjoining eight cells around it. The neighborhood, then, is a three-by-three cell square, or nine cells in total. In this case, the value of each cell in the output grid is determined by this corresponding nine-cell square in the input grid. For example, the output value may be specified as the largest value in any of the cells in the defined neighborhood in the input grid (Figure 25).

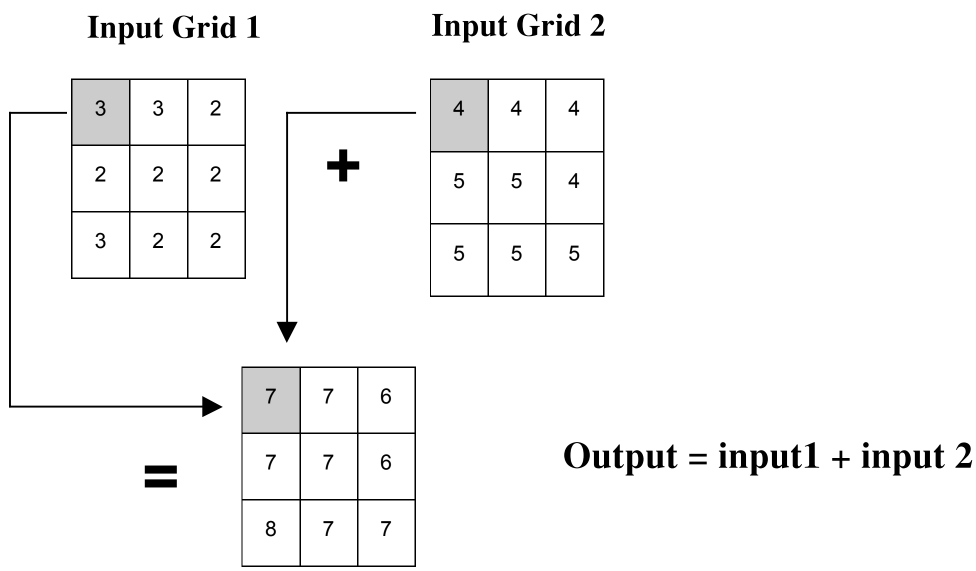

Figure 24. Example of adding values in two input grids to create output grid.

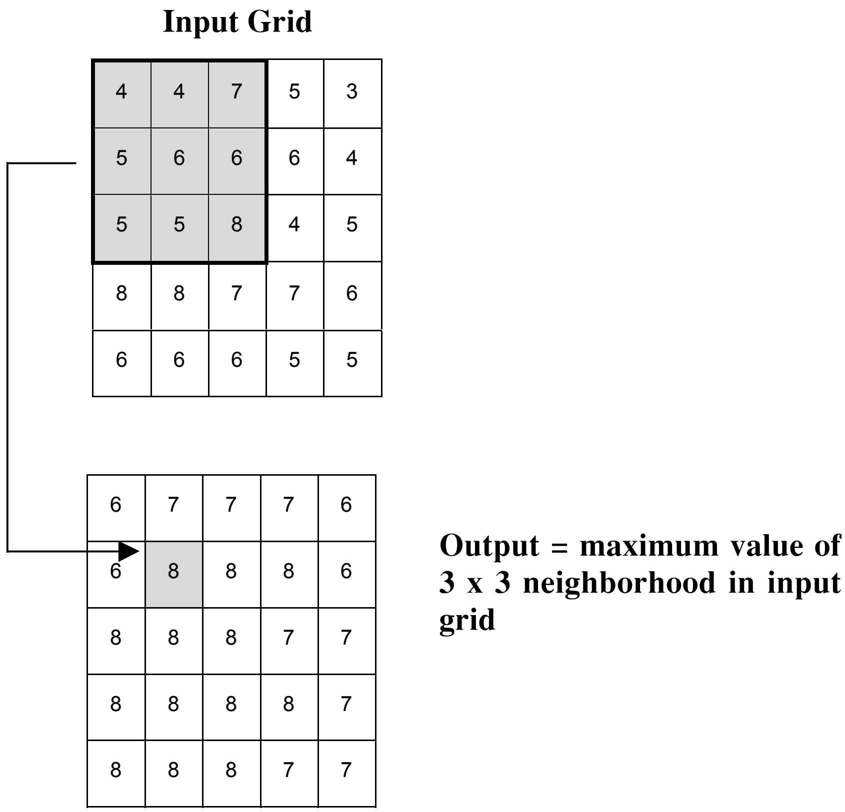

Figure 25. Example of neighborhood analysis. Maximum value in a 3-by-3 neighborhood in the input grid is used as the value in the output grid

APPENDIX B.
List of Commands Used

The Arc/Info GIS package version 7 produced by ESRI was used. Other packages have different commands and command syntax. Below, commands are shown as upper case; coverage or grids names are shown in bold lower case; and command arguments and variables are shown as non-bold lower case. This is only to visually distinguish the elements in the command for this document and is not needed when commands are issued.

In Arc:

- POLYGRID **select_par landuse1** luc (Task III)

In Grid:

- **landuse2** = CON(ISNULL(**landuse1**), 0, **landuse1**) (Task III)
- **1value** = CON(**landuse2** > 0, 9, 0) (Task IV)
- **expand1** = EXPAND(**1value**, 12, list, 9) (Task V)
- FILL **expand1 fill1** sink 10. (Task VI)
- **shrink1** = SHRINK (**fill1**, 12, list, 9) (Task VII)
- **clusters1** = CON(**landuse2** > 0, **landuse2**, **shrink1**) (Task VIII)
- **sink_id** = **expand1** + **fill1** (Task VIII)
- **fill_only** = CON(**sink_id** == 9, 90, 0) (Task VIII)
- **clusters_lu**= **clusters1** + **fill_only** (Task VIII)

APPENDIX C.
Input and Output Layers

Task	Step	Input	Output
I		kcparcel (vector)	
II	1	kcparcel (vector)	select_par (vector)
II	2	select_par (vector)	landuse1
III		landuse1	landuse2
IV		landuse2	1value
V		1value	expand1
VI		expand1	fill1
VII		fill1	shrink1
VIII	1	landuse1 shirnk1	clusters1
VIII	2	expnand1 fill1	sink_id
VIII	3	sink_id	fill_only
VIII	4	fill_only clusters1	clusters_lu

Note: raster data unless noted otherwise.

PIP: PEDISTRIAN INFRASTRUCTURE PRIORITIZATION
PIP DECISION SYSTEM

Contents

Introduction

PIP serves jurisdictions that have more than one cluster and that need to prioritize the allocation of capital improvement funds. PIP is therefore used *after* clusters have been identified on the basis of PLI_1 and PLI_2. It serves to help rank clusters for infrastructure improvement funding according to the highest expected benefits. With **PIP**, each cluster is subjected to a rigorous analysis through a four-component approach:

1. *Optimal* area-scale land-use and urban form conditions for pedestrian travel. These include appropriate intensity of development, appropriate origins and destinations, proximity factors, and topographical conditions (Chart 1).
2. *Optimal* transportation facility scale conditions for pedestrian travel. These include pedestrian infrastructure, transit level of service, and pedestrian safety considerations (Chart 2).

3. *Optimal* policy conditions for pedestrian travel. These include the general institutional, organizational, and community support for increased pedestrian travel (Chart 3).

4. *Optimal* total conditions, a summary of Charts 1 through 3 (Summary Chart).

Each component is defined by a list of main criteria to be considered. Each criterion in turn is decomposed into a list of sub-criteria. The sub-criteria are then translated into measures of the area's potential for pedestrian travel. The actual weight and score of each measure are defined by the users. Thus, **PIP** is an open-ended tool that takes into consideration the fact that different jurisdictions may emphasize various criteria differently. Hence, the weights assigned to each measure reflect the priorities assigned by a local jurisdiction, or multiple jurisdictions in the case of clusters located in two or more jurisdictions. For example, jurisdictions may decide to use some but not all of the criteria listed. They may also differ in considering the importance of the size and number of street-blocks as a measure of pedestrian potential. Similarly, they may weigh differently the fact that the area has or has not been identified in the comprehensive plan.

Weighted measures yield a score for each sub-criterion. Finally, a tally of scores yields a value for each component, and a tally of each component's total score yields a total value for the individual cluster. This value represents each cluster's potential for increased pedestrian volume following infrastructure improvement, and as such, helps rank the clusters as candidates for infrastructure investment.

NOTE: The exhaustiveness of the list of criteria and sub-criteria proposed in PIP reflects the lack of data available to confirm the power of variables in predicting the effect on pedestrian volumes. The open-ended weighting system proposed, on the other hand, reflects both the lack of data available and the potential need of local jurisdictions to tailor their prioritization process to special circumstances.

PIP uses criteria or factors similar to those used by Portland Metro's Pedestrian Potential Index and Pedestrian Deficiency Index (Oregon Department of Transportation 1995). However, Metro's approach addresses the entire metropolitan region, including both its urban and suburban areas. As a result, the Pedestrian Potential Index shows that areas with the highest potential for pedestrian travel are in urban areas, with very few locations in suburban parts of the region showing promise for pedestrian travel. Furthermore, the Portland Metro approach exists in a highly organized planning context with four levels of designated centers (Regional Centers, Town Centers, Main Streets, and Station Areas). In contrast, the central Puget Sound currently has only one formally designated level of nucleation (with 21 designated Urban Centers not organized in a hierarchical fashion). Many metropolitan regions do not have any designated centers beyond the established urban and suburban downtowns. Our approach and tools, therefore, address a policy and planning context that is less defined than Portland's. At the same time, however, **PLI_1** and **PLI_2** enable planners to make a more precise distinction than does Portland's approach between the large spread of *suburban* development that is not conducive to walking and those, albeit small, suburban areas that do present potential for walking.

Additional Sources for PIP

Cambridge Systematics and the Bicycle Federation of America (BFA) (1999). Guidebook on Methods to Estimate Non-Motorized Travel. FHWA-RD-98-165. Produced for the U.S. Department of Transportation, Federal Highway Administration. Washington, D.C..

Dixon, L.B. (1996) "Bicycle and Pedestrian Level-Of-Service Performance Measures and Standards for Congestion Management Systems." Transportation Research Record, No.1538.

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Oregon Department of Transportation, Bicycle and Pedestrian Program. (1995) Oregon Bicycle and Pedestrian Plan.

Christopher Porter, John Suhrbier, and William L. Schwartz. (1999) "Forecasting Bicycle and Pedestrian Travel: State of the Practice and Research Needs." Transportation Research Record, No. 1674: 94-101.

Sarkar, Sheila. (1995). "Evaluation of Different Types of Pedestrian Vehicle Separations". Pedestrian and Bicycle Research. Transportation Research Record, No. 1502,.

Turner-Fairbanks Highway Research Center. (1998). The Bicycle Compatibility Index: A Level of Service Concept, Implementation Manual. For the U.S. Department of Transportation. Federal Highway Administration. Publication No. FHWA-RD-98-095.

Shawn Turner, Gordon Shunk and Aaron Hottenstein. (1998). Development of a Methodology to Estimate Bicycle and Pedestrian Travel Demand. Texas Transportation Institute, Texas A&M University. Austin, Texas, (September): 48.

Pedestrian Infrastructure Prioritization—PIP, Chart 1

Cluster ID_______	Main Criteria	Sub-criteria	Measures/Related Spatial Unit of Data	Jurisdiction to fill in	
Component 1				**Weight**	**Score**
Area-Scale Considerations	**Density**	Sufficient density of population or employees	Gross density: Census block data Net density: parcel-level data		
		Sufficient absolute number of residents or employees within a walkable area	+/-2,000 residents within 500 acres or +/-500 employees		
	Land use mix	Appropriate land uses types	Res/Com/Office		
		Functional complementarity of land uses (O/D)	Combinations of Res/Com, Office/Com		
		Spatial complementarity of land uses	Within an area smaller than 500 acres		
	Topographical conditions	Ease of walking	Exclude residents/employees living +/- 100 feet of neighborhood center		
	Socio-demographic characteristics of population	Target special populations: children, older adults, ethnic minorities, households with few cars, etc.	Number and percent of population		
Total					

Pedestrian Infrastructure Prioritization—PIP, Chart 2

Cluster ID_____ / COMPONENT 2	Main Criteria	Sub-criteria	Measures	Jurisdiction to fill in: Weight	Jurisdiction to fill in: Score
Transportation Facility Scale Considerations	Existing pedestrian transportation infrastructure	Block size	Large, Medium, Small # of intersections/area		
		Extent of sidewalk network	Length of sidewalks % completeness		
		Sidewalk continuity	Y/N		
		Travel route distance on formal ped infrastructure	Route directness		
		Travel route distance on informal ped infrastructure	Route directness		
		Marked crosswalks (signalized, non-signalized)	% total intersections		
		Unmarked crosswalks	% total intersections Ave. #/intersection		
		Marked mid-block crosswalks	% total intersections		
		Ped supportive signalization: push buttons, traffic lights, stop signs, flashing crosswalk lights, crosswalk signs	% total intersections		
		Number of Driveways or Curb Cuts	# of access points/area		
	Auto Infrastructure and traffic characteristics	Traffic Volume	# at peak hours		
		Road Width	# lanes, actual width		
		Road Speeds	Posted MPH Actual MPH		
	Transit Level of Service	Existence of transit corridor	Y/N		
		Transit ridership within cluster or corridor area	#'riders/day/area		
		Level of service, seven-day, week-day only, frequency			
		Bus stops	# per mile		
		Existence of bus shelters	# per mile		
	Pedestrian Risk Factors	History of collisions by location	# of Pedestrian Accident Locations		
		Ped supportive signalization at high volume bus stops	% total intersections		
		Width of street along transit corridor	# lanes, actual width		
Total					

Pedestrian Infrastructure Prioritization—PIP, Chart 3

Cluster ID_______ / Component 3	Main Criteria	Sub-criteria	Measures	Jurisdiction to fill in: Weight	Jurisdiction to fill in: Score
	Long-term planning goals for area	Cluster subarea plan as part of comprehensive plan	Y/N		
		Area targeted growth	H/M/L		
	Medium-term planning and infrastructure goals	Capital Improvement Plan support	Long/short term/none		
		Zoning categories and related capacity	H/M/L		
		Development standards			
	Short-term development potential	Projects under construction, by type	# or sq. ft.		
		Projects in the pipeline	# or sq. ft		
		Road improvements by type, scheduled or planned	Y/N		
		ADA compliance program scheduled or planned	Y/N		
		Safe route to school program scheduled or planned	Y/N		
	Community support for pedestrian travel	Local improvement districts	Y/N		
		Business organizations	Y/N		
		Neighborhood organizations	Y/N		
		Abutting communities	Y/N		
		Commuters through the area	Y/N		
	Institutional or political support for pedestrian travel	WSDOT	Y/N		
		Local engineering department	Y/N		
		Planning department	Y/N		
		Transit service provider	Y/N		
		Elected officials and representatives	Y/N		
	Consideration of funding sources	CBDG monies	Y/N		
		Redevelopment monies	Y/N		
		Public/private partnerships	Y/N		
		Local improvement districts	Y/N		
		Other	Y/N		
Total					

Pedestrian Infrastructure Prioritization—PIP, Summary Chart

Cluster ID_______________	Jurisdiction to fill in		
Component	**Score**	**Weight**	**Total Score**
Component 1			
Component 2			
Component 3			
Total			

PART THREE: CONCLUSIONS AND FUTURE RESEARCH

This project has yielded three tools for allocating investments to improve pedestrian infrastructure. The tools are tailored to suburban clusters and corridors where past research has shown that the potential exists for substantial volumes of pedestrian travel. The first two tools, **PLI_1** and **PLI_2**, help differentiate between suburban areas that do and do not have potential for pedestrian travel. The third tool, **PIP**, supports decision-making processes to allocate infrastructure improvement investment to areas that do have potential for pedestrian travel.

Research indicates that the number and extent of suburban areas with potential for substantial pedestrian travel are larger than previously thought. However, these areas are typically deficient in pedestrian infrastructure, exhibiting low levels of connectivity and accessibility, with large street-blocks, incomplete sidewalk systems, large at-grade parking lots, fenced-in development, and other impediments. As a result, considerable investments will be required to retrofit suburban clusters and corridors with the safe and comfortable walking conditions that will support substantial increases in pedestrian volumes. The tools developed by the project reflect the two step-process necessary to effectively improve conditions for pedestrian travel in suburban areas: first, the identification of areas with high latent pedestrian demand and, second, the ranking of these areas for investments to yield the highest transportation benefits.

As noted in the introduction to this report, the tools generally yield benefits at the policy, implementation, and scientific levels. Below is a discussion of how they specifically add to current practice in urban and transportation planning for pedestrian travel, and what future research will be needed. Each set of tools is considered separately, followed by a summary of identified research needs.

PEDESTRIAN LOCATION IDENTIFICATION TOOLS

The Pedestrian Location Identification tools, **PLI_1** and **PLI_2**, add to current practice as follows:

- By focusing on medium-density residential land development, the tools focus attention on suburban land areas that have been neglected in the past as locations with potential for pedestrian travel.
- By considering combinations of land uses that are generators and attractors of pedestrian travel, they capture the characteristics of land-use mixes that have the highest potential for substantial volumes of pedestrian trips.
- By using small spatial units of land-use data, they adequately capture the characteristics of actual development on the ground and, specifically, those characteristics that support pedestrian travel. At the same time, because the small spatial units of data are available for areas of large extent, the tools can be readily applied to today's spread-out cities and urbanized regions.
- The small spatial units of data also allow a precise and accurate measurement of the land-use characteristics of the small areas that correspond to short walking distances.
- Generally, both tools help to quantify the attributes of compact suburban development. **PLI_2** has the advantage of making the process of delineating clusters objective, a task that needs to be done manually in **PLI_1**. **PLI_2** also enables the

planner to access a larger set of data attributes defining land development than is available in census data at the block level.

Ostensibly, the PLI tools have applications beyond pedestrian travel because they generally serve to identify areas of compact development in suburban areas. Compact development is of increasing interest to planners who are concerned with "smart growth" as a form of land development that is infrastructure-efficient—infrastructure including not only transportation systems, but also water and utility systems. Compact development also represents areas where special consideration is needed for public service delivery, including fire and police services. In this sense, the tools could be used in a number of public policy situations affected by the distribution and concentration of population and activities. Further work is needed, however, to illustrate other applications of the tools, testing them, for example, in areas where employment land uses dominate. Such work would also complete the identification of suburban areas that deserve special consideration for latent pedestrian travel demand.

PEDESTRIAN INFRASTRUCTURE PRIORITIZATION DECISION SUPPORT TOOL

The Pedestrian Infrastructure Prioritization tool, **PIP**, is a synthesis of previous efforts to identify the environmental and policy variables that affect pedestrian travel (FHWA 1999). The approach uses combines that of several of the tools that already exist to assist decision making about transportation infrastructure investment. It acknowledges three types of environmental factors known to affect pedestrian travel demand: area-wide characteristics defined by land uses and development patterns, characteristics of the transportation facilities, and policies that determine the level of support for pedestrian travel. The **PIP** criteria and sub-criteria constitute a list that is as complete as possible from previous research. The measures suggested to quantify the criteria constitute state-of-the-art practice in urban and transportation planning. As such, the tool assists transportation providers that need to comprehensively evaluate locations and facilities for pedestrian infrastructure improvements. At the same time, **PIP's** exhaustive list of criteria to be considered and its open ended weighting system mean that the tool demands substantial commitment on the part of its users. This reflects the current lack of solid empirical evidence about the power of variables in predicting pedestrian volumes; this subject is addressed in the section below. In the absence of such information, **PIP** provides a complete yet flexible framework for making decisions regarding infrastructure. It allows local jurisdictions to work with their own internal set of priorities.

FUTURE RESEARCH

The **PLI** and **PIP** tools attempt to advance both the concepts and the measures used in previous research to capture the characteristics of pedestrian-supportive land use and development patterns. They have been reviewed and tested by local jurisdictions in the Puget Sound. **PLI_1** is now used in other states. **PIP** has been reviewed by local planners and transportation providers and is scheduled for application to selected jurisdictions in the Puget Sound. However, as for previous efforts, and as noted in the recent literature (U.S. Department of Transportation 2000), the tools will need further testing. Specifically, variables that have been constructed theoretically need to be tested empirically for their predictive power. Field data are needed to quantify the demand for pedestrian travel associated with given land-use and development patterns, and with specific types of transportation facilities. Empirical evidence of the relative power of the variables identified will improve the effectiveness of **PIP** as follows: it will help jurisdictions select the most significant criteria, quantitatively relate land use and infrastructure improvements with increases in pedestrian volumes, and ultimately, quantify costs and benefits of land use and infrastructure improvement actions. This information will eventually reduce staff time necessary to apply the tool.

Empirical evidence and validation are needed both for area-wide, land-use related determinants of walking and for variables related to the characteristics of transportation facilities.

Questions regarding area-wide land use determinants include the following:

- The **PLI** tools do not follow previous assumptions that both residential and employment density must increase for pedestrian volumes to increase. Instead, they consider medium-density residential development as the dominant generator of pedestrian travel, and they consider retail and educational facilities as complementary to the dominant land use. Pedestrian travel is likely to and from these complementary land uses. Testing is needed to confirm that measures of land-use mix conducive to pedestrian travel should not assume co-variance between residential and employment land-use intensity. Furthermore, the demands for such travel in land-use concentrations that are primarily residential versus primarily employment need to be determined.
- The concept of functionally complementary land uses needs to be further operationalized, so that actual pedestrian volumes can be estimated between different land uses at different intensities.

- Within given land-use intensities and mixes, the effects on walking volumes of such variables as increased residential and/or employment density, presence of specific attractors/generators such as schools, parks, and others need empirical grounding.

- The effect of different sizes of walking sheds, establishing the spatial complementarity of land uses, needs testing as well. Specifically, the widely used 0.8-kilometer (0.5-mile) walking shed needs to be validated as applied to different land uses, populations, and topographical conditions.

Appropriate area-wide land-use intensity and mix are *necessary* conditions for pedestrian travel, yet they are *not sufficient* to fully support high volumes of pedestrians; appropriate transportation infrastructure is required.

Questions regarding the predictive power of variables related to transportation facilities include the following:

- The effect of different levels of service in pedestrian infrastructure on pedestrian volumes. Specific variables to be tested include block size and formal pedestrian routes, as they affect route directness, pedestrian safety, and comfort.

- The effect of vehicular traffic conditions (volumes and speed, and street width or number of vehicular lanes) on pedestrian volumes.

- The effect of transit levels of service on pedestrian volumes.

Data requirements to address these questions are extensive. Past research indicates that analyses will be complicated by likely covariance between variables, such as block size or sidewalk length, as well as by the interactive nature of area-wide and transportation facility variables. For example, a wide street will likely have a more significantly negative effect on pedestrian counts in low-density than in high-density areas. As a result, data gathering and analytical approaches to assess the predictive power of the variables will require substantial funding commitment. Such commitment is essential to quantify the relationship between land use, infrastructure improvement, and travel behavior. Accurate estimates of expected pedestrian volumes associated with land use and infrastructure conditions will support the development of cost and benefit analyses that will aid the effective prioritization of future infrastructure investments.

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